

# Understanding port performance: An examination of challenges in the contextualisation of performance in support of policy design in the port sector

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# Abstract

Owing to the prominence of maritime transport, the performance of ports as nodes in the maritime transport network is a critical enabler of a regions capability to trade internationally. Ensuring the performance of ports is therefore a frequent and prominent policy goal. Effective policy design requires an understanding of performance to evaluate and design policy interventions. A key challenge to evaluating port performance is the complexity of ports as infrastructure systems. Ports develop relative to the economic, physical and socio-political environments of the regions they serve. Understanding the performance of ports thus requires contextualisation of performance in respect of the port's operating environment. In multi-port regions, this is particularly challenging, as the performance of an individual port is most likely to be impacted by the performance of related ports. The evaluation of performance must therefore be contextualised relative to the individual circumstances of a given port and those of related ports. This thesis aims to contribute to our understanding of how to evaluate port performance as it pertains to policy design.

The thesis consists of a number of papers presented as chapters. Each chapter deals with a respective challenge to this process. The first paper presented in chapter 2, explores the dimensionality of performance and its implications for seaport performance evaluation. As entities, seaports produce a mix of private and public goods that have significant welfare implications for the regions they serve. In effect, performance in seaports can be viewed as multi-dimensional. The objective of this chapter is to conduct a systematic literature review of published studies on seaport performance measurement to identify, critically evaluate and integrate the various dimensions of seaport performance measurement. A review of the literature was thus carried out focusing on key questions in performance measurement system

design, outlining what to measure and how to measure it. The study finds that the volume of studies has been expanding rapidly, leading to significant advancement in the development of methods to create different measures of port performance across an increasing number of dimensions. However, there has been less progress in advancing means to define what constitutes performance as a construct, particularly when performance is perceived as multidimensional. In this review, five dimensions of seaport performance were identified. In addition, a formative construct of performance was proposed, to be used in the design of performance measurement systems to address policy concerns when performance is of a multidimensional nature.

Chapter 3 takes a temporal perspective, to examine the development of performance across ports in a port system over time in a case study approach. The paper examines performance change in the Irish state-owned port sector over the period 2000-2016. For analysis, qualitative sources are used to construct an explanatory account for quantitative measures of productivity, profitability and traffic shift-share change across the major ports within the system. The results show that overall change in performance largely follows that of the macro-economic performance of the region, characterised by pre-recession growth, decline during the recession and post-recession recovery. Across the ports, however, there was a notable divergence in performance post-recession. Identified factors affecting performance change across the period, include demand-side structural change, labour rationalisation, business model choice, and cargo mix choices.

Chapter 4 investigates the effect of size on technical efficiency in peripheral port markets. In peripheral port markets, a limited volume of traffic creates challenges in sustaining multiple competing Port Authorities (PAs). With a limited size, smaller ports have difficulty in attracting the necessary traffic flows to leverage capital for development. In many European

jurisdictions, recent policy reform has sought to concentrate resources in dominant ports or amalgamate smaller PAs to increase competitiveness and rationalize investments. This chapter formally examines the link between port size and achievable efficiencies through an efficiency analysis of Irish and Atlantic Spanish ports. To achieve this, the paper applies a two-step double bootstrap Data Envelopment Analysis (DEA) approach to examine the effect of relative size on technical efficiency across the two port systems in the period 2000-2015. The results indicate a positive relationship between size and technical efficiency amongst ports in peripheral regions. As the time-period covers the financial crisis, it is possible to further explore the effect of the recession and subsequent contraction in the market for port services on the relationship between size and technical efficiency. The findings indicate that the effect of size on technical efficiency becomes even stronger when market contraction is controlled for. Results also show that the efficiency gap between the larger and smaller ports increased considerably after the recession.

Chapter 5 measures performance from a network demand perspective. In many regions, capacity for port services is provided by a network of gateway ports. These gateway ports act as entry and exit nodes for a region to the wider freight transport system. Understanding existing drivers of port choice and the substitutability between nodes within the network is important for informing policy decisions regarding the allocation of often scarce resources in developing capacity. The objective of this chapter is therefore to examine demand for and substitutability between nodes in the Irish port network. A random utility maximisation framework is employed to examine the probability of routing a vessel, conditional on having chosen to run a service, through a given node based on identifiable port attributes. Using the output of the modelling exercise, several policy scenarios are simulated to examine substitutability across the port network. The model of port demand is created using a full

sample of port calls for the year 2016 using automatic identification system (AIS) data sourced from Marine Traffic.

Finally, chapter 6 explores how port managers achieve performance in matching supply of port services with demand. For countries that rely on maritime trade, the timely and appropriate development of port capacity is of strategic national importance. To achieve this, an exploratory case study is carried out in the Irish state owned port sector, where the decision to develop capacity is examined with senior executives in Irish Port Authorities. To facilitate this enquiry, key concepts from the strategic management literature are evoked to reconceptualise the capacity planning process as a capabilities search problem. The purpose of this conceptualisation is to provide a strategic framework to comparatively analyse decision making regarding capacity planning across organisations. From the case study, five generic capabilities critical to supplying capacity for freight markets in the Irish context were identified. The findings of the case indicate that underlying strategic decisions to develop capacity are assumptions about future capabilities in each of the five categories, with categories highly interlinked. Additionally, it is clear that across port contexts, the strategic importance of various capabilities will remain contingent on contextual factors accruing to the ports operating environment. This leads to practical implications for how the long term capability to supply port services for freight markets is evaluated. It is argued that any assessment of future capacity development within a given port must be cognisant of all capabilities required to develop capacity. Furthermore, the relative strategic importance of given capabilities are highly contingent on the context in which capacity is being developed.

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## Abbreviations

AIS:	Automatic Identifier System
BTI:	Buffer Time Index
CL:	Conditional Logit
CRS:	Constant Returns to Scale
DEA:	Data Envelopment Analysis
DGP:	Data Generating Process
DMU:	Decision Making Units
DFT:	Dublin Ferry Terminals
GDA:	Greater Dublin Area
IID:	Identically Independently Drawn
IIA:	Independent of Irrelevant Alternatives
IMTE:	Irish Maritime Transport Economist
LoLo:	Lift on Lift off
MTL:	Marine Terminals Limited
MCI:	Market Contraction Index
NPP:	National Ports Policy (2013)

NHHI:	Normalised Herfindahl-Hirschman index
PA:	Port Authorities
PSC:	Port Service Chain
RPL:	Random Parameters logit
RUM:	Random Utility Model
RP:	Revealed Preference
RoRo:	Roll on Roll off
SE:	Scale Efficiency
SLTO:	Social License to Operate
SP:	Stated Preference
TFP:	Total Factor Productivity
VRS:	Variable Returns to Scale
VSI:	Vessel Size Index

# Chapter 1 - Introduction

## 1.1 - Introduction

This thesis by papers explores issues related to the analysis of seaport performance in the context of port policy design. Given the prominence of seaborne trade, there is an inherent public interest in the performance of ports. The design of policy to ensure the effective functioning of the market for port services is an important policy issue. Effective policy intervention relies on a strong evidence base to design and evaluate the effect of policy interventions (Gertler et al., 2016). Port policy design follows suit.

Ports have many different actors involved in the supply and consumption of port services with roles and functions often intersecting (Bichou, 2006). In addition, port operations have impacts on the urban and physical environments in which they are embedded. The consequence of this is that ports are complex systems with a diverse range of stakeholders affected by their performance. As with any complex system, there are considerable challenges to creating a clear understanding of the functioning and performance of the underlying system, particularly when considering how port systems change over time and in response to changing forces in the ports macro and meso (industry) environment (Sánchez and Wilmsmeier, 2010; Vonck and Notteboom, 2016). This thesis provides a number of empirical studies that each deals with a respective challenge in the evaluation of performance in the design of port policy. The overall aim of the thesis is to contribute toward our understanding of how to evaluate port performance as it pertains to policy design.

This initial chapter sets out to frame an appropriate context for the empirical studies by introducing the key facets of port policy design and appropriately demarking the role of performance evaluation in its design. To that end, Section 1.2 introduces seaports as economic

systems and clearly outlines the public interest in their functioning. Section 1.3 sets out the key debates surrounding port policy design and the role of performance evaluation in its formulation. Section 1.4 introduces the papers and outlines how they contribute toward the overall knowledge of the task of performance evaluation in the design of policy interventions in the port sector. Finally, Section 1.5 details the relevant communication of the work in the form of accepted peer reviewed publications, papers under review, research papers and conference presentations.

## 1.2 - Seaports and the public interest

The fundamental role of a seaport is to act as a facility at which ships run alongside land to be unloaded of and loaded with cargo (Stopford, 2009). Performing this role, the port acts as a connection point or node within a wider network that facilitates the flow of cargo across land and sea. As a node, ports have traditionally attracted the development of adjacent industry giving ports a secondary role as an enabler of production. However, since the end of World War Two, the rise of globalisation, improvements in intermodal technology and the rapid advancement in information and communication technology has led to an expanded role for ports as focal points for the control of transportation flows in complex logistic networks<sup>1</sup>.

Globalisation has seen a dramatic increase in the volume of trade internationally but it has also led to greater integration across markets, greater mobility of factors of production and greater mobility of goods and services (Haralambides, 2017). For example, it is not uncommon for a car sold in the United States to be manufactured in Germany with parts shipped from Africa, Asia and Australasia. Such a transaction entails a further series of sub-transactions

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<sup>1</sup> UNCTAD estimate that the value of exports globally in merchandise trade has risen from 58.6 million dollars in 1948 to 17.8 billion dollars in 2017.

between numerous spatially distant agents. As described by Haralambides (2017) the strength of the tie between manufacturing and the location of the factors of production has been greatly weakened. The rise in globalisation has been facilitated by containerisation and subsequent improvements in efficiency and ease of intermodal transport. The net result is a dramatic increase in international trade and the volume of cargo flow, but also the complexity of trade flows. Advancements in ICT have enabled the controllers of trade flows, logisticians and supply chain managers to design and manage systems to manage and create efficiencies in the transportation of goods, respective of complexity. The result is an integrated global network of producers and consumers.

The role seaports play for a given region is in allowing access to this network for both producers and consumers. Seaports, and more specifically the effectiveness of the services they provide, act as a critical enabler of and source of competitiveness for, a regions capability to trade internationally. Effective port services enable and influence the costs of transportation. Transportation itself is a friction cost that is an essential component for almost all transactions and manifests in terms of both time, money and service level (Winston, 2013). At the most basic level, it is in the public interest that the market for port services is functioning in such a way that port services do not generate friction costs that hinder market transactions. The worst case scenario is that friction costs will be sufficient to deter the formation of markets completely. Increased friction costs accruable to port services typically arise from an under-provision of capacity which results in congestion or ineffective provision of port services due to managerial inefficiency.

Beyond a functioning market place, port operations have further effects that are likely to impact the public interest. These include positive externalities related to industrial development and direct and indirect value added economic impacts. Furthermore, port

operations can produce several negative externalities, including a detrimental effect on the physical environment and increased urban congestion. De Langen and Der Lugt (2016) provides a useful typology of public interests in the provision of port infrastructure, reproduced here in Table 1-1. Represented are public interests related to the functioning market such as access, competition, and a level playing field but also other externalities such as safety and environmental concerns.

Table 1-1 Public Interests in Ports

Public Interest	Explanation of public interest
Nautical safety	Nautical incidents have effects on society as a whole, including pollution. In addition, ships navigate in water owned by the state.
Minimizing negative externalities	Negative externalities harm the well-being of the general public. This applies to emissions as well as stench and noise and other negative externalities of port activities.
Sufficient competition	Dominant market positions of either the port authority or service providers in the port may lead to excessive pricing.
Market access	Insufficient market access reduces competitive pressure on service providers in ports and hurts port users and the general public.
Level playing field	Distortions from a level playing field due to differences in government policies (for instance regulation, subsidies, tax practices) lead to an inefficient allocation of resources: some ports will receive more cargoes than in an optimal situation, others less.
Port development initiative	Given the huge regulatory complexity and uncertainty, initiatives for new port development may not emerge even though they are in the public interest.
Land use changes	Given changing user needs (for instance larger ships), a transition of port facilities to urban functions may be in the general interest, but may not emerge 'spontaneously' given unaligned interests.
Continuity of port operations	A limited risk profile of the PDC is in the public interest given the effects of financial distress of the PC on port users and society at large.
Positive R&D externalities	Investments in R&D 'spill-over' to third parties. Thus, investments in R&D are in the public interest.

Source: De Langen and Der Lugt (2016)

### 1.3 - Key Aspects of Port Policy Design

Public policy in the port sector consists of the design of the institutional arrangements that govern the development, provision, and consumption of port services in a given regional

jurisdiction. Regulation at a national and supranational level is an important facet of policy design in the sector. Prominent examples are related to safety at sea, for example, the SOLAS convention, and market access for example, European Port Services Regulation. While regulation is an important component of port policy, the overwhelming majority of discourse has focused on the ownership and governance structure of port infrastructure. This is largely attributable to the wave of reform that has taken place internationally beginning in the 1980s (World Bank, 2007).

