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Cold Chain Strategies For Seaports: Towards a Worldwide Policy Classification and Analysis

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The refrigerated ('reefer') container market and cold logistics chains create opportunities and challenges for seaports. This high-value market grows rapidly, but places stringent demands on seaports' logistics processes, infrastructure, and energy provision. This study investigates how port authorities can address challenges and opportunities in this dynamic market environment. While previous research has outlined developments in port governance paradigms and the strategic scope of port authorities, the academic literature still lacks a comprehensive understanding of the policy options available to port authorities to respond to arising challenges and opportunities. This study presents a new dataset of policies, implemented by world's 50 largest container ports, addressing reefer transportation and cold chain logistics. Policy measures are classified according to content, goals, scope and port authority role. The findings from this worldwide comparative analysis illustrate that port authorities routinely pursue facilitating and entrepreneurial policies extending far beyond their traditional 'landlord' responsibilities. There is little evidence of coherent and comprehensive cold chain strategies of port authorities, addressing the logistics, marketing, technology, and sustainability dimensions. Based on the inventory of policies in the reefer segment, this study outlines the general tenets such a strategy should contain as a consideration for policymakers.

Keywords: *Cold chain, Container transport, Ports, Port policy, Reefer containers.*

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1. Introduction

This article focuses on the policy measures that can be implemented by port authorities to better attract and facilitate transportation of refrigerated containers. Refrigerated or 'reefer' containers are a fast-growing segment in the container shipping market (Arduino, Carrillo Murillo and Parola, 2015). 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 and 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 Maritime Research, 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- and container logistics- related actors, including port managing bodies (commonly referred to as 'port authorities'). While port authorities (in their role as 'landlord', focusing on regulation and infrastructure management in the port area (World Bank, 2007)) are not directly involved with physical chain processes (generally managed by private sector firms), they do have an important role in terms of their responsibilities for port infrastructure, regulation, coordination, land use, and marketing. These port-managing bodies generally have statutory responsibilities to maintain and enhance the port's competitiveness, quality of service, and infrastructure, and to ensure the port's societal license to operate in terms of mitigating externalities and ensuring a trend towards more sustainable port activities. Nearly all port authority responsibilities have specific implications in the reefer market. Reefer containers, with built-in refrigeration and monitoring and control technology and sensitive cargo, place more stringent demands on port infrastructure, energy supply, and handling processes than standard containers (Behdani, Fan and Bloemhof, 2018). Moreover, the perishables logistics chains of which they are an integral part are characterized by issues of growing energy consumption and food loss and waste (FAO, 2011). Considering these myriad issues and responsibilities, port authorities have an important role to play, as they are the only actor in a port area that is problem owner of all issues arising related to the reefer chain, including competitiveness, efficiency, infrastructure, and sustainability. Therefore this paper focuses on the policy dimensions of accommodating reefer containers and cold chain logistics activities in port clusters.

Extending from this is 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 and Notteboom, 2015). However, ports compete not only for cargo volume, but also for cargo added value (De Martino, Carbone and Morvillo, 2015). Therefore a more differentiated perspective on container flows is desirable (Castelein, Geerlings, & Van Duin, 2019). For policymakers and managers this is particularly relevant, as it allows better tailoring of policy and processes to the demands of specific cargo markets – such as the reefer market. By focusing on port policy directed at a specific container market segment, this study contributes new knowledge on how ports position themselves in specific supply chains (Robinson, 2002).

Moreover, this approach contributes an in-depth perspective on the policy measures at the disposal of port authorities to respond to challenges and opportunities in their environment. Strictly speaking, these organizations function not only as 'port authorities' (in a strict regulatory sense), but also as 'port managing bodies' or 'port development companies', depending on their scope and

governance structure. 'Port authority' is commonly used as the generic term for the entity that manages a port area (Verhoeven, 2010), and for brevity this study will use this term throughout. Studies in port governance generally focus on governance models, institutional reform, and their outcomes (Borges Vieira, Kliemann Neto and Goncalves Amaral, 2014). Most attention has been paid to the predominant port governance model, i.e. the 'landlord' port authority: a corporatized entity, often with public ownership, with a role 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 (Heaver *et al.*, 2000; Robinson, 2002; Verhoeven, 2010; Notteboom, De Langen and Jacobs, 2013). Earlier studies suggested ways in which changing contexts impel port authorities to broaden their scope to the foreland and hinterland (Dooms, Van der Lugt, & De Langen, 2013; Notteboom & Rodrigue, 2005; Van der Lugt, Rodrigues, & Van den Berg, 2014; Zhang, Zheng, Geerlings, & El Makhloufi, 2019) and extend their role beyond that of the landlord to for example being a cluster manager, facilitator, or entrepreneur (Verhoeven, 2010; Hollen, Van den Bosch and Volberda, 2015).

At the heart of this literature is the question 'what can a port authority do?' However, the question how developments in ports' strategic scope are translated into tangible policy measures has received little attention in this body of literature. This relates to the issues of how a port authority can insert itself in specific supply chains and help create more value for the port cluster (Jacobs and Hall, 2007), and how to meet new demands that require a change in strategic scope. Verhoeven (2010) has introduced a theoretical framework for the functions a port authority may fulfill, and how the governance context, power position, and resources and capabilities of a port authority determine the actions a port authority may take in fulfilling these functions. Accordingly, Verhoeven proposes a typology of port authority roles ranging from a 'conservator' to 'facilitator' to 'entrepreneur' – a spectrum along which a port authority takes on a more active role in the supply chains the port services, takes on more different responsibilities (and risks) and widens its strategic scope geographically (beyond the boundaries of the port cluster). This study presents a novel empirical application of this framework by applying it to a new dataset covering the policies implemented by major container ports worldwide, specifically for the reefer market. Applying this framework to the case of the reefer market, this study sets out to answer the research question: "how can port authorities respond to challenges and opportunities in the reefer market, and what roles do they need to develop to implement these actions?"

The authors present a newly compiled dataset of reefer- and cold chain-related policies implemented by the world's 50 largest container ports. To the best of the authors' knowledge, this is one of the first studies that is based on systematically collected information on port policy content for a worldwide set of major ports (see Gonzalez Aregall et al. (2018) for another recent example). The dataset describes the characteristics of these policies in great qualitative depth (including instruments, activities, goals, scope, stakeholders involved, and port authority role). Drawing on this new rich dataset, this study addresses the question how ports can respond to challenges and opportunities in this niche market. The study surveys the policy measures implemented by the largest container ports in the world to identify the spectrum of measures applied. Using the detailed information collected on port policies, the study provides a typology of measures, and discusses these by type, scope, goal, port authority role and stakeholder involvement. In addition to classifying policy instruments, the authors discuss the conditions under which ports' strategic scope tends to extend. Through the novelty of the dataset collected, the detail of information, and the insights in port policy and port authority strategy obtained through examination and analysis thereof, the study contributes to the further development of port policy research. 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.

2. Background

From the existing academic literature two relevant aspects should be highlighted. 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 of 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 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 Maritime Research, 2016), driven by three factors (Accorsi, Manzini and Ferrari, 2014; Arduino, Carrillo Murillo and Parola, 2015; Behdani, Fan and Bloemhof, 2018; Castelein, Geerlings and Van Duin, 2020): First, as incomes increase worldwide, people tend to increase their consumption of exotic, non-local food, and demand this regardless of seasonality. Secondly, there is a modal shift of temperature-sensitive goods away from air transport and conventional reeferships towards reefer containers, with 85% of the maritime perishables trade expected to be transported in reefer containers by 2021 (Drewry Maritime Research, 2017). Third, as reefer containers become more ubiquitous, the range of goods transported in them 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.