While ownership of port infrastructure has remained largely public, the governance structure of the public bodies responsible for port development, the Port Authorities, have changed significantly with increased autonomy and commercialisation. In addition, the complexity of ports as infrastructure systems has grown over time, with an increased number of services and service providers involved in the utilisation of port infrastructure. This has led to a greater degree of private sector participation within the ports. Before describing the nature of extant forms of governance in the port sector, it is worth exploring the key debate that influences much of this reform. Namely, to what degree should ports be owned and services delivered by the private sector, and when the private sector is involved, how it should be regulated?

### *1.3.1 - Key Debate in Port Policy Design*

Winston (2013), commenting on the transportation sector, more widely frames the debate as a question of market failure versus government failure. Market and government failure occurs when private or public provision of infrastructure leads to outcomes that are sub-optimal<sup>2</sup>.

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<sup>2</sup> Optimality is most frequently assessed in terms of Pareto Optimality, as introduced by Italian economist Vilfredo Pareto. Pareto optimality can be defined as a state of allocation of resources from which it is impossible to reallocate so as to make any one individual or preference criterion better off without making at least one individual or preference criterion worse off.

Private sector provision as per Winston is justified when either there is no presence of market failure or the social costs of government failure far outweigh the cost of market failure. Both forms of failure are used to justify policies in the port sector. The challenge for policymakers is determining the appropriate role of the private sector. As outlined by De Langen and Der Lugt (2016) once a public interest is identified, the next question is to what extent performance can be ensured through regulation or full public provision.

The two most prominent market failures that lead to social costs applicable to the port sector given privatisation, are the threat of under-provision of infrastructure and the threat of economic rent extraction. The former may occur due to the high cost of infrastructure development. Capital expenditure projects in the port sector typically involve expensive land acquisition, dredging, and subsequent complex planning processes (Dooms and Verbeke, 2006; Taneja et al., 2010; Dooms et al., 2013). In light of costs, lengthy lead times and risk, there is a fear that the private sector would have little incentive to develop infrastructure appropriately. Finally, the commercial returns associated with port infrastructure development are typically relatively low, with long associated gestation periods before projects generate returns (Haralambides, 2017).

Rent extraction is a feature of the degree to which ports are natural monopolies. Traditionally, ports were seen as natural monopolies due to the costs associated with users in a given region switching to another port further away which restricted inter-port competition. In addition, given the high start-up costs and benefits accruing to economies of scale, the threat of market entry is typically low in the port sector. As intermodal technology and hinterland connection has improved, the substitutability between ports has increased in a process described by Noteboom and Roderique (2005) as hinterland penetration. From a policy perspective, both under-provision of infrastructure and economic rent extraction are likely to

have negative social costs in terms of under-provision of port services, increased costs to the consumer or both.

A final argument relates to externalities associated with port infrastructure provision. Most prominent is the positive economic impact of ports as outlined above. There is often a justification for regional, national and supranational governments to assist in the financing of port infrastructure projects to boost/ensure the competitiveness of a region and boost direct employment. This is often called a public good argument. It is questionable however whether port services constitute public goods in a classical sense. Baird (2004) for instance, points out that port services do not strictly adhere to the classical conditions for port services. They are not non-rivalrous, they are typically excludable and don't exhibit non-reject ability of consumption. While port infrastructure provision can be justified due to their externalities, port services themselves aren't necessarily public goods.

As per Winston (2013), government failure on the other hand, occurs when the public provision of infrastructure results in inefficient prices, and operations and poorly allocated investments. The World Bank (2007) outlines two prominent instances of government failure that led to the large scale reform of the port industry in the 1980s. The first is the influence of central government in restricting the capability of port bodies to respond to changing market requirements. Here the World Bank (2007) notes overly rigid planning, command, and control structures as contributing to stasis within the sector. The second is the under (given budget restrictions) or over-investment by government. In terms of the latter, the report outlines several prominent examples of so-called 'white elephant' investments. Here mis-investment in port infrastructure has led the unnecessary duplication of infrastructure and the development of infrastructure in locations that are uncompetitive due to geographic and/or physical constraints. Another factor which influences the investment under the public provision model is political

influence (Baird 2004). Haralmbides (2017) attributes the latter to the availability of cheap public funds.

A final factor influencing the trend toward increased private sector participation is the growing complexity of ports. This is well encapsulated in the UNCTAD's (1994) Port Generations model (Beresford et al., 2004). The model describes three generations. The first generation ports began in the 1960s, proceeding to second generation ports from 1970-80 and finally third generation ports from the 1980s onwards. From the first to the third generation, ports are characterised as evolving from isolated interchange points between land and sea to multi-functional production units as represented in table 1-2. Subsequent extensions of this work have led to fourth and now fifth generation ports (Lee and Lam, 2016)<sup>3</sup>. Growing functionality and subsequent complexity greatly challenge the capability of Port Authorities to effectively manage all facets of port operations. Outsourcing to the private sector in the form of concessionaire agreements and licensing is an attractive means to deal with this problem. As will be explored further in the next section, the use of such agreements has become the dominant paradigm in port management as ports look to manage the development of increasingly complex infrastructure systems.

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<sup>3</sup> These models are subject to some criticism. Most prominently Beresford et al. (2004) argues ports evolve continuously rather in discrete steps. Beresford et al. (2004) shows that many ports display features of first generation and third generation ports simultaneously. Furthermore even within ports, different terminals might display features of alternate generations. Beresford et al. (2004)'s critique shows that the port generations model is largely stylistic however it is illustrative to the growth in functionality in ports over time.

Table 1-2 UNCTAD's Generations Model

Period of Development	First Generation (Before 1960s)	Second Generation (After 1960s)	Third Generation (After 1980s)
Main Cargo	- Break bulk cargo	- Break bulk and dry/liquid bulk cargo	- Bulk and unitized containerized cargo
Attitude and strategy of port development	- Conservative - Changing point of transport node	- Expansionist - Transport, industrial and commercial centre	- Commercially oriented - Integrated transport centre/logistic platform for international trade
Scope of activities	- Cargo loading Discharging, Storage, - navigational service - Quay and waterfront area	- (1) - Cargo transformation; ship-related industrial and commercial services - Enlarged port area	- (1,2) - Cargo and information distribution; logistics activities - Terminals and distribelt towards landside
Organization characteristics	- Independent activities within port - Informal relationship between port and port users	- Closer relationship between port and port users - Loose relationship between activities in port - Casual relationship between port and municipality	- United port community - Integration of port with trade and transport chain - Close relationship between port and municipality - Enlarged port organization
Production characteristics	- Cargo flow - Simple individual service - Low value added	- Cargo flow - Cargo transformation - Combined services - Improved value added	- Cargo/information flow - Cargo/information distribution - Multiple-service package - High value added
Decisive factors	- Labour/capital	- Capital	- Technology/know-how

Source: Beresford et al. (2004)

### 1.3.2 - Port Policy Design in Practice

The scope for market and government failure in the provision of port infrastructure is prevalent and used frequently to justify the involvement of private and public sectors in the provision of port infrastructure. A UK example presented by Goss and Stevens (2001) is illustrative. In the post- World War Two period, in response to a perceived market failure, many of the largest

ports were nationalised, falling under the British Transport Docks Board (BTDB). Subsequently, following a reversal of policy, the BTDB was privatized in response to a then perceived government failure.

The UK is an exception in fully privatising ports as public private partnerships have become the norm in most jurisdictions. As identified in Brooks and Cullinane (2006), and reconfirmed in Brooks et al (2017), the dominant form of governance has been the landlord port model. As represented in the commonly applied framework of the World Bank (2007) in Figure 1-1, the landlord model is characterised by public ownership but private provision of port services. In contrast to the full privatisation or public provision (tool port model) the landlord and its hybrids are attempts to balance the mix of private and public provision to best achieve the perseverance of the public interest in port service delivery.

Figure 1-1 World Bank Port Management Types

Basic Port Management Models				
Type	Infrastructure	Superstructure	Port Labour	Other Functions
Public Service Port	Public	Public	Public	Majority Public
Tool Port	Public	Public	Private	Public/Private
Landlord Port	Public	Private	Private	Public/Private
Private Service Port	Private	Private	Private	Majority Private

Source: World Bank (2007)

The World Bank model as represented in Figure 1-1, provides a useful means for segmenting port governance models. However, empirical evidence shows that the situation is far more nuanced. Again, this is very well evidenced in the case studies presented in the twin compositions by Brooks and Cullinane (2006) and Brooks et al (2017). The exact arrangements of what gets privatised, what services are privately provided and how these arrangements are governed and regulated are found to differ significantly across jurisdictions. Brooks and Cullinane (2006a, p.18) suggest that simple classifications for ports governance structures are

not directly applicable in practice. A survey elicited responses from 42 ports in ten different countries on the strategic intent of the port, as well as the allocation of responsibility for port-related activities including cargo handling services. The results were used to create a typology of governance structures based on combinations of the devolution of responsibility for port-related activity. Out of a total of 512 possible configurations, 34 combinations were identified to be in use across the ports surveyed.

In addition to the governance and ownership structure, the aforementioned regulation plays an important role. Examples of prominent regulatory frameworks are the safety at sea and planning regulations that are common means used to insure against negative externalities. Market regulation is also common, for example, in Spain pricing restrictions have only recently been amended (Coto-Millán et al., 2016). Again, the challenge for policymakers is choosing the right institutional arrangements to best achieve the public interest in a given context.

Understanding what institutional arrangements will likely result in the best performance outcomes relies on a level of causal understanding of the likely effects of a given set of arrangements in a given market environment. Economic theory points toward the degree of competition as dictated by the market for port services as a key influencing factor. Winston (2013), in particular, highlights the extent to which firms possess market power, their incentives and the power of consumers.

The UK experience and the outcomes of privatisation are illustrative. Baird (2013) argues that a focus on profits in the short to medium term is having a detrimental effect on investment in new infrastructure. However, Farrell (2013) and Monois (2017), point out that there is evidence that under the right incentives port investment is occurring. Elsewhere, Monois (2017) contends that the rate of development in the east coast of England versus development in Scottish ports provides evidence that sufficient competition is important for

port development in a purely market system. Baird (2016) goes further, stating that the effect of privatisation on port capacity development in Scotland has resulted in existing Scottish Ports becoming ‘technologically obsolete and entirely unsuited to accommodating modern ships and cargo handling systems’. The author argues that private equity firms have prioritised the acquisition of large economic rents at the expense of Scotland’s ability to trade internationally. This evidence points specifically to the importance of the level of competition between ports (and often within), as a key force in determining what level of privatisation should occur.

A second force that has been found to be highly significant but not necessarily encapsulated in traditional economic theory is the role of existing socio-political processes and wider institutional forces in a given region in influencing the outcome of a particular programme of reform. Ng and Pallis (2010) showed the role of existing institutional norms and subsequent path dependency in determining the outcome of port governance reform despite generic solutions. Subsequent studies including Dooms et al (2013) and Notteboom et al (2013) have further illustrated the role of path dependency in influencing the outcome of port reform. The extant empirical evidence strongly points to the importance of accounting for the existing economic and political environment in the design of port policy. This leads Parola et al (2017) to posit that the evaluation of port reform processes should take into consideration the ‘embeddedness of ports in (multiscale) institutional and economic contexts, as de-contextualisation may cause rigid processes which fail to match the industry requirements and may cause institutional divergence’

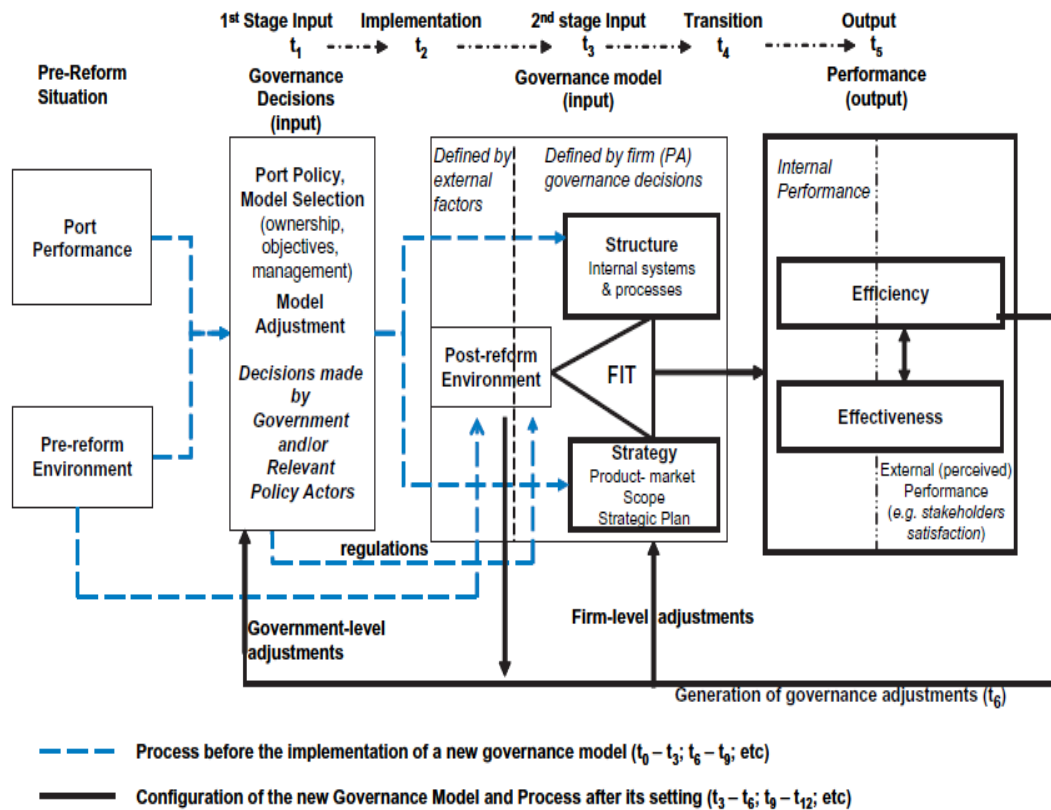
### *1.3.3 - Contextualising Port Performance in Policy Design*