To consider the role of seaports in (containerized) cold supply chains, it is important to first outline what the typical cold chain looks like in terms of processes and actors involved. In their essence, cold supply chains are characterized by the need for the product to be kept continuously at a specific temperature at which its quality is preserved optimally, or at least within a tolerable range around this desired temperature (Behdani, Fan and Bloemhof, 2019). Each product has distinct temperature and atmosphere requirements, such as bananas that need to be kept at a temperature within a narrow range around 13-14°C with the additional need for atmosphere control to prevent early ripening due to excreted ethylene. For long-distance, intercontinental transport of temperature-sensitive goods with a maritime leg, intermodal reefer containers have become the standard load unit. In a cold chain with reefer container transportation, the vast share of the transportation distance – from container stuffing at the origin to stripping at the destination – is covered with the cargo inside the container. Especially during container stuffing and stripping, there is a risk of cold chain breaches due to the ambient temperature deviating from the cargo's desired storage temperature. Figure 1 shows the stages of a cold logistics chain with a containerized part.

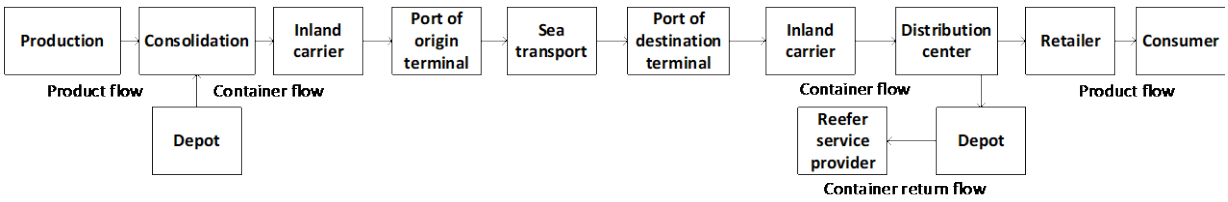

Figure 1. Schematic overview of containerized cold chain processes (source: elaborated from Castelein et al. (2020).

In this stylized example we assume intercontinental transportation of a perishable cargo (based on the outline sketched by Castelein et al. (2020)). The product is produced in the region of origin, stored temporarily (cold storage), and consolidated in a reefer container, coming from an empty depot. From the point where it is consolidated, the container is transported to a port, and loaded onto a deep-sea vessel at a container terminal. The vessel sails from the port of origin to the port of destination – usually a journey of several weeks – where the reefers are unloaded at a terminal and transferred to hinterland modalities (truck, barge, or rail) for transportation further inland. At a distribution center (either within the port cluster or further inland) the container is stripped, after which the cargo is distributed further, if necessary with further processing in between. Once stripped, the empty reefer container is returned to a depot, perhaps stored, and cleaned, maintained, and inspected (the so-called pre-trip inspection or PTI) before being allocated to another shipper. Figure 1 only outlines the physical processes and the actors involved To facilitate this physical process, administrative, transaction, and governance processes are implemented by various stakeholders, many of which are not directly involved with the physical supply chain processes (Van Baalen, Zuidwijk and Van Nunen, 2008). On the governance side, this includes customs and inspection authorities, and port managing bodies (port authorities), and on the transaction side shipping agents, forwarders, banks, and insurance companies that perform coordination and administrative functions. As far as these chains pass through seaports, the physical activities take place within the jurisdiction of port managing bodies. The extent to which these activities take place within port areas can differ however, in particular the consolidation and distribution. The transfer from inland carrier to the port terminal and from the terminal to the deep-sea container vessel (at the origin) and vice versa (at the destination), depot processes and reefer servicing usually take place inside the port cluster, but in many cases also consolidation and distribution centers are located in or near port clusters. Considering the number of stages in the chain that are directly port-related, port clusters are highly relevant for cold supply chains.

While a port is only a localized cluster 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 *et al.*, 2011).

Another consideration is the relevance of reefers for port's energy policy. Ports tend to be clusters of energy-intensive (industrial and logistics) activities, energy transport, and power generation ('energy hubs'), while sustainability considerations also place demands on ports to mitigate their emissions and environmental impact. All these demands should be taken into account in port authorities' policymaking (Acciaro, Ghiara and 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 *et al.*, 2018, 2019). Considering recent developments such as the Paris agreement of 2015 stressing the importance of mitigating 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

The reefer sector poses opportunities and challenges for port-related actors and port authorities. Notwithstanding that private sector companies (e.g. carriers, terminal operators, logistics service providers) undertake initiatives related to supply chain optimization and exploring new markets independently from policy, as discussed this analysis focuses on the policy dimensions relevant for the role of reefer container supply chains in port areas. This entails considerations regarding port governance, strategy-making, and policy options.

The World Bank (2007) distinguishes several governance models, with the 'landlord' port being the most commonly observed and generally recommended. There has been considerable discussion whether this is the best model for port authorities in a period of significant change in the logistics environment, and what their role relative to the supply chains they service should be. Major external factors include consolidation in the liner and terminal operator sector (Heaver *et al.*, 2000; Notteboom, 2002; Panayides and 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 (Verhoeven, 2010; Van der Lugt, Dooms and Parola, 2013). These goals include straightforward financial performance criteria, ensuring the competitiveness of the port cluster, sustainability goals, and meeting responsibilities to a wide range of stakeholders (including 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, Van den Bosch and Volberda, 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 (World Bank, 2007). Research so far has identified several ways in which port authorities extend their roles, either by using 'traditional' landlord policy instruments in innovative ways, broadening their strategic scope beyond the port boundaries, or by engaging in previously unexplored activities (Verhoeven, 2010; Notteboom, De Langen and Jacobs, 2013). Concession agreements – aside from being a source of income – can be used to incentivize port user behavior that is desirable from the perspective of the port authority's other goals (Notteboom and Verhoeven, 2010; De Langen, Van den Berg and Willeumier, 2012). The role of regulator can also be extended into standard-setting to further the port's societal goals (Lam and Notteboom, 2014) or signal and address market failures. Another dimension of port policy development is a broader conception of infrastructure. While physical infrastructure is traditionally within the scope of the landlord port authority, more entrepreneurial port authorities also invest in 'knowledge infrastructure' (Hollen, Van den Bosch and Volberda, 2015), including information technology (Cepolina and Ghiara, 2013) inter-organizational relations, collaboration, and connectivity (De Martino and Morvillo, 2008; Hollen, Van den Bosch and Volberda, 2015), and innovation (De Martino *et al.*, 2013). When a port authority extends its role into that of a 'cluster manager' or 'community manager', other considerations also play a role, 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, Van den Bosch and Volberda, 2015).

In a supply chain-oriented logistics environment, port authorities 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 and 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 and Haezendonck, 2013; Panayides *et al.*, 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 and Rodrigue, 2005) – or the development of the hinterland region itself (Cahoon, Pateman and Chen, 2013), and internationalization towards the foreland (Dooms, Van der Lugt and De Langen, 2013).