The importance of contextualisation in institutional design is further reflected in the prominent theory of port governance design (notably the models of Balthazar and Brooks (2000, 2006, and Brooks and Pallis (2008). Balthazar and Brooks (2006, 2001) propose the use

of contingency theory to create a predictive framework for analyzing the impact of a port governance model. Here performance is determined by the configuration of three inputs; the strategy of the port, the governance structure imposed on the port and the operating environment in which the port operates. They propose that the level of fit between the three inputs will determine performance. Brooks and Pallis (2008a) expand upon this framework to create a process model for port institutional reform as represented in Figure 1-2. Here port reform is conceptualised as a dynamic process where the policymakers assess port performance in the context of the existing port environment and design and implement policy change. The resulting effect of the policy is a function of the aforementioned fit between strategy, environment, and structure. The policymaker then assesses the performance as measured through the efficiency and effectiveness of port service delivery in the context of the ports environment and repeats the process.

As conceptualised, there are three key challenges for the policymakers. In time period one, the policymaker is required to match the objectives of reform with the correct policy instruments. The match between the objectives of reform and the instruments to implement the reform is further contingent on the environmental context. To predict the effect of the instruments requires an understanding of the effectiveness of various policy instruments in the context of the operating environment. The second challenge is implementation encapsulated in time periods two to four. The third challenge is further contextualising the effect of the post-reform performance in the context of the post reform environment. This is conceptualised as a dynamic process that should lead to readjustment and further reform. This thesis is mainly concerned with the first and third challenge, and in particular contextualising performance in the context of the ports environment.

Figure 1-2 Brooks and Pallis's Model of Policy Design:



Source: Brooks and Pallis (2008a)

#### 1.4 – Overview of the thesis

The overarching theme of the thesis is the contextualisation of port performance to provide support in the design of port policy. The challenge facing policymakers in contextualising port performance in relation to its environment is that there is a high degree of heterogeneity across ports as infrastructure systems. Ports are generally comprised of many physical elements but also many different and often conflicting agents (for example terminal operators and local community groups) with ports characterised as complex socio-technological systems (Bekebrede and Mayer, 2006). Port development, therefore, is relative to the actions and influence of a diverse range of actors and stakeholders involved in its development. Ports as individual units typically develop relative to their immediate environment but also the wider

system of ports of which they are apart. Systems of ports similarly evolve relative to the wider transport and economic systems (Sánchez and Wilmsmeier, 2010). To understand port development, therefore, it is necessary to understand development in the context of these further systems, which are typically diverse.

The thesis contains a literature review and four empirical papers that deal with specific challenges in the process of contextualising port performance in the support of policy design. It is worth noting that the scope of analysis is not uniform throughout all five papers. The literature review deals with port performance holistically, dealing with performance accruing to port infrastructure generally. The literature review therefore, considers performance from the perspective of multiple units of analysis and does not restrict the analysis to a specific geographic region. The remaining empirical papers focus on performance in the context of Irish ports, with paper 3 (chapter 4) extending the analysis to also include North Atlantic Spanish ports. Also, the major unit of analysis within each paper varies, with analysis pertaining to performance of individual port infrastructure systems, individual production units within ports and systems or networks of port infrastructure systems. This is reflective of the nature of port infrastructure systems, given that ports are composed of multiple production units and port infrastructure systems perform relative to the network that they are embedded within.

The remainder of this section outlines the overarching research objective, specific research objectives of the individual papers presented as chapters, the respective structures of the chapters and finally the overall research framework.

#### *1.4.1 - Research Objectives*

The overarching aim of the thesis is to contribute to the extant literature on port performance through providing insight into how performance can be contextualised in the context of port

policy design. To facilitate the achievement of this, a number of ancillary objectives are formed. As aforementioned, these objectives are motivated by specific challenges in evaluating performance in the process of policy design. Each objective will be discussed in turn.

**Objective 1. Examine how policy makers can decide what to measure to achieve policy objectives.**

For policy makers deciding what performance is and how to measure it when either evaluating ex-post or predicting performance ex-ante is challenged by inherent complexity. Port infrastructure systems have multiple stakeholders whose interests are not necessarily aligned (for example terminal operators and local community groups). In addition, port performance has second-order welfare effects as described in section 1.3. Therefore, what constitutes performance can vary, contingent on the interest of the stakeholder group or stakeholder groups in question. Port performance as such is multi-dimensional and a key challenge to the policymaker is ascertaining what dimensions are relevant when designing specific policy interventions. Objective one therefore seeks to explore how policy makers can measure performance respective of these challenges.

**Objective 2. Examine how policy makers can evaluate port performance change over an extended period of time respective of the key internal and external drivers that influence port performance.**

A key challenge in examining performance change over an extended period of time is accounting for the environmental factors external to the control of the individual port managers that drive performance. Ports and port systems evolve over time and in response to various forces in the port and maritime industry (meso), and wider macro-economic environment in which the ports are embedded (Beresford et al., 2004; Sánchez and Wilmsmeier, 2010; Wilmsmeier and Monios, 2016). Demand for port services is derived from the requirements of

international trade and ports evolve relative to changes in the nature of this demand. The capability of ports to sustain performance given changes in the ports contextual environment, represent a key aspect of port performance, identified recently by Notteboom (2016) as the ports adaptive capacity. Objective two seeks to examine how policy makers can examine and identify performance effects in the port context over time given the potentiality of multiple causes of performance.

**Objective 3. Examine how policy makers can evaluate the performance of a port as a node in providing access to the maritime network relative to other ports in a port network.**

In many regions port services are provided by a network of ports. When capacity is provided by a network of terminals it is essential that cargo can flow through the nodes of the network in an efficient and effective manner. The effect of a dysfunctional network is increased costs to both importers and exporters, and at worst, a loss of access to international markets. In such cases it is thus a policy objective to ensure that there is enough capacity across the network to effectively accommodate traffic requirements. Understanding existing drivers of port choice and the substitutability between nodes within the port network is important for informing policy decisions regarding the allocation of often scarce resources in developing capacity. Understanding substitutability between nodes is particularly important as given the nature of capacity development; nodes in the system will tend toward periods of under capacity. Objective three, therefore, seeks to examine how policy makers can derive insight into the performance of ports as nodes in a port network.

**Objective 4. Examine how policy makers can understand how port managers achieve performance in matching supply and demand for port services.**

The appropriate supply of port capacity is a critical enabler of a regions capability to trade internationally. For policy makers at the regional and national level, therefore, it is a critical

requirement to be able to assess whether the bodies responsible for the development of capacity are performing in this function. To be able to assess whether or not capacity is developing appropriately requires policy makers to define what constitutes appropriate capacity development in a given port context. This requires an understanding of how port managers achieve performance in supplying capacity to given freight markets. Objective three therefore seeks to develop a framework for understanding how port managers achieve a match between supply and demand for port services in respective freight markets.

#### *1.4.2 - Structure of remaining chapters*

Chapter 2 (paper 1) is related to objective one. The chapter explores this topic through a systematic review of the extant literature on port performance measurement. The chapter outlines the review process in detail, including how studies were located, selected for review and subsequently analysed. The findings are subsequently presented as a thematic categorisation of the dimensions of performance and how performance is measured within the specific dimensions. Based on the review the chapter proceeds to discuss how policy can accommodate multiple-dimensions in the evaluation of port performance. Finally, the chapter concludes with a discussion of the potential implications for policy.

Chapter 3 (paper 2), and chapter 4 (paper 3), both relate to research objective two. Paper three takes a temporal perspective, to examine the development of performance in Ireland's largest state-owned ports over time. Ports do not develop in isolation. This chapter looks to contextualise the performance of Irish ports in the context of major macro and meso (industry level) changes that have influenced how ports achieve performance over time. The time period covered is 2000-2016, which encapsulates the pre-financial crash boom period from 2000-2008, the post-crash recessionary period and the post-recession recovery period.

To achieve this, a mixed methods approach is applied to develop an understanding as to how PA's perform in achieving productivities across port contexts and time-periods. Here performance change is measured for selected ports within the Irish state-owned port system using measures of total factor productivity, profitability and traffic shift-share. Qualitative sources are then referenced to contextualise the change in observed performance in terms of external environmental and internal managerial factors that influenced the change in productivity. Using the qualitative sources and in particular the yearly management review of performance, it is possible to identify key factors that have influenced relative levels of productivity across the ports sampled. The chapter concludes with a discussion of the results and the implication for policy in Ireland and policy more generally.

Chapter 4 builds on chapter 3, through expanding the sample size to include North Atlantic Spanish PAs. The chapter investigates a key factor identified in chapter 3 as influencing performance across ports, namely the relationship between size and technical efficiency in peripheral port regions. Peripheral regions are characterised by limited volume. In such a market it is questionable whether there is enough volume of traffic to support multiple competing PAs. Recent reforms in several European jurisdictions have reflected this with either a concentration of resources or merger of formerly independent Port Authorities. Despite this, the evidence regarding port efficiency and scale of business is mixed. In the thesis it is argued that this is partly attributable to the type of sampling employed. Through purposeful sampling this chapter seeks to explore this relationship more thoroughly.

To investigate the effect of size relative to the market and technical efficiency the common Simar-Wilson two-step double bootstrapped procedure is employed. This approach involves firstly measuring technical efficiency in a first stage Data Envelopment Analysis (DEA) and then proceeding to regress the resulting scores against a number of covariates of

interest using a bootstrapped truncated regression approach. The dataset is comprised of a panel set of fifteen years of observations (2000-2015) for the ten Spanish North Atlantic Ports and five Irish state-owned ports with traffic above one million tonnes on average. The time period covers both the run up to the financial crisis of 2008 and the recovery period. Thus it affords the opportunity to examine whether the effect of size is altered by a contraction in the market. To this end, two regressions are used, the first investigates the effect of port size on efficiency over the period in a manner that is unrestricted. The second investigates the effect of size in an interactions model to examine if the magnitude of effect is altered by the market contraction. The chapter concludes with a discussion of the findings and implications for policymaking.

Chapter 5 (paper 4), corresponds to research objective three in examining port performance at the port network level. This chapter proposes a means to model demand across a network of nodes through a novel application of discrete choice analysis using Automatic Identification System (AIS) data. The model of port demand is created using a full sample of port calls for the year 2016. The chapter firstly models demand through estimating the probability of a carrier choosing to run a service through a given node in the network based on the attributes of the terminals. Using the model, substitution patterns are examined using simulations of policy scenarios.

Finally, chapter 6 (paper 5), explores how port managers achieve performance in matching supply of port services with demand consistent with objective four. This chapter sets out to create a framework for understanding capacity plans in the context of key factors influencing strategic decision-making in port capacity planning. To facilitate this inquiry, key concepts from the strategic management literature are evoked to reconceptualise the capacity planning process as a capabilities search problem. Using the concepts introduced, two research objectives are formed. Firstly, to identify the critical capabilities PAs require to consistently

achieve performance in the matching of demand with the supply of port services for freight cargo in the long run. Secondly, to explore across port contexts how PA's in strategic decision making are responding to respective challenges and opportunities to develop capabilities to serve freight markets.

To achieve the research objectives a case study is then carried out on the five Tier 1 and Tier 2 state-owned Irish ports. To identify the critical capabilities, semi-structured interviews were conducted with senior executives of Irish ports with oversight of port capacity and master planning. In the interviews, executives were asked to examine how they chose their existing plans in the context of the critical decision criteria that influenced their decision making process. Interviews were then transcribed and analysed using causal mapping techniques to identify the critical capabilities required to develop capacity. To improve face validity, resulting critical capabilities were then discussed and validated in follow up interviews. To explore across port contexts how PA's are responding to respective challenges and opportunities in the development of capabilities a second stage analysis was carried out. Here a thematic analysis of transcripts, field notes and publicly available corporate documents was carried out. This was done by using the critical capabilities identified in the first stage analysis as themes and examining how PAs are developing these capabilities in a given port context.