These aspects and respective evolutions of port authority functions and responsibilities have been incorporated in a conceptual framework by Verhoeven (2010). He distinguishes four port authority functions, namely the traditional landlord, regulator and operator functions and that of community manager, in which the port authority takes on more coordinative and stakeholder management responsibilities (e.g. addressing bottlenecks, implement ICT solutions, marketing, ensuring the port's societal 'license to operate'). Furthermore, he distinguishes the broadening of port authorities' strategic scope at three levels, ranging from the port cluster itself (local), regional and global. From this framework, labelled a 'renaissance matrix,' three hypothetical roles of port authorities arise: the conservator (strictly limited to traditional functions and responsibilities as a landlord, regulator and operator, local scope), the 'facilitator' (with a better-developed community manager function and a local and regional scope) and the 'entrepreneur' (with commercial aims and a local, regional, and global scope in all functions). Verhoeven labels these 'types,' but perhaps the term 'role' is more appropriate, as these features are not necessarily constant across policy domains: a port authority may act as conservator in one domain, and as entrepreneur in another. The dimensions of this 'matrix' are shown in Table 1:

Table 1. Port authority 'renaissance matrix'

Type	Conservator	Facilitator	Entrepreneur
Landlord			
Regulator			
Operator			
Community manager			
Geographical scope	Local	Local, regional	Local, regional, global

Source: Based on Verhoeven (2010)

Features and activities of port authorities in terms of scope, responsibilities, and aims can be placed in this matrix, corresponding to a certain type/function combination. Verhoeven goes on to hypothesize that four factors determine the type of features and activities a port authority will exhibit, namely its power position relative to government, the autonomy and responsibilities legally accorded to it, its financial capabilities, and its management culture. Furthermore, Verhoeven expects port authority features to change over time, due to changes in the market environment and in the governance context. The question to be addressed with this framework in mind is how port policy is used to respond to growing opportunities and demands in the reefer market, and accordingly what roles port authorities need to develop to implement these policies.

3. Data and approach

3.1 Case selection

To obtain an overview of what is done globally by ports to address the challenges and opportunities arising from a rapidly growing, high-value reefer market, the study draws on information from the world's 50 largest container ports (Lloyd's List, 2017). To the best of the authors' knowledge, this type of study (a worldwide inventory of policies pursued by major port authorities) has been conducted only rarely so far (Gonzalez Aregall, Bergqvist and Monios, 2018). The motivation to scrutinize 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) policy measures aimed at the reefer market. Second, larger ports tend to have greater 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. These multi-purpose gateway ports are also, according to

Verhoeven (2010), most likely to expand their roles and extend their geographical scope. For each port, the authors collected information on the measures taken to facilitate reefer transportation and cold chain logistics.

3.2 Data collection

Data collection started with ports' official (English) web pages, annual reports, and press releases. Additionally, 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. For each port, sources were searched until no new information was found, and all reefer-related policies were recorded and compiled. Only those policy initiatives were included of which it was clear that they were specifically aimed at facilitating the handling and transportation of reefer containers. Despite not imposing a time limit, the measures found were generally not dating back further than 10-15 years.

It should be emphasized that this sampling approach does not guarantee that no relevant action has gone unnoticed, possibly remaining 'unknown unknowns.' For two reasons however, the authors consider this risk 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 potential users, 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 overlooked action by one port authority– 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 constructing reefer racks and plugs, performing plugging and unplugging services, and the availability of reefer servicing and container inspections (PTIs, or pre-trip inspections). Moreover, actions by private sector companies or government agencies in which the port authority itself was not involved were not counted as port policy, but public-private partnerships with port authority involvement were included. Third, multiple initiatives stemming from the same policy (e.g. subsidizing multiple barge connections for reefers, as part of the same program) were counted as one policy.

For every policy identified, as much information as possible was recorded. First the policy instrument. Secondly the geographical scope of the policy, distinguishing between actions taken inside the port cluster, towards the hinterland or foreland (the so-called foreland-seaport-hinterland triptych (Ducruet et al. (2010) citing Vigarie (1968)) or impacting on the entire cold chain. Third, the policy goal. Fourth, where applicable, the stakeholders with which the port authority partnered in implementing the policy. Furthermore, policies were coded for the dimensions included in Verhoevens' (2010) framework as outlined in Section 2.2, namely port authority function, role, and geographical dimension. Aside from these information categories, extensive notes were taken on all other information found regarding the policy in question.

3.4 Analytical approach

Due to the limitations of the data, statistical analysis or performance evaluation of policies is not possible. Instead, this study takes an inductive approach using the available information from a

broad sample of ports. 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).

The research question formulated in the beginning of this paper is essentially twofold: 1) "how can port authorities respond to challenges and opportunities in the reefer market, and 2) what roles do they need to develop to implement these actions?" The first question invites a predominantly descriptive answer, based on the policies recorded and their characteristics. In addition, based on the outline of the reefer market, typical containerized cold chains and the challenges for seaports formulated in section 2.1, a discussion will be possible of where the focus lies of policymakers, and possible blind spots of issues and/or stakeholders that are not (yet) within the scope of port policy. For the second part of the question, the policies included are classified along the dimensions of Verhoeven's conceptual framework. Based on the overall pattern, conclusions can be drawn about what roles port authorities are taking in implementing these measures. Moreover, this analytical approach facilitates discussion of what would be required from port authorities to pursue reefer chain issues that are so far not within the scope of port policy. Ultimately, this exercise will also yield insights into the extent to which the 'renaissance port authority' framework is suitable for analyzing port policy in a specific domain, and whether there are conceptual issues to be addressed in the further development of this framework for empirical applications.

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 Dataset summary

For 35 of the 5o ports surveyed, 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 2) shows that the ports that implement relatively most measures (3 and more) also tend to be the larger ports in terms of container throughput (the correlation between ports' Lloyd's List rank and the number of measures identified is -0.25, indicating a weak negative correlation, showing that as rank drops from 1 to 50, the number of measures tends to decrease). This skewness suggests that it makes sense to starts with the world's largest ports when compiling such a policy inventory. It should be noted here that the number of different policies is not necessarily indicative of the magnitude of resource commitment or impact, but rather of the diversity of policies implemented.

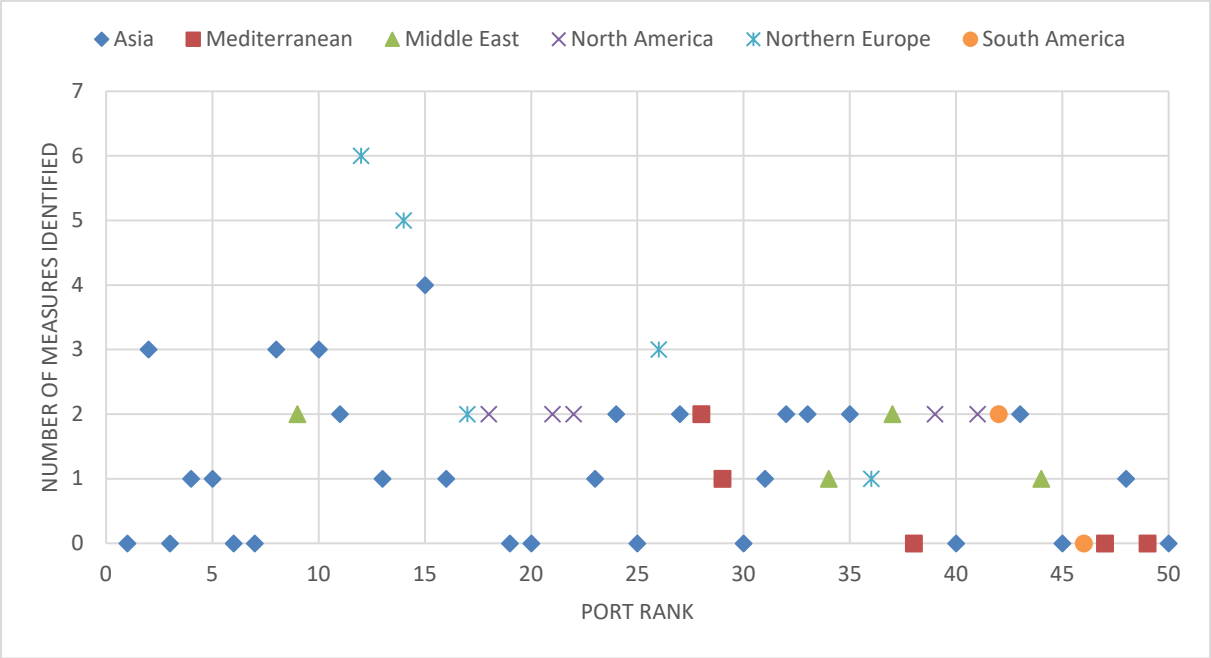

Figure 2. Number of reefer-related measures by port ranking and region (source: own compilation, based on Lloyd's List (Lloyd's List, 2017)

Another important aspect is the geographical distribution of the investigated ports. Expanding the distinction in Figure 2 between ports in different regions, Table 2 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 little or 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 2 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 relatively few relevant policy measures are recorded. This can be expected to be due to the transshipment focus of the larger container ports in the region (Piraeus, Marsaxlokk, Algeciras, and Port Said are considered to be transhipment hubs with transhipment incidences over 65% (Notteboom, Parola and Satta, 2019)), which have a smaller market for hinterland-oriented policies or value adding activities. Furthermore, it may be that perishables exports from Mediterranean regions go predominantly to other destinations in Europe, for which land transport may be preferred. If this hypothesized explanation is true, reefer- and cold chain-related policy may not be as relevant for ports in these regions. Clearly, for North-Western European ports (notably Antwerp, Rotterdam, Bremerhaven, and Hamburg) most distinct measures were identified on average.

Table 2. 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	1	0	2

Another potential limitation of the data also shows from this breakdown, namely that two major export regions for reefer cargoes (Latin America and Africa) are underrepresented. This is because these regions have numerous smaller, specialized reefer ports, some only serving a few clients (Dynamar, 2017)). In this light, it is useful to verify the extent to which the top 50 overall container ports are important reefer ports, and compare them with major reefer-handling ports outside the top 50. Unfortunately, worldwide data on the share of reefer containers in a ports' container throughput is not available. To give a rough indication of the absolute numbers and relative importance of reefer containers in ports' throughput, we can compare the number of reefer plugs in top 50 ports and major reefer ports outside the top 50 (Table 3) (in this case being a major port in a country with major reefer exports, such as Chile, Ecuador, Argentina and South Africa – the closest approximation of what constitutes an important reefer port, given the availability of data) - assumption that a greater number of reefer plugs corresponds with a greater number of reefer containers.

Table 3. Comparing the of reefer plugs for select top 50 and non-top 50 container ports

Port	Country	Container throughput (TEU)	Reefer plugs	Reefer plugs per 100,000 TEU throughput
Included in top 50				
Singapore	Singapore	36,600,000	12000	33
Qingdao	China	18,010,000	5976	33
Rotterdam	Netherlands	14,800,000	18500	125
Antwerp	Belgium	10,400,000	8000	77
Colon	Panama	3,900,000	4100	105
Santos	Brazil	3,600,000	6000	167
Not included in top 50				
Guayaquil	Ecuador	1,800,000	5000	278
Buenos Aires	Argentina	1,500,000	3000	200
Valparaiso	Chile	1,100,000	3700	336
Cape Town	South Africa	888,976	4000	450

Source: (Drewry Maritime Research, 2016; Dynamar, 2017; Lloyd's List, 2017)

Two main takeaways: First, all ports in major food exporting countries have relatively more reefer plugs (more reefer plugs per 100,000 TEU of throughput): the comparison between Santos, Colon, and Rotterdam (all top 50 ports located in food exporting countries) and other ports in the top 50 (Singapore, Qingdao, Antwerp) shows that ports in food exporting countries have relatively more reefer plugs, and can be expected to have a larger share of reefer containers in overall container throughput. Overall, the top 50 container ports are not as specialized in reefer cargoes as smaller ports in major exporting regions. Secondly however, in absolute terms the top 50 container ports tend to have greater total volumes of reefer containers than the non-top 50 ports considered. The conjecture that the largest container ports have larger overall reefer throughputs than smaller container ports with a larger share of reefers, is supported by the observation that the largest container ports perform a hub function and serve as import gateways to major importing markets.

For the purpose of this investigation, the world's major container ports are the most interesting, not only because of the larger absolute numbers of reefer containers being handled there, but also because these multipurpose gateway ports tend to be governed by port authorities with greater resources, capabilities, and scope.

4.2 Policy goals

The sampled ports show a broad range of goals behind port policies, beyond commercial goals such as throughput, market share, or cargo added value. Not all measures recorded were accompanied by a statement explaining the goal. Some ports report 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 specific final goal was reported, this was recorded in the dataset, along with other relevant notes. Roughly, the stated goals relate to sustainability, food safety, trade facilitation, efficiency improvements, and increasing competitiveness. Table 4 shows these goals with specific examples (not exhaustive) of port policies implemented with that goal.

Table 4. 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	→ United States, Indonesia, China.
	• Aim of establishing a 'halal hub' with quality control and certification	→ Port Klang
Sustainability	• Energy use of cold stores: shift to renewable energy	→ Bremerhaven (Ger.)
	• Modal shift away from trucks, stimulate use of barge and rail for reefer transport	→ Antwerp, Rotterdam, Long Beach, Valencia, Dalian
	• Reduce congestion: expedited treatment of trucks with reefers, exemptions from restrictions, modal shift	→ Long Beach, New York/New Jersey, Seattle/Tacoma, Manila → Hamburg, Singapore
	• Reduce food waste (various monitoring and control initiatives)	
Trade facilitation (national) / support domestic perishables-producing sectors	• Cold chain policies as part of nationwide plan to improve post-harvest distribution system	→ Indonesia, Japan, India, Taiwan, China → Rotterdam, Los Angeles, Santos
	• Improve connectivity of exporting regions	
More efficient service to customer	• Expedited clearance by customs and inspection agencies; prioritization of trucks picking up reefers at terminal gate	→ Long Beach, New York/New Jersey, Seattle/Tacoma, Manila, Tanjung Perak
	• Container tracking within the port or worldwide	→ Hamburg, Singapore
Increase competitiveness (market share, value added)	• Marketing: Host trade shows for perishables traders	→ Hamburg, Algeciras
	• Marketing: outreach to shippers	→ Multiple
	• Co-invest in cold stores with value added logistics activities	→ Multiple

Some specified policy goals (as stated by the port authorities themselves) can be considered instrumental goals, the achievement of which contributes to achieving a higher strategic goal. For example, some port authorities (e.g. the port of Jeddah) aim to reduce the dwell-times of reefer containers (specified policy goal), but remain unclear whether this is to reduce energy use, make better use of existing infrastructure, to prevent product spoilage, or several of these (final) strategic 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.