The final chapter (chapter 7) concludes the thesis by outlining the contribution of each chapter, their limitations, future research avenues and finally policy implications.

#### *1.4.3 - Research Framework*

As outlined the thesis contains a number of papers that each aim to contribute to the literature on port performance through improving our understanding of how port performance can be contextualised in support of policy making. The overall research framework is presented in

Table1-3.. Presented in the table is the overall research aim, the specific research objectives, the research carried out to achieve the research objectives and methods employed. Also included are empirical papers that have resulted from the research, with full references reported in section 1.5.

Table 1-3 Research Framework

<b>Overarching Aim: Contribute to the understanding of how performance can be contextualised in the context of port policy design.</b>		
<p><b>Gap:</b> Given multidimensionality of performance there is a gap in understanding of how to ascertain what dimensions are relevant from a policy perspective</p>	<p>Objective 1: Examine how policy makers can decide what to measure to achieve policy objectives.</p>	<p>Research: The study presented in chapter 2, aims to achieve the objective through a review of extant literature on port performance.</p>
		<p>Methods: A systematic literature review was carried out.</p>
		<p>papers:</p> <ul style="list-style-type: none"> <li>- <i>“Port Performance from A Policy Perspective – A Systematic Review of the Literature”</i></li> </ul>
<p><b>Gap:</b> The capability of ports to sustain performance over time, given changes in the port’s contextual environment, represents a key aspect of port performance. A major challenge identified in examining port performance change over an extended period is accounting for the environmental factors external to the control of the individual port managers that drive performance.</p>	<p>Objective 2: Examine how policy makers can evaluate port performance change over time respective of the key internal and external drivers that influence port performance.</p>	<p>Research: To achieve the objective two studies were carried out. Chapter 3 contains a review of Irish port performance over the period 2000-2016. Chapter 4 presents an examination of the relationship between technical efficiency and relative size in Irish and North Atlantic Spanish ports between 2000-2015.</p>
		<p>Methods: study one (chapter 3) employs a mixed methods case study where qualitative sources were used to contextualise quantitative measures of port performance change.</p>
		<p>Study two (chapter 4) employs data envelopment analysis to measure technical efficiency and a second stage truncated regression to examine the relationship between relative size of the port and technical efficiency.</p>
<p><b>Gap:</b> There is an identified difficulty in modelling relative demand for port services across ports in a network, which is important for policy makers when port capacity for a region is provided by a network of ports.</p>	<p>Objective 3: Examine how policy makers can evaluate the performance of a port as a node in providing access to the maritime network relative to other ports in a port network.</p>	<p>Research: To achieve the objective an analysis of demand and substitutability between nodes within the Irish container terminal is carried out as presented in chapter 5.</p>
		<p>Methods: A novel application of discrete choice analysis is conducted where automatic identifier system data is used to model demand and substitutability across the port network.</p>
		<p>papers:</p> <ul style="list-style-type: none"> <li>- <i>“Examining demand and substitutability across terminals in a gateway port network: A discrete choice model of Irish ports.”</i></li> </ul>
<p><b>Gap:</b> For policy makers, the evaluation of whether port capacity is been developed appropriately at the individual port level requires an understanding of how port managers achieve performance in supplying capacity to given freight markets. This understanding is challenged by the complexity of port development.</p>	<p>Objective 4: Examine how policy makers can understand how port managers achieve performance in matching supply and demand for port services.</p>	<p>Research: To achieve the objective a case examining how port managers in Irish ports achieve performance in matching supply and demand is carried out as presented in chapter 6.</p>
		<p>Methods: The paper employs qualitative data analysis methods to analyse data generated through semi-structured interviews and secondary sources.</p>
		<p>papers:</p> <ul style="list-style-type: none"> <li>- <i>“Factors influencing strategic decision-making in port capacity planning: A case study of the Irish port sector”</i></li> </ul>

## 1.5 - Communications of work

### **Journal Articles:**

#### *Published*

Hynes, S., Mateo-Mantecón, I., O'Connor, E\*, Tsakiridis,A. (2018). Relative size and technical efficiency in peripheral port markets: evidence from Irish and North Atlantic Spanish ports. *Marit Econ Logist* (2019). <https://doi.org/10.1057/s41278-019-00119-5>

\*Note: The journal policy is to list the authors in alphabetical order. The PhD candidate is the corresponding and lead author on the paper.

O'Connor, E; Evers, N; and Vega, A (2019) Port Performance from A Policy Perspective – A Systematic Review of the Literature, *Journal of Ocean and Coastal Economics*: Vol. 6: Iss. 1, Article 3. DOI: <https://doi.org/10.15351/2373-8456.1093>

O'Connor, E., Hynes, S., Vega, A., Evers, N. (2019) Examining Performance Change and its drivers in Irish Ports 2000-2016. *Maritime Business Review*.

O'Connor, E., Hynes, S., Vega, A., Evers, N., 2018. Examining demand and substitutability across terminals in a gateway port network: A discrete choice model of Irish ports. *Case Studies in Transport Research* (forthcoming)

#### *Under Review*

O'Connor, E., Evers, N., Vega, A., 2018. Factors influencing strategic decision-making in port capacity planning: A case study of the Irish port sector. *Case Studies in Transport Research*.

### **Conference Papers:**

O'Connor, E, Evers, N, Vega, A, 2018 Factors Influencing Strategic Decision-making in Port Capacity Planning: A Case study of the Irish Port Sector. The Jean Monnet symposium on the future of European Port Policy, 28-29 June 2018, Chios, Greece

O'Connor, E, Hynes, S, Vega, A, Evers,N 2018. Examining demand and substitutability across terminals in a gateway port network: A discrete choice model of Irish ports. SIGA2 2018 Conference- The Port and Maritime Sector: Key Developments and Challenges, Antwerp 2018

O'Connor, E, 2017. Port Policy and Capacity Development – Case Study in Irish Ports. VI MEETING ON INTERNATIONAL ECONOMICS: FREIGHT TRANSPORT IN EUROPE: FACTS AND CHALLENGES, Instituto de Economía Internacional, Valencia Spain

O'Connor, E., Vega, A., Evers, N., 2016. Identifying the dimensions of seaport performance from a stakeholders perspective A systematic review. Presented at the International Association of Maritime Economics, Hamburg.

## Chapter 2 - Port Performance From A Policy Perspective – A Systematic Review of the Literature

### 2.1 - Introduction.

Seaports are recognised as strategically important infrastructures for the regions they serve, with performance in seaports having significant welfare effects (Coto-Millan et al., 2000). Seaports direct economic benefits through facilitating operations and transactions between private parties. They also generate additional indirect benefits as public goods in the form of trade enhancement, second order increases in production volumes and collateral increases in trade-related services (World Bank, 2007).

For policymakers, performance of seaports represents a mix of private and public interests. There is a heightened desire for public policy makers to measure the effects of seaport performance and policy programmes to regulate and manage port performance. A difficulty for policy makers is that these interests are often in conflict (de Langen, 2006; F. Parola and Maugeri, 2013; Galvao et al., 2016). For example, de Langen (2006) highlights potential conflict amongst stakeholders in five key areas that affect port development. They include environmental protection, urban development, labour conditions, resident interests and overall economic development. It is the task of the policymaker to ensure that the public interest is preserved as well as delivering value for money. In understanding performance in a given port, the policymaker must contend with multiple dimensions of performance respective of the diverse interests of stakeholders and balance the interests of different stakeholders.

This multi-dimensionality is an important aspect of port performance from the policy perspective. Research into seaports has developed to encompass many different approaches across numerous academic disciplines (For existing literature reviews in this area see: Gonzalez

and Trujillo, 2008; Panayides et al., 2009; Pallis et al., 2010; Woo et al., 2011; Vieira et al., 2014a; Dutra et al., 2015; Langenus and Dooms, 2015). The body of knowledge thus far has evolved around the port as a unit of analysis further illuminates diverse stakeholder interests. Adopting a systematic approach to the literature, the objective of this study was to conduct a review of published studies on seaport performance measurement to identify, critically evaluate and integrate the various dimensions of seaport performance measurement. Using this approach the factors of seaport performance can be identified and the relationships between them explored. In addition, the implications of the multidimensional approach for how performance in the seaport setting is evaluated from a policy perspective is explored culminating in the proposition of a formative construct of port performance.

The chapter proceeds as follows. Section 2 presents the methodology employed in the study while Section 3 provides an analysis of the findings including the categorisation of the literature according to the identified dimensions of performance measured. Section 4 follows with a discussion of the findings of the review, while Section 5 addresses the key policy implications of the study. Finally, Section 6 outlines conclusions and implications for future research.

## 2.2 - Methodology

A systematic literature review (SLR) involves the clear documentation of steps taken within the review process together with justification for decisions made. This ensures transparency, while allowing for the work to be reproducible. SLR's can be contrasted with traditional reviews. Traditional narrative reviews have been criticised for the manner in which searches and selection criteria are subject to the implicit bias of the researcher (Hart, 1998; Smith et al, 2009; Tranfield et al, 2003). There is a palpable risk of bias inherent in conducting a narrative

literature review on a broad subject such as seaport performance. Namely the temptation to follow dominant themes and approaches from the dominant disciplines in relation to seaport performance measurement with the risk of omitting, underexploring or potentially ignoring important work along the way. This is particularly prevalent given the multidisciplinary nature of the seaports performance research. In order to overcome potential bias, a systematic approach is taken to reviewing the literature with a view to overcoming limitations of traditional narrative reviews in regards to eliminating bias through adopting a replicable, scientific and transparent process.

The methodology suggested in Tranfield et al. (2003) and Denyer and Tranfield (2009) is employed in this review. A systematic review is defined as ‘a specific methodology that locates existing studies, selects and evaluates contributions, analyses and synthesizes data, and reports the evidence in such a way that allows reasonably clear conclusions to be reached about what is and what is not known’ (Denyer and Tranfield 2009, p. 39). A similar approach was applied in order to review the literature on port competitiveness in Parola et al. (2016).

The methodology is outlined in the following four steps:

#### Step 1: Question Formulation

The review question should provide focus for the review process, providing a reference point for the creation of strategy in relation to the location, selection and evaluation of studies. Neely et al. (2005,1228) define performance measurement as the process of ‘quantifying action, where measurement is the process of quantification and action leads to performance’. Put simply, performance measures can be defined as metrics used to quantify the efficiency and/or effectiveness of an action, whereas a performance measurement system is the set of performance measures. Nudurupati et al. (2011) further propose that contemporary literature on the design of performance measurement systems focuses on two fundamental questions,

namely; what to measure and how to structure the Performance Measurement System, i.e. they try to answer the question how to design the Performance Measurement System? (Nudurupati et al., 2011, p. 287).

In accordance with the above, the questions for this systematic review were formulated as follows: How has the literature on seaports performance, in particular on the process of performance measurement system design, addressed the fundamental questions of i) what to measure and ii) how to structure the performance measurement system? In order for a review question to be searchable, the research question must be broken down into key words. For this analysis, the key terms were selected 'Port', 'Performance' and 'Measurement Systems'.

## Step 2: Study Location

Following the formulation of the research questions, the next step in the systematic review process is the location of studies. The systematic review involves the location, selection and appraisal of the relevant knowledge specific to the research inquiry (Denyer and Tranfield 2009). The following steps help to identify the location of studies.

### Step 2.1: Selecting Databases

In order to ensure as much coverage of published literature as possible, existing literature reviews are examined in conjunction with key articles identified in early scoping work. Woo et al. (2011) conducted an extensive review on methodological issues in seaport research, and found that the academic journals Maritime Management and Policy and Maritime Economics and Logistics were the publications most cited during the period 1980-2009, with 233 and 101 citations between them respectively. Other prominent journals identified, included Transportation Research Part A: Policy and Practice and Transportation Research Part B: Methodological and Transport Reviews. The databases Scopus, EconLit, Business Source

Complete and Academic Source Complete provided comprehensive coverage of the identified journals of importance, as well as additional coverage of multiple disciplines important to satisfy the principle of inclusivity.

Step 2.2: Search strategy and preliminary exclusion criteria.

Four preliminary exclusionary conditions are established and applied to the searches in turn. First, in practical terms, it is necessary that the review is limited to studies that have a bearing on the specific research question. Initially, all articles unrelated to seaport performance were automatically excluded. The second condition was that only articles published in peer reviewed articles were included for review. This seeks to improve quality control in the initial search. Third, the applicability of articles is confirmed by the presence of the three selected key terms in the title, abstract and keywords. Finally, only articles in the English Language are selected.

Step 2.3: Using keywords to create search strings, pilot searches and the subsequent refinement of search strings.