Three general observations can be made. 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, for example intensifying customs and quality controls for improved food safety, which typically entail longer time in transit for larger amounts of cargo. Conversely, ports can achieve synergies between policies addressing efficiency and sustainability goals, as smoother handling and shorter time in transit generally reduces overall energy consumption and reduces the risk of product waste. A frequently observed example of a policy aimed at such synergies is the establishment of cold logistics clusters: the co-siting of cold storage, value added logistics, customs and quality inspections, and reefer servicing at a location with good intermodal connectivity. The clustering of these functions reduces transportation distances (improving efficiency and reducing transportation emissions) and reduces the risk of cold chain breaks. Third, a considerable number of ports pursue policies aimed at trade facilitation, and often more specifically export stimulation. Particularly in Asia, these port policies are often tied in with a nationwide strategy 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 geographical scope

A port authority can extend its scope geographically by pursuing policies beyond the boundaries of the port authority's jurisdiction: 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. Figure 3 classifies the reefer-related measures observed by their scope, and lists the (number of) ports that implement a (generically described) type of measure. It should be noted that this visualization of the geographical scope of port policy is not based on any assumptions about ports' governance models or strategic scope, but only shows the type of policies that the examined real-world port authorities pursue in different geographical dimensions relative to their ports. These dimensions can be conceptualized as the 'foreland-seaport-hinterland triptych' (Ducruet et al. (2010), citing Vigarie (1968)) – a geographical representation of a seaport's position as a node in logistics networks extending towards its foreland and hinterland. The extent to which an individual port authority's strategic scope extends beyond their port cluster boundaries depends on that port's governance model, and the port authority's scope, goals, resources, and capabilities. Due to these differences, policies implemented by one port authority may not be feasible to pursue by another.

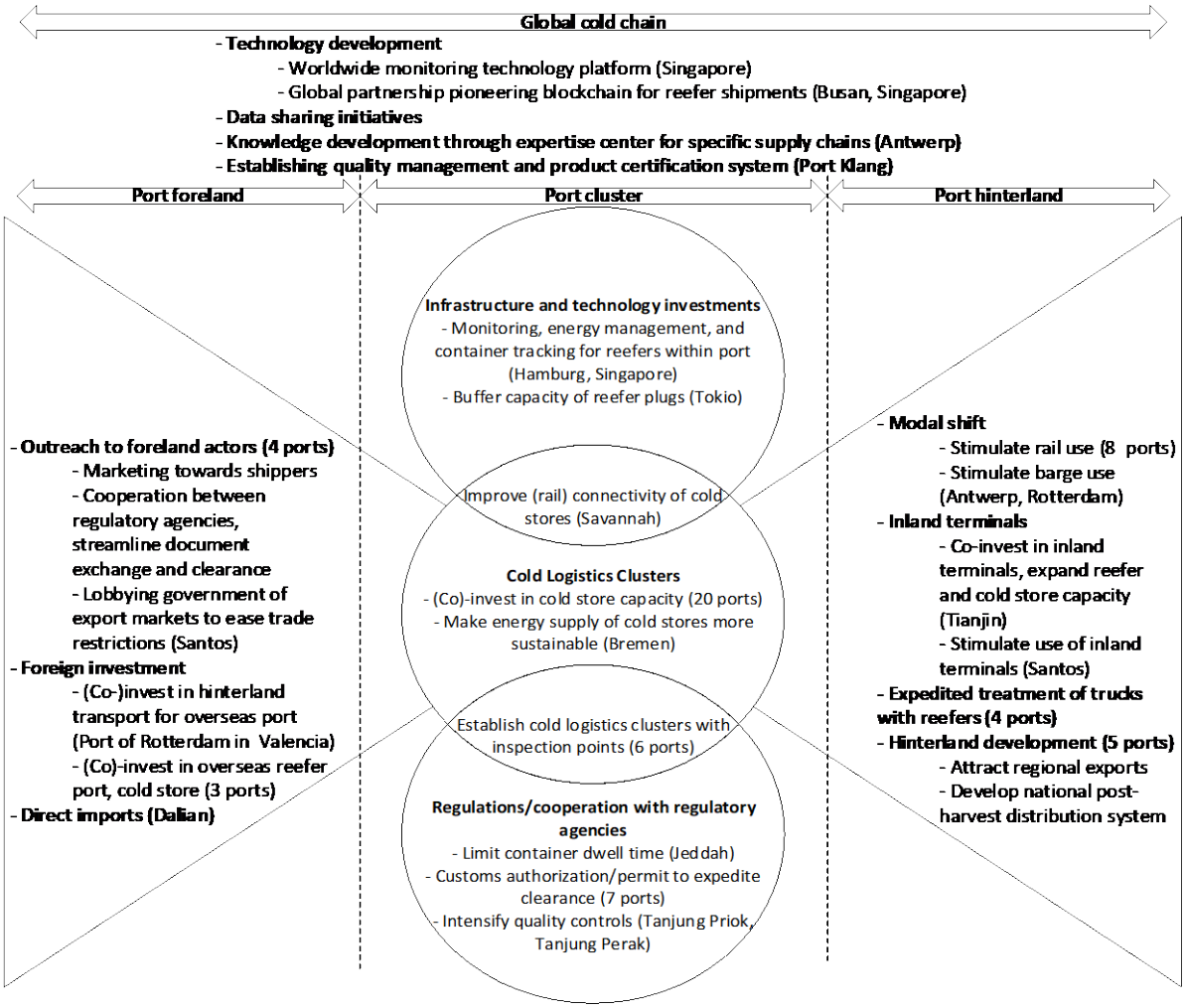

Figure 3. Schematic overview of the full spectrum of port policies for cold chains

Policies for the port cluster

The most diverse measures are observed within the port cluster. Most frequently this involves port authority involvement in the construction of cold storage capacity through their landlord and/or operator roles. 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, Tianjin). This type of cluster policy includes customs and inspection facilities, reefer servicing and cold storage, streamlining cargo clearance and container servicing – augmented with well-developed intermodal connections. For example, in the Port of Rotterdam cold logistics facilities in the 'coolport' cluster are located in the proximity of barge and rail terminals, or even have their own quayside to handle barges. Furthermore, this cluster was set up in the proximity of container depots, ensuring reefer storage and servicing facilities nearby. Whereas the Rotterdam 'coolport' cluster is an example of a location decision being based on pre-existing functions in the area, other ports (for example Long Beach and New York/New Jersey) extend the port rail network to cold storage facilities and reefer quays. There is little evidence of ports being actively involved in the energy management of port-based cold chain functions, with the exception of Bremerhaven undertaking a project to power cold stores with newly constructed wind turbines.

In their regulatory function, 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 – ranging from co-locating regulatory inspection points with cold logistics facilities (e.g. Tianjin) to assisting port-based companies to obtain import authorization from regulatory agencies (e.g. Dalian, Tanjun Priok, Savannah, Taican). In these cases the port authority acts as a facilitator towards other agencies and port-based companies, but in other cases the port authority itself acts as an enforcer of regulation, for example the crackdown ondangerous counterfeit refrigerants being used for reefer maintenance in the port of Ho Chi Minh City. Port authorities can also stimulate quicker handling and transport of reefer containers by establishing new regulation. One port authority (Jeddah) regulates the dwell times of reefer containers at the port's terminals to stimulate quick pick-up. Other ports allow off-hours pickup of reefer containers at terminals (Long Beach, New York/New Jersey, Seattle/Tacoma) or establish dedicated express lanes for trucks carrying reefers (Manila)

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 keep the port's reefer plug capacity always 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). In this case the port authority acts more as a facilitating community manager, mediating between port users, energy companies, and grid operators, rather than a direct infrastructure developer. In a similar role, port policies are observed that actively facilitate knowledge exchange and coordination by acting as a matchmaker and mediator between firms. 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 producers, shippers, and service providers.

Foreland policies

The simplest policies directed towards the foreland are outreach or marketing to overseas shippers. This can be general marketing efforts, or directed efforts towards shippers in specific regions and sectors (e.g. the port of Salalah actively engaging with African horticulture companies to attract transhipment traffic). More entrepreneurial ports also direct their investment policies towards the foreland parts of their reefer chains, such as by directly investing 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 cases in cooperation with higher-level government agencies that also seek to lower trade barriers. National governments and port authorities can exert lobbying efforts, such as the Port of Santos that lobbies with foreign governments to ease restrictions on Brazilian beef – an important category of export cargo for Santos. Another example of trade facilitation efforts by port authorities is the spearheading of regulatory agency cooperation to streamline administrative procedures, such as the Port of Antwerp working with Belgian and Peruvian customs agencies to streamline reefer clearance with digital certification.

Hinterland policies

In the hinterland dimension of reefer transport, port policies frequently address modal split. Seven policies have been identified that aim to facilitate rail transportation of reefers or temperature-controlled goods, with port authority involvement ranging from coordination and facilitation (e.g. Rotterdam and Valencia) to providing regulation for priority status for reefer containers on trains (Tanjung Perak) or port authorities being active as investor and operator (Qingdao, Tianjin, Dalian, Yingkou). Rotterdam and Antwerp have taken steps to increase the modal share of inland

waterways transport of reefers through pilot projects and subsidies for starting barge connections. Multiple port authorities stimulate the use of inland terminals, and some even invest in inland terminals or cold storage facilities (e.g. Tianjin) 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. Examples of countries where port policy explicitly contributes to these national policies include China, India, and Indonesia.

Cold chain policies

A limited number of port policies have an impact on the entire cold chain, in most cases related to end-to-end monitoring of reefer shipments, or data sharing and coordination between stakeholders along the cold chain. An exception to this type of policies is the quality certification program for Halal products being (Port Klang). Despite this example, most policies spanning the full chain are ICT-related. For example, the Port of Rotterdam has several data-sharing initiatives and projects that aim to connect data from various sources to allow for container tracking and prediction. Whereas one ports (Hamburg) invest in container tracking in and around the port with sensor networks, several more port authorities are involved in initiatives that revolve around new technologies and data exchange – notably experiments with emerging blockchain technology – along the entire reefer chain (e.g. Singapore, Busan, Antwerp). While these technologies will in the future likely also have an impact on transportation of standard containers, port authorities and their partners in these projects use the reefer chain to pioneer these technologies, as reefer containers already have the embedded technology that make remote monitoring possible and 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

We can distinguish a variety of policy instruments employed by port authorities, including investment, regulation, infrastructure provision, networking, pricing, incentives, subsidies, coordination, mediation, 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 entirely 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 and foreign. The role of the port authority differs strongly, even between initiatives that at face value seem similar. Take for example cold logistics clusters: Some port authorities make active use of concession policy and take on a mediating, facilitating role towards the other stakeholders that ultimately have to operate in or through the cluster (e.g. cold storage, depots, inspection authorities, terminals), but are not involved in the operations themselves. On the other hand, there are port authorities that become a shareholder in service providers (either as a wholly owned subsidiary (e.g. Dubai) or as a joint venture with a specialized private-sector counterpart (Jeddah, Dalian, and Bremerhaven)). In doing so, they take on a more entrepreneurial role as operator. In both cases, partnering with other stakeholders is necessary,

because these organizations have capabilities that the port authority lacks and is not likely to develop itself (for example in warehouse operations or customs inspections), but the role of port authorities in these initiatives determines the resource commitment, degree of risk, and the degree to which the port authority has to be involved in the management of the organizations involved.

Especially 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, often even internationally. Examples include container tracking, data sharing initiatives and blockchain experiments that involve shippers, port users, technology companies, and organizations involved in the administrative dimension of the transport chain. Again, the role of the port authority in these initiatives depends on its strategic scope and its capabilities. Considering the example of blockchain experiments, the Port of Singapore (managed by worldwide terminal operator PSA) makes use of PSAs global network and capabilities in managing container handling operations to experiment with blockchain for the purpose of expediting administrative processes. However, they still needed the expertise and capabilities of a shipping line (PIL) and an ICT company (IBM) to effectively address all relevant aspects of this project. The Port of Busan has undertaken an experiment of similar scope, but in a larger consortium, involving not only a carrier (HMM) and a technology company (Samsung), but also various government agencies to facilitate coordination with foreign counterparties, and a knowledge institute to add to the knowledge and capabilities of the port authority. Recently, Samsung has also entered in a similar project with the Port of Rotterdam, this time involving also a financial services company (ABN AMRO) to address the trade finance and insurance dimensions – specifically for reefer transportation of flowers. Between these examples, the role and commitment of the port authority differs, as does their intention to remain involved once the experiment can be extended into a commercial product, marking the difference between 'facilitator' and 'entrepreneur' ports in this domain.

As ports' scopes broaden towards the foreland or hinterland, also the stakeholder coalitions in which policies are implemented change. Towards the foreland examples include marketing initiatives in which the port authority seeks out foreign shippers (e.g. the Port of Dalian acting as direct importer), carriers, or even foreign governments (e.g. the Port of Santos lobbying foreign governments to ease trade restrictions on Brazilian beef). In addition to these one-on-one marketing efforts, there are also examples of more long-term strategic partnerships, either between a port authority and foreign customs and inspection authorities (e.g. the Port of Antwerp working with Belgian and Peruvian customs to expedite reefer clearance with a digital certification) or foreign ports and government (the Port of Rotterdam developing ports in Brazil). In these cases, port authorities commit more resources to a long-term relationship, and contribute their expertise to the joint project. Furthermore, these examples of 'facilitator' roles towards the foreland – even without equity investments – are emphasized as initiatives in which the port authority can learn from the project and its partners and further develop its own capabilities. Also in foreland-oriented policies, port authority roles differ from 'facilitator' (acting as a matchmaker, mediator, or representative or engaging in long-term strategic partnerships) to 'entrepreneur'.

Towards their hinterland port authorities partner with inland terminals, transportation service providers, regional government, and logistics and production clusters. Also these partnerships show differing degrees of commitment and different port authority roles. The majority of hinterland-oriented policies involve the stimulation of a modal shift of reefer containers from truck transport to barge or rail. In these initiatives, port authorities either operate hinterland transport services themselves (as for example Dalian, Qingdao, and Tianjin), or work together with a transportation service provider (e.g. Valencia, Rotterdam, Antwerp, Tanjung Perak). In the latter case, these port authorities limit their financial stake in the project but take on a predominantly coordinating role, using their own network and expertise to assist the service provider and increase the chance of the initiative being successful. Inland terminals and logistics and industry clusters are also important partners of port authorities in their hinterland strategies. Also here, 'entrepreneur' ports invest in inland terminals or cold logistics facilities and extend their landlord

and operator functions beyond the port perimeter, while 'facilitator' ports limit their financial commitment, but instead focus on using their expertise and network to achieve their policy goals. In Asia in particular, port authorities contribute their expertise and capabilities as a facilitator to policies pursued by national governments aimed at increasing the export competitiveness of the domestic perishables sector.