Search strings are used from the key words identified in Step 1. To ensure inclusivity, deviations of the search terms are included and the terms brought together using Boolean Operators. In order to test and refine the search strings, initial pilot tests were conducted using Scopus, being the largest of the selected citation databases<sup>4</sup>. As each database has different functionalities, each exclusionary step taken is related to the condition that the review is limited to studies that have bearing on its specific research question. The most common issue arises surrounding the plurality in meaning of the term 'port'. As the word port is used to describe a variety of settings in areas such as electrical engineering and computer science, literature

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<sup>4</sup> Search Strings used are presented in Appendix A.

linking the word ‘port’ and ‘performance’ is extensive, covering a wide variety of unrelated disciplines. An essential component of the SLR is the clear documentation of exclusion criteria and recording of searches. Upon completion, a total of 1,766 articles were identified across the four databases. Reflective of the multidisciplinary nature of the research, articles are spread throughout fields, with the highest number in engineering and social sciences, but also across disciplines such as computer science and environmental science.

### Step 3: Study Selection and Evaluation

A relevancy appraisal checklist (Petticrew and Roberts, 2008) is then used to rank articles based on their relevance to the research questions (the checklist is presented in Table 2-1). As shown in Table 2-1, studies in Group A are used for further analysis, while studies in Group B provide support to the analysis where relevant but are not counted in the final analysis or findings. Studies in Group C are excluded on the basis that they are not sufficiently relevant to the context of the research questions. Following the application of the Relevancy Appraisal Tool, 227 articles are identified as Group A studies. Following Denyer and Tranfield’s (2009) methodology, a review of grey literature is conducted to improve completeness. Grey literature refers to studies that are published outside of peer-reviewed published articles and include conference papers and industry reports. From this category, 14 studies are added, giving a total of 243 studies included for literature analysis.

Table 2-1 Relevancy Appraisal Checklist

Group A	<ol style="list-style-type: none"> <li>1. Empirical Studies that measure the performance of seaports in relation to the ports' primary function as a centre for the transfer of goods and people and related activity.</li> <li>2. Analytical studies that contribute to theory on seaport performance measurement in a way that is not captured or rigorously tested in empirical work including: Studies that apply a system of measurement to measure the performance of seaports and create performance measurements, metrics or indicators.</li> </ol>
Group B	<p>Studies that contribute to theory on seaport performance measurement, but do not measure seaport performance directly or measure elements of performance too narrow in scope or context to provide general insight into the effects of the ports' primary functioning as described above.</p> <p>Studies that review or critique Group A studies.</p>
Group C	<p>Studies that address elements of performance unrelated to the effect of the performance of a ports primary functions as described above</p> <p>Articles in which the principle theory or finding put forward has been integrated into later more comprehensive studies</p> <p>Empirical or analytical studies whose original contributions have been undermined by later studies in their field of research</p>

#### Step 4: Analysis

After the selection of sources, it is necessary to analyse the contained data as a means of categorising the literature and identifying the different dimensions of performance. Categories were formed by grouping studies based on the dimensions of performance and the resulting measures examined.

### 2.3 - Findings

In total five dimensions were identified as detailed in Table 2-2. What follows is a thematic discussion of the literature identified within the review, focusing on the measures of performance created in each of the five respective dimensions of seaport performance.

Table 2-2 Seaport Performance Dimensions

Performance Dimension	What's Measured	Measures
Operational Dimension	Efficiency and Productivity (128 Studies)	Relationship between inputs and outputs
	Engineering Optimum (17 Studies)	Present vs Potential production
Customer Perspective Dimension	Effectiveness (8 Studies)	Quality of service provision
	Competitiveness (30 Studies)	Determinants of seaport choice
Logistics-Chain Dimension	Network Accessibility (13 Studies)	Foreland accessibility, Hinterland accessibility
	Supply Chain Integration (6 Studies)	Communication systems, Value added services, Multimodal systems and operations
Macro Dimension	Environmental Impact ( 10 studies)	Emissions, Noise pollution, Water pollution, Antifouling, Hazardous cargo waste (OECD)
	Economic Impact ( 21 Studies)	Employment, trade facilitation, regional impacts
Organisational Dimension (8 studies)	“Fit” Between Internal and External Factors	Gap between performance and strategic objectives

### 2.3.1 - Operational Dimension

Performance on the operational dimension measures how well relevant resources are utilised in the provision of seaports services. Notably the unit of analysis in this category differed across studies. Ranging from studies examining the provision of individual seaport services within a port (e.g. terminal operators) to looking at the provision of all services from a given port, to studies that examined the provision of services from clusters of seaports. Within the literature reviewed, two main approaches to operational level performance were identified. The first measures the efficiency and productivity of seaports from an economics perspective. This typically involves measuring the relationship between inputs and outputs in the production cycle using empirical data. The second approach measures current production levels in respect

to potential production in a theoretical capacity. This is typically measured through calculating the seaport's engineering optimum level of performance (Talley, 2006).

Examining the economic perspective first, seaport productivity has been a topic of research since the 1970s, with early studies on seaport productivity focused on partial productivity measures (G. DeMonie, 1987; Suykens, 1983; Tongzon, 1995; UNCTAD, 1976). Partial productivity measures are useful when assessing specific factors of production but when used in isolation have been found to give a misleading picture of overall productivity (Notteboom et al., 2000). As such, measures of productivity and efficiency that take into account all inputs and outputs have come to be favoured in the literature. The two main types of measures favoured are total factor productivity measures and measures of productive efficiency. The measurement of productive efficiency mainly follows the approach laid out in Farrell (1957). Overall efficiency is separated into technical efficiency (maximisation of production possibility) and allocative efficiency (cost minimisation of input ratios, or profit maximisation depending on the behavioural assumption, Kopp and Diewert, 1982). Reference technology is calculated through estimating a production possibility (or cost minimisation) frontier and examining the performance of existing seaports relative to the frontier. The two most prevalent methods for estimating efficiency frontiers are the non-parametric Data Envelopment Analysis and the parametric Stochastic Frontier Analysis.

The second approach measures seaport performance against the potential operational capacity of seaports, through simulation or analytically by using queuing theory. An advantage of this approach is that it allows for the testing of alternative strategies and configurations and the examination of seaport operations under varying conditions. Through doing this the models created act as decision supports, allowing management to estimate the results of various strategies, and inform subsequent decisions. In addition, on a strategic management level, they

provide insight into the productive capabilities of a seaport, thereby informing investment decisions on when additional capacity is required.

### *2.3.2 - Customer Perspective Dimension*

Studies in this category were grouped in order to examine the effectiveness of seaport service delivery and to examine the competitiveness of a seaport as determined by seaport service choice. In a competitive environment, the level of demand for services, relative to competitors, can generally determine the quality of services. Seaports, however, often serve as captive markets and the quality of services provided in seaports will only be one factor in determining a seaport's competitiveness. Therefore, in order to measure the quality of seaport services and competitiveness, it is necessary to measure seaports performance from the perspective of its customers.

The most prominent research on seaport effectiveness comes from a series of studies by Brooks, Schellink and Pallis (M. Brooks et al., 2011; M. R. Brooks et al., 2011; Brooks and Schellinck, 2013; Schellinck and Brooks, 2015), where effectiveness is defined as 'doing the right things' for the customer. Framed from a marketing perspective, effectiveness is delineated as a complement to efficiency (described as 'doing things right'). As discussed in the literature, it concerns the quality of service from the user perspective. In total, eight studies created measures of effectiveness, with data collected by way of survey and methods such as importance-performance analysis, Analytic Hierarchy Process and Confirmatory Factor Analysis employed to validate measures.

The second category is larger and more diverse with thirty studies selected. These studies are grouped on the basis that they focus on measuring the criteria that determine competitiveness from the seaport users perspective. In comparison with the measurement of service effectiveness, these studies analyse the factors that determine seaport quality and will

often factor in determinants outside of the seaports' control. For instance, most frequently, the stakeholder perspective is the shipping line with an increasing trend towards looking at the shipper and intermediaries (Tongzon, 2009; Yeo et al., 2011; Yuen et al., 2012; Ng et al., 2013). The majority of studies reviewed measure the factors of seaport competitiveness through modelling seaport choice in a multi-criteria decision-making model. Analytical Hierarchy Process is the most popular method employed to estimate preference weights; it relies on expert decisions on pairwise comparisons. Discrete choice modelling was also prominent in the reviewed literature.

### *2.3.3 - Logistics Chain Dimension*

Seaports act as functional nodes within a transport network for the movement of goods within the supply chain logistics process. There is a body of literature that measures performance of seaports in relation to its position within the transport network and the supply chain, with two interrelated types of measures identified in this review. The first type refers to hinterland and foreland connectivity and accessibility measures. The second concerns the seaport's position or integration within the context of their supply chain.

The concept of regionalisation of port systems describes the increase in linkages between hinterland and ports as well as the integration of intermediate hubs for transshipment purposes (Notteboom and Rodrigue, 2005; Rodrigue and Notteboom, 2010). These developments are key drivers in the shift in the traditional seaport paradigm from 'captive' to 'contestable' or shared hinterlands (Ferrari et al., 2011). Cullinane and Wang (2010) describe the competitiveness of seaports as nodes, as relative to the mass of other nodes and the cost of reaching those nodes via the infrastructural network. In the literature reviewed, the use of graph theory is most commonly applied to create measures of accessibility. Measures include

the connectivity between nodes in the maritime transport network and measures of accessibility of seaports in relation to hinterlands they serve.

The findings of this review show an apparent increase in the number of papers that seek to measure the position of seaports in their logistics and supply chains. The publication of key articles such as Robinson (2002); Carbone and Martino (2003); Bichou and Gray (2005), describe the shifting paradigm in port functions, as resulting in the increasing view of ports as embedded components of value driven chain systems. Seaports add value through the provision of services to other elements of the value driven chain and, as such, cannot be viewed in isolation. Rather, a key element of a seaports' performance is the integration of seaports within logistic and supply chains. Measures of supply chain integration in the literature include measures of value added services, multimodal integration and the use of ICS (Information Communication Systems) platforms.

#### *2.3.4 - Macro Dimension*

This dimension is concerned with a seaport's performance that has unilateral effects on the inhabitants of the regions they serve; performance at this level is thus classed as the macro dimension. Seaports as producers of public goods inevitably have long-lasting impact on their service regions. The performance of seaports has national and regional welfare implications that extend beyond their regular commercial port activities (Dekker and Verhaeghe, 2012). Consequently, the studies reviewed contained measures of performance on the macro dimension that relate to the environmental and economic impacts of seaports.

Seaports have direct and indirect economic impacts on the region in which they operate; through their commercial activities they generate wealth and employment for a region while, in addition, they facilitate trade and indirectly contribute to economic wealth generation. The

measures produced widely reflect this. The measures outline the direct and indirect effects of seaports on employment and added value, trade facilitation and the spatial economic impact of ports on their regions. Input/output and computable general equilibrium models are the two most common methodologies employed to create these measures.

Seaports generate adverse environmental effects through regular activities. The OECD recognises effects such as air pollution, noise, water pollution stemming from ballast water handling, oil spills and antifouling of ships and waste from hazardous cargoes; all of which potentially produce negative effects on their environs. As a result, there is a need to evaluate the environmental effect of seaports. 11 studies that measured the performance of seaports on environmental grounds were identified as part of the SLR. Identified studies included those that measured the direct environmental impact of seaports as well as their spatial environmental impact.

In addition, the wider literature on seaport sustainability indicates that macro performance is increasingly important for strategic management of seaports. (Dooms et al., 2015) provide a thorough literature review of port economic studies. They note that the amount of academic literature on the area is fairly limited, while there is a proliferation of impact studies by the seaports themselves, most often published as part of development plans. Included in their review is a meta-analysis of thirty-three port studies in Belgium, the UK, France and North America. Likewise, Puig et al. (2015) found that of the seventy-nine ports surveyed in a 2013 ESPO survey, 90% of respondent ports stated that they have an environmental policy and 94% of ports have designated environmental personnel. These results represent an improvement from the last ESPO Environmental assessment survey. In this review, however, only articles published by independent bodies are considered for inclusion on the basis of impartiality.

### 2.3.5 - Strategic Dimension

The final dimension identified contains studies concerned with the performance of seaports at a strategic management level. Performance on this dimension is concerned with the effects of strategic decisions on the performance of the seaports and how effective these decisions are on achieving strategic goals. In particular, there is a large body of literature that examines the institutional arrangements in seaports and in particular the strength of the governance relationship in ports, and the effectiveness of governance systems in achieving the strategic goals of its shareholders in terms of performance. This can largely be attributable to the large scale reform and restructuring in the seaport sector since the 1980s. While no agreed definition of governance exists, it generally refers to the rules and structures in place that govern managerial decisions and at the governmental level scope of managerial autonomy of the port relative to their shareholders.

Examinations of existing case studies indicate that a single best model for the governance structure of a seaport does not exist. In addition to this, the outcome of institutional reform has been found to be path dependent on the local/national institutional frameworks and the political traditions in place (Ng and Pallis, 2010;Notteboom *et al.*, 2013). Comparative to the overall body of research however, there are relatively few studies that test the fit of the governance structure empirically (Vieira *et al.*, 2014). In total, six articles were identified in the reviewed literature that examines the fit of governance structure. Analytically, this involves the creation of evaluation frameworks under which seaport reform and governance structure fit can be examined, while empirically performance is examined pre and post reform.