Two types of partnerships and policies are surprisingly *not* encountered or only to a very limited degree. 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 opportunity to generate more value added from reefer cargoes shipped through the port. Second, the policies observed 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.

4.5 Port authority roles

Section 2.2 introduced the 'renaissance port authority' framework ('matrix') of port authority functions (landlord, regulator, operator, community manager) and roles (called 'types' by Verhoeven (2010): Conservator, Facilitator, Entrepreneur). To explore the roles port authorities may need to develop to pursue certain cold chain or reefer-related policy measures, this section classifies the measures observed along the dimensions of the framework. As the measures themselves have already been extensively described, this section focuses on the application of the framework and the findings from this exercise. Table 5 shows the framework, with the observed port authority actions matched to the appropriate function and port authority role.

Table 5. Port authority 'renaissance matrix'

Type / Function	Conservator	Facilitator	Entrepreneur
Landlord		• Cluster cold chain activities • Strategic partnership with overseas reefer port • Partnerships with cold clusters in hinterland • Assist development of hinterland post-harvest distribution system (in combination with community manager role)	▪ Co-invest in cold chain logistics cluster ▪ Direct investment in overseas reefer port (port itself or port service providers) ▪ Investment in cold stores in hinterland ▪ Connect docks and cold stores with rail sidings • Invest in reefer infrastructure capacity
Regulator	• Quality control on reefer servicing • Intensifying cargo quality control	• Co-site customs and inspection authorities with cold chain activities • Coordination with overseas (foreland) customers • Cooperation with businesses and regulatory agencies for authorizations and expedited clearance • Expedite reefer pick-up • Penalize long reefer dwell times	▪ Establish quality certification system ▪ Establish security seal system for reefers
Operator		• Cluster cold chain activities (in combination with landlord function)	▪ Energy management for reefer racks ▪ Co-invest in cold store (possibly in cold cluster) ▪ Invest in and operate refrigerated train connection ▪ Invest in cold stores in hinterland (regional) or overseas (global) • Reefer imports by port authority
Community manager		• Make connections with hinterland producers (regional exporters) • Coordinate and subsidize hinterland barging projects • Promotion of port towards foreland (global) • Setting up stakeholder network and expertise center for perishable cargoes • Stimulate green energy use • Lobby government of export destinations to ease trade restrictions	• Worldwide reefer monitoring • Blockchain consortia for reefer shipments • Setting up data sharing platform • Sensor networks in port
Geographical scope	• Local	• Local, regional	• Local, regional, global

Source: Based on Verhoeven (2010)

It is immediately apparent that nearly all policies specifically geared towards the reefer market imply port authority roles beyond the traditional landlord functions. Only the specific attention to quality control and enforcement of standards could be subsumed under the 'conservator' role, as it implies enforcement of existing regulation – but still this requires awareness of the unique challenges of this segment. Apart from these examples, among these global multi-purpose gateway ports facilitating and entrepreneurial roles are the norm rather than the exception.

For some policies, such as cold logistics clusters, it shows to be necessary to combine multiple functions and roles simultaneously. For port authorities that go furthest in this, this entails dynamic use of concession policy to co-locate related activities (Landlord – Facilitator) with investment in facilities and port service providers (Landlord/Operator – Entrepreneur) and coordination with regulatory agencies to co-locate and coordinate activities (Regulator – Facilitator). Along the functions of 'regulator' and 'community manager', there is a greater diversity of policy measures implemented from a 'facilitator' role, rather than 'entrepreneur', perhaps because regulation and community-related issues tend to be complex, port- or country-specific and difficult to commercialize for use in other settings. Examples of entrepreneurial actions in the community manager function involve the (commercial) scaling of ICT, such as monitoring solutions, data-driven tools, and experiments with blockchain. Similarly for regulatory functions, the actions for which the port authority can take on a more entrepreneurial role are not context-specific and scalable (e.g. product certification and container security seals). In the landlord and operator functions, there is greater diversity in entrepreneurial actions, but these tend to have a predominantly local scope, focusing on investments in cold logistics facilities within the port cluster. Interestingly, some policies that emphasize the 'facilitator' role are in fact implemented with a global scope (e.g. promotion and lobbying). These lack the entrepreneurial element of direct commercial involvement, but still have the global scope that the framework associates only with the 'entrepreneur' role.

5. Discussion

The study has mapped and 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 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. In the course of this positioning, 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 geographically towards their hinterland and foreland.

This application of Verhoeven's (2010) framework shows that 'renaissance port authorities' are indeed to be found among the world's major container ports: the major container ports worldwide commonly take on facilitating and even entrepreneurial roles to respond to challenges and opportunities in the reefer market. This implies that making the deliberate decision to focus policy towards one particular segment where the port authority identifies challenges and/or opportunity is an act of strategic orientation that puts the port authority beyond the more passive, mechanistic 'conservator' role. The fact that this shows to be the case for 35 of the 50 surveyed container ports, despite vast differences in governance models and institutional contexts, shows that Verhoeven's model is generalizable to port authorities worldwide. In its application to the case of reefer transportation and cold chain logistics, the framework proved to be of added value by showing how port authorities leverage different roles in the pursuit of policy goals. An interesting finding from applying the framework to the dataset is that in many cases, policies require a combination of functions and roles, such as cold logistics clusters being commonly set up with a port authority acting as an entrepreneurial landlord/operator and as a facilitating community manager. It also highlighted some nuances in that port authority roles can be different (facilitator versus entrepreneur) in pursuing the same type of policy, depending on the resources committed, risks taken, roles of other stakeholders involved, and the ultimate aim of the port authority. It appears that the difference between a facilitator and entrepreneur is the presence of a commercial orientation. With this point, also the main limitation of the framework that has shown in the analysis should be discussed. In the 'renaissance matrix', the geographical orientation progresses from local for a conservator role to regional and global for facilitator and entrepreneur roles,

respectively. While the step from facilitator to entrepreneur is made by adding direct financial and commercial involvement, the expansion of geographical scope does not appear to be synchronous with this role progression. The data show that port authorities can take on a facilitator role in policies with a global scope, such as international partnerships. So while the model is valid to classify port policies in functions and roles, and it can be applied in a generalized way across institutional contexts, its simultaneous incorporation of expanding geographical scope runs into limitations when applied empirically.

The limitations of the study itself 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. Secondly, the policies included in the sample 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. Third, while the authors showed that ports expand their role and scope, differences between ports in terms of governance and operating environment should be recognized. In the discussion of the results, we have acknowledged regional variation where appropriate. In Verhoeven's framework, four governance factors (the port authority's power, autonomy, resources, and management culture) determine the roles it is able to fulfill. While the data allowed classification of port authority roles for different policies, linking governance factors to port authority behavior was unfortunately not possible given the data available.

Regarding port policy in its governance context, other observations can be made based on the study findings. Although public port authorities have been commercialized and corporatized, in their more ambitious endeavors 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.

Two important port-based facets of cold chain logistics activities – processing and energy management – were surprisingly not encountered, which deserves some further discussion. This may be because responsibility for this has not been devolved to port authorities, but in case it is within the scope of port authority responsibility, it may be due to a lack of perceived importance (the port authority has other priorities) or lack of capabilities (the port authority does not have the expertise to play a facilitating or coordinating role). Furthermore, energy use in ports is typically a transaction between a user (e.g. container terminal) and a provider, the information of which is usually kept private, due to the commercial sensitivity of this information – the energy use of a container terminal is closely related to its degree of activity (Van Duin and Geerlings, 2011). For users, the priority may be with the stability of their energy supply for optimal temperature control, with the energy mix and rates considered to be given. Due to the nature of these transactions, information asymmetries can prevent port authorities from becoming actively involved with energy management in their port cluster.

It may make sense that processing activities are outside of the scope of port authority responsibility, either because of the location (inside or outside of the port cluster) of these activities or their nature (operational). Before the mass containerization of reefer cargoes, conventional

reeferships would unload at the quayside in ports, with the cargo being stored straight away in warehouses at or near the quayside. The introduction of the reefer container has reduced this necessity, and may have shifted the location of value added logistics activities to outside of the port cluster. However, other research (Castelein, Duin, & Geerlings, 2019) shows that importers prefer to strip their reefer containers in or close to the port cluster, due to the limited free time the carrier (the container owner) allows them to return the empty container before charges for late delivery apply. Therefore, one would expect facilities of perishables-shipping firms to be located near (or at least well connected to) the port. This includes the potential for functional linkages with firms and processes in the port cluster, which can be explored by a port authority with a sufficiently broad strategic scope. Regarding the nature of processing activities, it may be that private-sector parties perform these operational activities without any need for tailored policy – much in the same way that other types of industry in port areas (though subject to regulation) are not a regular policy focus of port authorities. In two ways port policy may address these activities in a strategic manner. First, in line with the frequently observed formation of cold logistics clusters, they can aim to co-locate processing activities with associated activities, reducing transportation and creating more value. This ties in with the second point, namely that considering literature regarding active involvement of port authorities in other industrial sectors (e.g. Herder & Stikkelman (2004) on methanol-based clusters), policy can support the reduction and higher-value utilization of waste flows. As product loss and waste is a highly relevant sustainability issue in the food chain, this deserves more attention. Examples could include, as mentioned, co-location of complementary activities to reduce transportation distances and the risk of cold chain breaks, but also connecting waste flows from cold chain activities (product loss in logistics and processing waste) to bio-based industry in the port cluster where these waste flows can be used as an input in higher-value-generating processes, including the production of biofuels and bioplastics.

While energy management is becoming more of a focus area for port authorities (Acciaro, Ghiara and Cusano, 2014; Parise *et al.*, 2016), this is not yet reflected in cold chain logistics activities, despite reefer containers and cold storage facilities exhibiting a large and growing energy demand with associated negative externalities. Important aspects addressed in port policy are greening of the energy mix (including renewables such as wind and solar power), stimulating energy efficiency in operations, and supporting energy-saving innovations, including smart grids. In these aspects, port authorities are involved through their role of infrastructure manager, and as process facilitator building cooperative arrangements between utility companies, grid operators, and energy-consuming port users. Organizational challenges lie in adequately matching demand and supply of energy, with more variable supply coming from renewables, and demand from port activities still growing, including energy demand peaks from reefer containers. Interestingly, blockchain technology can play an important role in matching demand and supply in smart power grids, but for the cold chain it is specifically explored in administrative and monitoring and control applications. Moreover, reefer containers and cold stores can play an important role in smart grids due to the nature of their energy demands. While cooling down to their setpoint temperature, they require power, but when cooled down to their setpoint temperature or slightly below (a so-called cold buffer function), they can remain off-power for a while before needing to actively start cooling again. These fluctuations (and potential flexibility) in demand can be used in smart grids to better match power consumption to more fluctuating production from renewables. So while we did not see evidence of port authorities incorporating cold chain activities specifically in their energy management strategies, it is clear that they are developing capabilities and playing an active facilitating role in a transition to more sustainable energy use. This trend in combination with the still growing importance of the cold chain logistics sector makes this a likely development for the future.

6. Conclusions and recommendations

This study presents several considerations for research and policy. To port policy research, this study has produced three main contributions. First the collection of a new dataset of policy measures implemented by the world's leading container ports, in a systematic way that is novel to the field. Secondly, examination of this data has provided insight in the full spectrum of policy measures port managing bodies can potentially pursue to better facilitate the growing cold chain logistics and reefer transportation sectors. Third, analysis of the data using the 'renaissance port authority' framework shows what roles and capabilities port authorities should develop to pursue these policies, and the strengths and limitations of this framework in an empirical application.

The authors can also formulate several recommendations for future research. Most importantly, future research should focus on which types of policies achieve the desired outcomes, and which factors impede or enhance the effectiveness of policies. The qualitative 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, ideally quantifying costs and benefits. More generally, similar exercises can be done into the tailoring of port policies for specific (niche) markets – ideally extended with information on policy outcomes in more mature markets. Furthermore, the study warrants several recommendations for future research using the same theoretical framework: while the 'renaissance port authority' model is generalizable and yields insightful findings, the way geographical dimension of port authority scope is incorporated in the model deserves further consideration.

While this study focused on the world's major container ports, smaller reefer ports may show a different approach in policy focusing on this market. The measures surveyed did show one aspect of reefer-related policy that is probably unique to major multi-purpose gateway ports, namely the goal of mitigating the risk that time-sensitive reefer cargoes are not held up in congested port areas and at or around terminals. These efforts to efficiently accommodate reefer container flows amid other (perhaps less time-sensitive) port activities makes up a large share of policies observed in this study, but may not be as relevant for specialized reefer ports. Also, the containerization of reefer cargoes has introduced a tension between standardization and economies of scale in container shipping on the one hand, and the time-sensitivity of reefer cargoes on the other that warrants policy focus to mitigate the downsides of this trade-off. As the larger container ports are more likely to handle the largest container carriers and the largest absolute numbers of containers, this issue of differentiation will be more relevant to them than to smaller, specialized ports, that typically receive smaller vessels (or perhaps have a focus on conventional reeferships) and do not have this need for differentiation of cargo flows. It would be relevant for future research to consider specialized ports and their efforts to better accommodate reefer logistics and cold chain activities, and compare and contrast the efforts and roles of port authorities in ports of different sizes and scopes.

For managers and policymakers, this study provides a comprehensive overview of what major ports worldwide do 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 cold chain strategies. 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. Based on the findings, 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. Considering sustainability concerns, the energy mix of these cold clusters can be made more sustainable, and smarter energy management techniques can be implemented. 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. Such modal shift policies include infrastructure investments in intermodal connectivity for cold stores, start-up subsidies for barge connections, and investments in inland terminals. Marketing and lobbying efforts can be exerted towards the foreland, but port authorities can also stimulate cooperation between different national customs and inspection agencies to expedite clearance of goods. Furthermore, 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, and to be at the forefront of technological developments. 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. The application of Verhoeven's framework to real-world instances of port policy has shown that worldwide ports are taking on facilitating and entrepreneurial roles to respond to challenges and opportunities in the reefer market. This does not mean that this behavior comes naturally to port authorities, but depends on the presence of conducive governance factors. If port authorities do not make progress towards their strategic goals (e.g. competitiveness, sustainability), it is vital to consider whether they have the power, autonomy, resources, and management culture that allow them to take on the roles necessary to pursue their goals effectively.

The reefer market is still growing, and ports would serve themselves well by considering all relevant aspects of this niche market for their own policymaking. In addition to the high-value cargoes and opportunities for value added, two global developments emphasize the broader 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. It is also in this segment that the use of blockchain technology is first being pioneered. This 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 developments in the reefer market. Furthermore, considerations regarding sustainability, logistics processes, technology, and competitiveness are top priorities for ports, and the reefer segment poses several challenges in these domains that require port authorities to develop new activities and capabilities to address. The findings from this study serve 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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