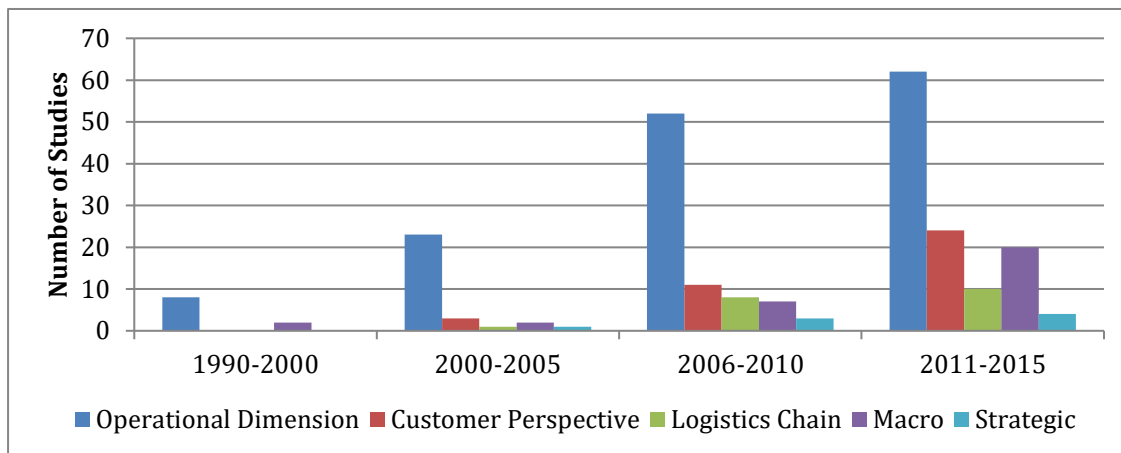
Other measures examine the effects of alternative strategic management decisions (García-Morales *et al.*, 2015), and the effects of a centralised and decentralised regulation on seaport capacity, efficiency and tariffs (Zheng and Negenborn, 2014). In addition to the studies

identified, within the literature on efficiency there are a number of studies that look at the effects of reform on efficiency levels in seaports.

### *2.3.6 - Summary of findings*

Figure 2-1 illustrates the dominant measures of operational performance across the reviewed literature. However, there has been a greater dispersion in the topic of measurement in recent years. Seaport performance measurement as a whole is increasingly multidimensional and, while this review does not address the validity of the various constructs of measurement created, the range and increased complexity of approaches toward measuring seaport performance is growing. This is consistent with the spatial and functional evolution of ports over time as observed and documented in the various models of port development such as Birds Anyport model, the Port Generations model, the WorkPort model and port regionalization. Ports are complex systems. They evolve over time and what constitutes performance similarly evolves over time. This is evident in the growth in the number of studies that examine measuring seaports' competitiveness of a ports' capabilities i.e through adding value to the logistics supply chain, a feature of so called fourth generation ports (Marlow and Paixão Casaca, 2003). Similarly, as noted in Dooms et al. (2013), the composition of salient seaport stakeholder groups and the nature of such relationships can change over time. Again, this is evidenced in this review by the growth in studies measuring not only value added performance but also environmental performance. This corroborates the findings of Dooms et al. (2013) where there was a noted increase in the importance of such issues amongst stakeholders as a port developed.

Figure 2-1 Profile of Reviewed Studies



In the face of evolving and multidimensional performance, there is a clear need to understand what performance is relevant at any given time in any given port. Furthermore, the findings of this review suggest that it is necessary to assess seaport performance across a number of dimensions to facilitate a more accurate appraisal of port performance, particularly when overall seaport performance and the needs of multiple seaport stakeholders are relevant.

To date however, there are a limited number of studies that incorporate more than one dimension in analysis. Woo et al. (2011) recognise that port performance is multifaceted and propose a performance measurement model that incorporates performance across both efficiency and effectiveness dimensions. Shiau and Chang's (2015) case study on the sustainability of Keelung Port, proposed a number of indicators along environmental, economic, and social dimensions. The indicators were selected using a social construction of technology framework and involved interaction with multiple groups of stakeholders. Consequently, there are a number of studies that assess the effects of port performance on one dimension or another, for example governance structure on efficiency (Carvalho et al., 2010; Cheon et al., 2010) , efficiency on trade facilitation (Doi et al., 2001) and efficiency on environmental performance (Chin and Low, 2010).

Despite this, mainstream seaport performance studies have tended to be unidimensional in their measurement scope. This is entirely valid and consistent with the objectives of the studies concerned; however there has been little consideration given to evaluating performance from a multidimensional perspective. This is particularly relevant when such evaluation is required for effective state policy formulation to ensure that a seaport's development and strategy is consistent with national economic policy, so as to maximise overall national welfare. It is therefore worth examining how, in the context of performance measurement system design, a construct of performance can be created to incorporate a number of relevant performance dimensions.

Finally, De Langen (2006) identifies five areas of potential conflict amongst the stakeholders of seaports; environmental protection, urban development, labour conditions, resident interests and overall economic development. Central to conflict in this context is a tension between the performance of ports in the facilitation of the execution of private transactions and performance in contributing to overall public welfare in the provision of public goods such as economic development. Port performance can thus be framed as affecting two key types of stakeholder. Stakeholders affected by performance commercially through the direct impact of the performance of a seaport on their commercial activity and public stakeholders who are affected through the performance of ports on overall public welfare. Applying both these perspectives to the dimensions of seaport performance identified in the review, it can be observed that performance on the operational, customer perspective and global supply chain dimensions have commercial on the markets they serve, while performance of seaports on the macro dimension can be evaluated from the welfare perspective and performance on the strategy dimension has scope to have both commercial and welfare effects.

## 2.4 - Discussion

As discussed in the introduction and highlighted throughout the findings of the review, there is a need for policymakers to understand and contextualise port performance across multiple dimensions at one time. As highlighted in this review, there has been significant advancement in the development of methods by which to create different measures of port performance. However, it is argued that there has been less progress in advancing means to define what constitutes performance as a construct particularly when performance is multidimensional. It is argued that there is a need to define port performance as a construct in a multidimensional setting. Performance itself is a latent construct and has to be measured by indicators that form an approximation to the value of the latent construct. A key distinction in measuring performance is the form which this latent construct takes as it has strong implications for the form of the sub construct (if multileveled) and measures and indicators that are employed. The primary distinction is whether the construct is reflective or formative. Schellinck and Brooks (2015) argue for the latter approach to measuring port performance in relation to effectiveness of port service delivery. The authors argue that ‘relative to a reflective construct a formative construct ... provides the level of detail that exhaustively captures the relevant/causal criteria for overall port performance’ (Schellinck and Brooks, 2015, p. 7) . It is argued for reasons explored below that this logic extends beyond effectiveness to port performance that is multidimensional.

In order to examine this (as demonstrated in Schellinck and Brooks (2015)), it is necessary to compare formative and reflective constructs. A formative construct differs from a reflective one in terms of direction of causality from latent construct to measure of construct (or sub construct when the construct is multi-tiered). In reflective constructs, causality is deferred from latent construct to measure as such the construct causes, with the measures being

the effects of the underlying construct. In reflective constructs, measures of the construct must be unidimensional - that is all measures must measure the underlying construct consistently with a change in the underlying construct causing a common change in variance amongst the measures. Measures must therefore be inter-correlated. Thus, in a reflective construct it is possible to add and remove measures and change the underlying latent construct. In formative constructs, the causality defers from measure to construct, as such the measures cause the construct. An important difference between the two is that in formative constructs there does not have to be inter-correlation between the measures. In contrast, to reflective measures a removal of an indicator may alter the construct being measured (Diamantopoulos et al., 2008; Petter et al., 2007). A reflective measure implies an underlying latent construct that is fully formed and exists objectively.

As described by Schellinck and Brooks (2015) what constitutes performance as a construct in a port setting is contingent on the perspective of the stakeholder concerned and how it is contextually defined. This is evident if the different dimensions of seaport performance are examined in turn. Operationally, seaports need to meet the requirements of their user-firms that also provide services within seaports. As seaports provide services, they need to meet the needs of customers. However, from the literature, it can be seen that the determinants of market demand for seaports services extend beyond the individual services provided by seaports, with seaports competing as parts of wider logistics and supply chains. Thus, commercially, seaports must perform to facilitate the execution of this supply chain. Considering the operational, customer and supply chain dimensions, seaports must therefore meet the needs of stakeholders ranging from the internal stakeholders involved in the provision of services, to the wider industry level partners who combine with seaport service providers to create effective logistics and supply chains.

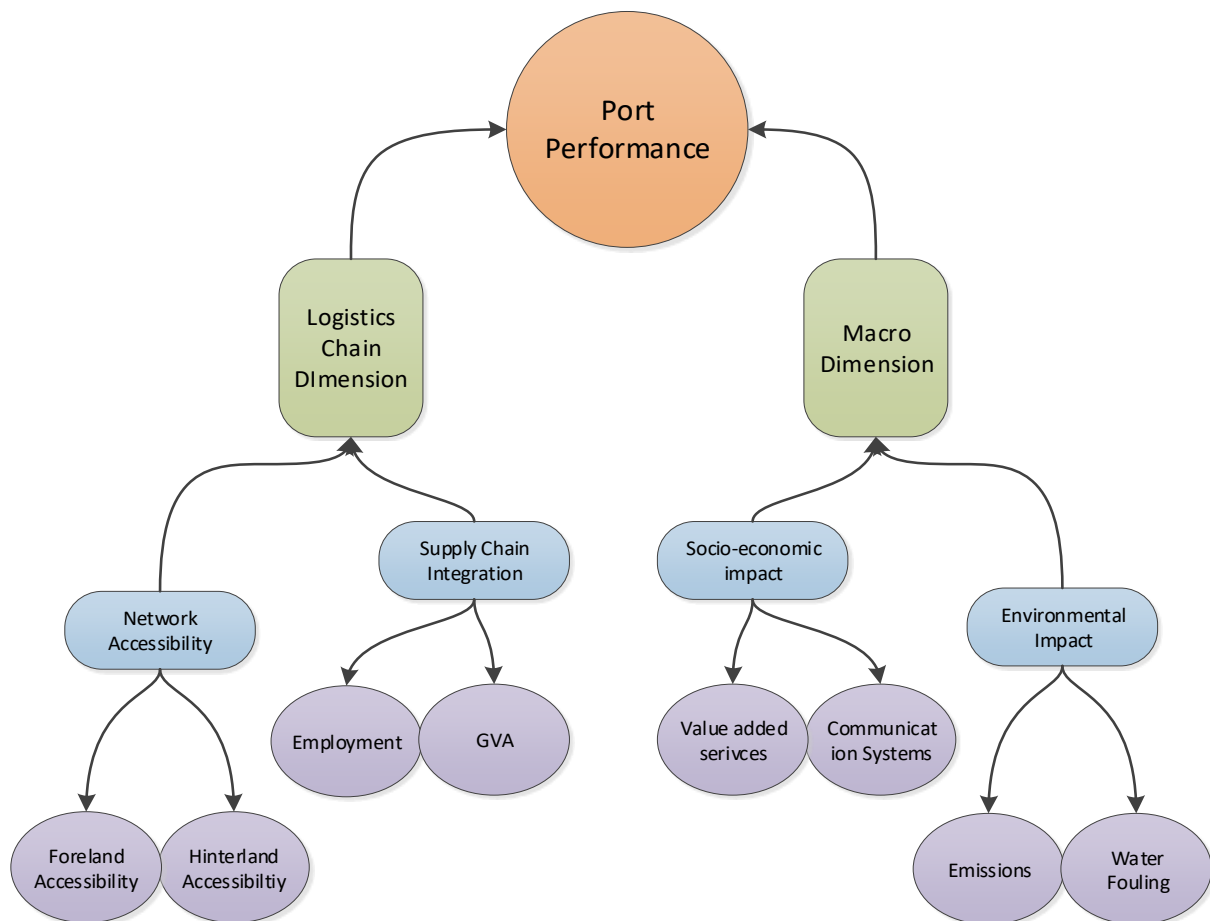
On the macro dimension, a port's performance has implications for a much larger number of stakeholders. The unilateral effects of performance at macro level on regions and nations suggest that seaports have welfare implications through the public goods they produce. Performance across the different dimensions can affect different stakeholders in different ways and to different degrees. The importance of different dimensions of port performance is subjective and contingent on the perspective of the port stakeholder. Reflective structures require an objective construct of performance that is unidimensional, with a relationship between sub-constructs and measures in that they share common antecedents and consequences. Port performance is multidimensional and subjective and its measures are not necessarily related. For example, what causes strong competitiveness may not cause good community stakeholder relationships. It is therefore argued that a holistic measure of multidimensional performance requires a formative construct of performance.

To examine what this formative construct may look like, an example has been conceptualised and presented in Figure 2-2. Here, performance is shown as a function of the port's network and macro performance effects. The dimensions of performance that are chosen determine how performance is defined. It is clear that the measure proposed only represents a fraction of what could be measured in the context of seaport performance. If, for example, a third dimension such as customer satisfaction were added, it would essentially be a different construct of performance. Similarly the first order, subconstructs are formative too; for example, if environmental impact was deemed to be unimportant, the concept of macro performance would similarly change to a different construct.

When it comes to the third order however, the constructs change from formative to reflective, possibly leading to a major effect on how performance is determined and measured. In contrast to the first and second order, the measures or indicators need to be co-linear and

related, as they are measuring the same thing. For example, the level of emissions does not necessarily tell you about the level of supply integration, therefore is not a good measure in a reflective sense. Similarly, at the reflective level, one could add or remove measures to improve the accuracy of the measure without fundamentally changing what one is measuring. For example, in terms of assessing the socio-economic impact of the port, one could add a spatial component to measure regional impacts yet still be measuring the socio-economic impact of the port, but with a potentially better measure.

Figure 2-2 Port Performance as a formative multidimensional construct



## 2.5 - Policy Implications

A formative approach to performance measurement has a number of implications for policymakers. Firstly it means that performance of a seaport or seaport system needs to be defined by the policymaker. For example, if reform is to improve efficiency and effectiveness then performance is determined by these two constructs. Similarly, the performance of a policy program to improve the macro-environmental performance would not be measured by looking at the port's profitability. When considering performance in relation to port policy and its implications, performance is a formative construct determined by the objectives of a policy programme. Thus, the onus is on policymakers to develop clear definitions of what their expectations are for the performance of a seaport system within their policy remit. If the latter is to ensure that the public interest is preserved through the operation of public infrastructure, the port's performance must therefore be measured to secure that interest.

This, however, is not a simple task as identified by Vieira et al. (2015) and most recently by Brooks et al. (2017). There is a lack of causal understanding of what type of policy programme works in which context. Much of this can be attributed to the complexity of port systems. Driving this complexity, is that ports have diverse stakeholder base holding conflicting and diverse interests (e.g. terminal operators; local community and environmental groups) (Bekebrede and Mayer, 2006). As a result, it is difficult to know how port performance in the port system should be assessed. On a related issue, Pilcher and Tseng (2017) pointed out that much of the difficulty in evaluating policy reform can be attributed to a number of factors. Firstly, they argue that ambiguity in interpreting the key terms of port reform can cause difficulty in interpreting performance; for example, efficiency and productivity can have a plurality of meanings. This is consistent with the findings in the review, as concepts such as efficiency ranged from tight definitions (such as Farrell's productive efficiency) to more

loosely defined concepts of operational competency. Similarly, the review noted that competitiveness, effectiveness, accessibility and socio-economic impacts are often loosely defined. This is not a fate peculiar to the port industry and one only has to look at the debate surrounding the definition of quality in industrial production to see this is a common occurrence.

Perhaps, as identified by Langenus and Dooms (2015), where the port industry falls down is that international advisory bodies tasked to develop port performance metric systems have not reflected such contingency related factors in performance evaluation. In particular, the weaknesses lie in meso-level metrics, similar to the work done in port system evolution by the World Bank in previous decades. In contrast, in the more heavily regulated industries of pharmaceutical production, the good manufacturing practice guides produced by international bodies provide a vital resource on which to base action to improve performance.

Secondly, as argued by Pilcher and Tseng (2017) semantic issues such as those above can be overcome by better definition. It is argued that the other factors identified, time, geography and context (which it is argued are all contextual) pose the most challenge for policymakers.<sup>5</sup> Multidimensional formative constructs are context dependent (Schellinck and Brooks, 2015). As discussed above, what constitutes performance is dependent on a host of factors including perception of the concerned stakeholders but also contextual and contingent related factors such as spatial (geo-positional, institutional, market etc.) and temporal (lifecycle, environmental dynamics, societal attitudes etc.). In addition, port performance often involves different levels of performance such as performance at the cluster versus performance

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<sup>5</sup> Latent subs-constructs of performance such as efficiency and effectiveness that require strict definition are unidimensional performance constructs and, as such, are context independent and open to standard definition. It is worth noting however that while the latent construct may be reflective, the measure will tend to be context dependent, in particular it may be necessary to control for spatial and temporal factors to create an accurate representation of the latent construct.

at the individual actor level (terminal operator, customs or port authority etc.). The organisational complexity of seaports presents an added level of difficulty in determining how performance is defined. If performance is taken to be what represents the public interest and is to be a formative construct, it must therefore be defined in terms of what constitutes the public interest. Further, it is necessary to have an understanding of how spatial and temporal factors affect port performance and how policy measures are likely to affect performance as well. A lack of a clear definition of performance in a given context poses a serious limitation to the measurement and subsequent development of port policy. Much of the literature surveyed in this review details ways of measuring performance effects; it is argued however that there still remains a lack of rigorous attempts to attribute this to the measures of port performance.

For policymakers to make evidence-based interventions on port performance measures, as well as being able to assess changes in the level of a port's performance, it is also necessary to be able to interpret causal factors related to such changes. A truly holistic multidimensional performance measurement system should be based on a causal understanding of different levels of performance. This is firmly accepted in the wider literature on performance measurement (Neely et al., 2005; Nudurupati et al., 2011). Suwignjo et al. (2000) for example argue that the identification of performance dimensions and their inter-relationships are a crucial first step in the design of performance measurement systems. It could be suggested that the strategic management literature offers some insights. For example, the balanced scorecard performance measurement tool, commonly used to assess organisational performance, provides a strategic performance measurement mapping tool (Kaplan and Norton, 2000, 2001). However, the inability to map complexities and contextual diversity of port settings present a severe limitation. It is argued, therefore, that the issue in performance measurement in the port setting is not necessarily a problem with creating measures of performance (of which there are

multiple); it is a problem of defining what performance is in a given context as this rests on an understanding of causality which is underexplored. In terms of this review, it is argued that the gap in the literature comes not in our understanding of how to measure performance but in our understanding of what to measure in a given context.

## 2.6 - Conclusions and future research implications

The objective of this study was to conduct a systematic literature review of published studies on seaport performance measurement to identify, critically evaluate and integrate the various dimensions of seaport performance measurement. The systematic approach aims to minimize researcher bias, with subjective decision making limited to decisions on search strategy and selection criteria. While this approach maximizes coverage of studies reviewed, it should not be treated as complete, due to the possible omission of some studies. For example, macro impact performance studies on a seaport's spatial impact on their urban environment and integration in port cities are not included in the review; this may be attributable to decisions taken in creating search strategy.

With the exception of a limited number of studies such as Woo and Pettit (2011), most studies on seaport performance have been focused on unidimensional performance. Notwithstanding limitations, this review provides a novel categorization of the literature that reflects the multidimensional nature of seaport performance. As recognized in Woo et al. (2011), seaport performance is multifaceted. When policy formation affects multiple stakeholders it is necessary to assess seaport performance across a number of dimensions. It is argued that the multidimensional nature of seaport performance necessitates a formative rather than a reflective approach to port performance measurement. From a policy perspective, this requires an identification of the components of performance upon which policy a programme depends. As identified in Viera et al. (2014) and Brooks et al. (2016) a limited understanding

of how policy impacts performance in the seaport setting seriously limits the capability of policy makers to do this. Therefore it is argued that there is a need to focus on what causes performance in the seaport setting rather on simply focusing on the creation of measures of seaport performance.

## Chapter 3 - Examining Performance Change and its drivers in Irish Ports 2000-2016

### 3.1 - Introduction

Accounting for 85% of the total volume and 56% of the total value of merchandise trade, the shipping sector is a critical enabler of Ireland's trading capacity (Vega and Hynes, 2017). Despite its importance, volume of demand for port services is limited by the relatively small size of the Irish hinterland and peripherality of the region to major trade lanes (making Irish ports unsuitable for transshipment traffic). Without a sizeable volume of demand, there are concerns as to the viability of a market mechanism in ensuring competition and subsequently competitiveness within the sector (Competition Authority of Ireland, 2013). The effective performance of the Irish seaport sector is thus a strategic objective at the national policy level with the sector seeing a number of reforms and policy initiatives since initial reform with the passing of the Harbours Act 1996-2000 (Department of Transport, Tourism and Sport, 2013).

Despite its recognized importance however, there has been little formal evaluation of performance within the port sector in Ireland. Mangan and Cunningham (2000), performed an early performance evaluation of the effects of the full enactment of the Harbours Act in 2000. The authors found that the programme of reform was largely successful in commercializing the ports. However, they argued that it would take more time and further reviews to fully assess the impact of reform. In 2002, a review into the success of the governance reform was officially commissioned and undertaken by consultants firm Raymond Burke Consulting (Burke, 2003). The resulting report was largely supportive of the trajectory of reform and supported the view that there were improvements from commercialization. It did, however, highlight a few outstanding issues, most prominently, ambiguity surrounding the future exchequer funding of port infrastructure development as cause for further reform. Subsequent to these initial reviews

of post-reform performance, there has been little further evaluation of the performance of Irish ports.

This chapter seeks to address this gap through an examination of performance change within Irish ports for the period 2000-2016. To achieve this objective a case study approach is adopted which involves an in depth analysis of the four largest ports in the Irish state. To analyse performance over time, a mixed methods approach is adopted. Here productivity, profitability and traffic shift-share growth are measured for selected ports within the state-owned port system. Qualitative sources are then referenced to contextualise the change in observed productivity in terms of external environmental and internal managerial factors that influenced the change in observed performance.

The case study approach allows for the contextualisation of performance in respect of the key drivers that have influenced observed performance change. Given the longitudinal nature of the case study, this affords the opportunity to examine how port managers have adapted to major economic environmental change over time. This is important as ports and port systems evolve over time and in response to various forces in the port and maritime industry (meso), and wider macro-economic environment in which the ports are embedded (Beresford et al., 2004; Sánchez and Wilmsmeier, 2010; Wilmsmeier and Monios, 2016). Demand for port services is derived from the requirements of international trade and ports evolve relative to changes in the nature of this demand. The capability of ports to sustain performance given changes in the ports contextual environment, represent a key aspect of port performance, identified recently by Notteboom (2016) as the ports adaptive capacity. In the Irish situation the time-period under review includes a period of unprecedented boom and bust and subsequent recovery.

The remainder of the chapter is structured in the following way; Section 2 introduces the case description, detailing the policy framework, ports selected for review and the major macro and meso level changes that have occurred over the period under review. Section 3 outlines the methodology employed and data sources used to complete the analysis of performance. Section 4 presents the results of the performance analysis. Section 5 includes a discussion of the results, and identifies key factors that have influenced performance across the ports selected. Section 5 finishes with a discussion of policy implications of the results in respect of the policy framework outlined in Section 2, while section 6 contains a conclusion and outlines the implications of the research.

### 3.2 - Case Description

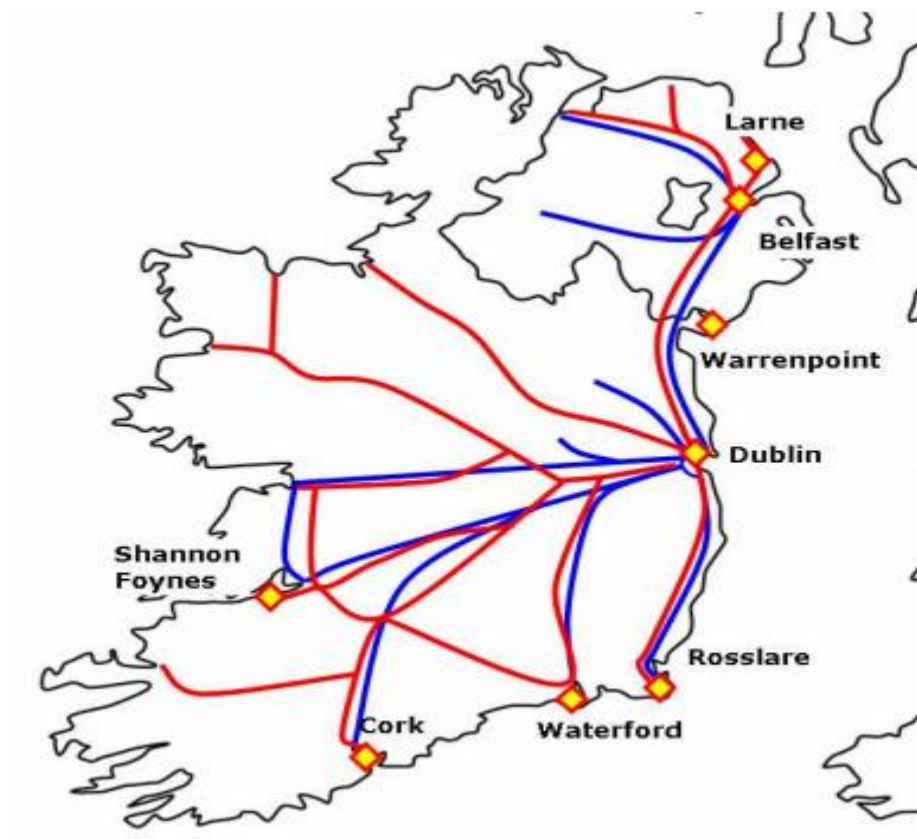
The state-owned port sector in the Republic of Ireland was created in its current guise under the Harbours Acts 1996-2000. Prior to 1996, Irish port infrastructure was controlled by harbour authorities, which had a high degree of direct government departmental control (Mangan and Furlong, 1998). There was a growing concern regarding the suitability of these governing arrangements for the effective development of port infrastructure. Mangan and Furlong (1998) point to inadequacy of board of directors composition and highlighted the degree of ministerial approval required for operational change including the setting of rates, borrowing money, carrying out harbour improvements and the acquiring and disposing of property. Such concerns and a growing culture of public administration reform (owing to the advancements of new public management in the late 1980s), led to the appointment of a review group in 1991. The findings of the review recommended reform, concluding that Ireland's ports have been severely constrained in their ability to respond commercially because of the restrictive legislation under which they operate (Mangan and Furlong 1998).

Following on from the recommendations of the review group, the Harbours Act 1996-2000 was enacted. The act commercialised the ten largest state owned ports, creating commercial state-owned enterprises. The government retained ownership as the sole shareholder with the resulting ‘port companies’ being given a largely commercial mandate. Most operating restrictions were removed; however, the port companies still required ministerial approval regarding large scale borrowing and the establishment of subsidiary companies. New boards of directors were established to be responsible to the Minister for the conduct and operation of the port companies. As described in the Ports Policy Statement 2005, the legislation was intended to give key Irish ports the commercial freedom to operate as modern customer oriented service industries, in the process providing more cost effective and efficient services to meet the needs of their customers. In commercialising the ports rather than fully privatising them, the recommendations of the review group were followed. (The review group had found that privatisation was not at the time a realistic option given the complexity of the process and uncertain additional benefits).

The sector was further reformed in 2013 with the introduction of the National Ports Policy (2013) (NPP). NPP outlined a strategy to tier state owned ports, based on a combination of their throughput, market share and capability to provide capacity for future growth to serve the national interest. Tier 1 and 2 ports were classed as ports of national significance and are to be retained under full state ownership, while Tier 3 ports of regional significance are to be transferred to local authorities. NPP states that Tier 1 ports are mandated to ‘lead the response of the State commercial ports sector to future national port capacity requirements’ with Tier 2 ports also recognised as having a responsibility to develop additional national capacity .In this way NPP is a move away from the previous policy of multiple independent competing ports. NPP cites the wider trend toward consolidation in the shipping market and the use of larger ships as influencing factors.

While in total ten ports were subject to initial reform under the Harbours Act 1996, it is not possible to look at all ten ports in sufficient detail. For that reason, the largest four state-owned ports are selected for examination, Dublin Port, Port of Cork, Shannon Foynes Port Company and the Port of Waterford. Following NPP, these are the ports that remain under state governance in addition to Rosslare.<sup>6</sup> Figure 3-1 gives the location of each as well as the other large ports on the island, while Table 3-1 outlines the key characteristics and competitive position of each of the ports in the year 2000.. The years 2000 to 2016 were chosen as the time-frame.

Figure 3-1 Map of the Irish port system



Source: Competition Authority of Ireland (2013).

<sup>6</sup> Rosslare falls under a different governance system due to an historical arrangement whereby the port is a part of the state rail company Iarnród Éireann.

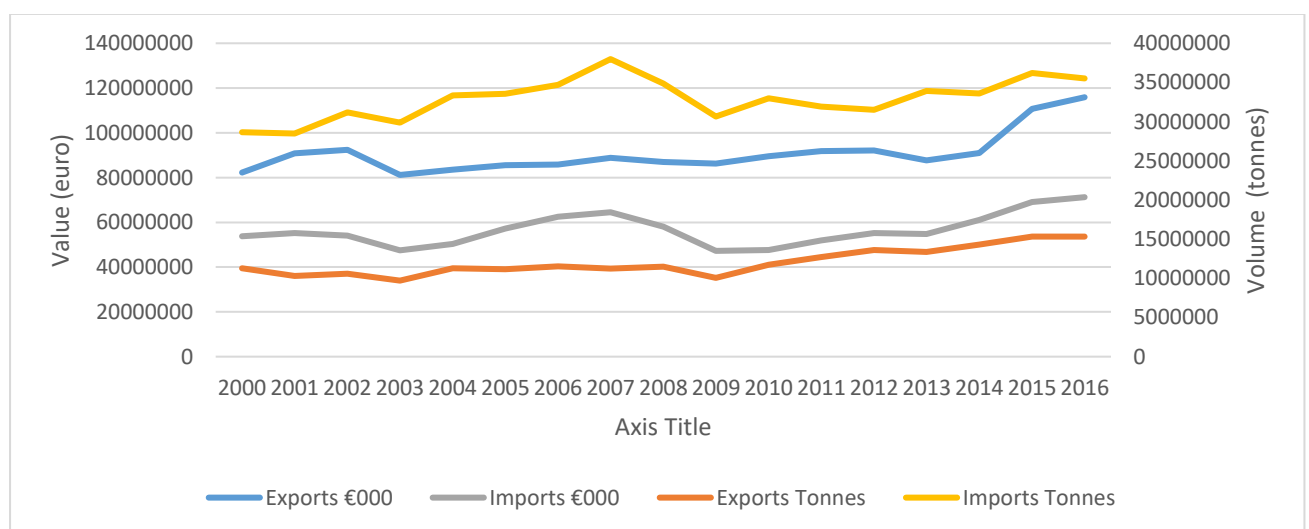
Table 3-1 Key Characteristics and market position of ports sampled in year 2000

<b>Dublin Port Company</b>	Dublin port is the largest port on the island of Ireland, handling all five major traffic types. In the year 2000, the port held market leading positions in both the RoRo and LoLo markets. To service these markets the port benefits from close proximity to the largest population base in Ireland, the Dublin metropolitan area, and the UK, Irelands largest trading partner. The port facility is located in the city and consists of dedicated terminals and common user facilities.				
Traffic in year 2000 000's tonnes (Market Share)	<b>RoRo</b>	<b>LoLo</b>	<b>Liquid Bulk</b>	<b>Dry Bulk</b>	<b>BreakBulk</b>
	6536 (35%)	4176 (55%)	3342 (24%)	1588 (11%)	250 (16%)
<b>Port of Cork</b>	The port of Cork is the third largest port on the Island of Ireland and second largest port in the Republic of Ireland. It handles all five major traffic types and in the year 2000 was seen to specialise in liquid bulk traffic. The port is located on the south coast and has a number of separate facilities located around Cork harbour.				
Traffic in year 2000 000's tonnes (Market Share)	<b>RoRo</b>	<b>LoLo</b>	<b>Liquid Bulk</b>	<b>Dry Bulk</b>	<b>BreakBulk</b>
	191 (1%)	968 (13%)	6365 (46%)	1556 (11%)	139 (10%)
<b>Shannon Foynes Port Company</b>	Shannon Foynes Port Company specialises in the handling of Bulk traffic, and is the largest Bulk port on the Island of Ireland. In the year 2000 the port consisted of a number of user dedicated terminals and two common user terminals, spread out across the deep-water Shannon Estuary on the west coast.				
Traffic in year 2000 000's tonnes (Market Share)	<b>RoRo</b>	<b>LoLo</b>	<b>Liquid Bulk</b>	<b>Dry Bulk</b>	<b>BreakBulk</b>
	N/A	N/A	1903 (14%)	8230 (57%)	150 (9%)
<b>Port of Waterford</b>	The Port of Waterford is located on the South East of the island and handles four of the five major traffic types. In the year 2000 the port company was overseeing the movement of facilities from the ports traditional location in the city quays to a new location further along the coast.				
Traffic in year 2000 000's tonnes (Market Share)	<b>RoRo</b>	<b>LoLo</b>	<b>Liquid Bulk</b>	<b>Dry Bulk</b>	<b>BreakBulk</b>
	N/A	1014 (13%)	245 (2%)	498 (3%)	115 (7%)

### Macro level Change

The period was characterised by pre-recession boom, a financial crisis beginning in 2007 and a subsequent economic recovery beginning in 2013 (Whelan, 2014). This pattern has translated to trade in international goods as represented in Figure 3-2. In terms of the structure of trade in the early 1980s and 1990s, the structure of Irelands merchandised exports shifted from low value to high value low volume manufactured goods (Brunt, 2000). As with most developed countries, this creates an imbalance in shipping terms as the volume of imports exceeds the volume of exports, (despite the value of exports far exceeding the value of imports). This has largely been consistent over the period with euro per tonne ratios at an average of 8,000 euro per tonne for exports and 1,700 euro per tonne for imports. Examining the tonnage imbalance following the crash however, there has been a closing of the gap somewhat, with tonnage imbalance falling from 27ml tonnes in 2007 to 20ml tonnes in 2016, with the number falling as low as 17ml tonnes in 2013. Export activity in volume and value terms has risen above pre crash levels (up 30% in value terms and 36%). The rise in exporting activity is consistent with economic commentary on the recovery which has been described as export led. In contrast, imports in volume terms had not yet reached 2007 levels by 2016.

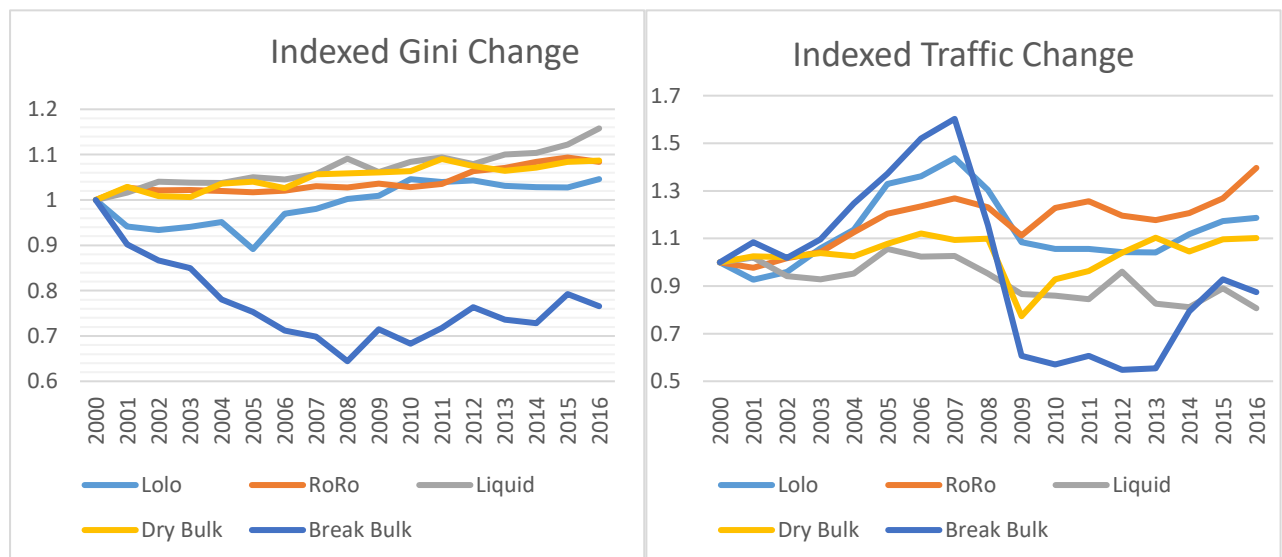
Figure 3-2 International Merchandise Trade



### Meso level Change

As displayed in Figure 3-3 the boom bust and recovery cycle largely translated to growth across the cargo market sectors in the Irish case. The exception to that is liquid bulk, which has seen steady decline. This market is largely driven by demand for petroleum products which has decreased in line with changing consumption patterns and increased energy efficiency (SEAI, 2016). The cyclical pattern was most pronounced in break bulk. High prerecession growth in this market was largely fuelled by a sectoral boom in construction, which has been most strongly affected by the crash (Whelan 2014). Dry bulk quickly recovered, reaching pre-recession highs in 2013. The dry bulk market is driven by input demand for the agri-food industry and large scale industrial production.

Figure 3-3 Traffic and Concentration Index Change



The unitised sector (comprising of Roll on Roll off (RORO) and Lift on Lift off (LOLO) traffic is more closely aligned with activity in the domestic economy. Here contrasting recovery rates can be seen, with RoRo recovering at a much quicker rate than LoLo. This may be explained by two factors. Firstly RoRo traffic is more closely aligned with trade with the UK, which was

less affected by the recession. Secondly there has been a redistribution of traffic from LoLo to RoRo. This is attributable to the introduction of a new hybrid ‘conro’ service operated by Cobbelfret, a Belgian company who had previously operated LoLo services through its sister company C2C.<sup>7</sup> This service operates from Dublin to Zeebrugge and Rotterdam and competes directly with short sea and feeder LoLo services to the continent. When taken as a whole, total unitised traffic volumes have just returned to pre-crash in 2016 rising to 35.5 ml tonnes up from 35 ml tonnes in 2007.

Unitised traffic moves mainly from ports on the east and south coast. Examining the evolution of competitive dynamics in the RoRo sector first, there has been increased concentration over time. Traditionally RoRo traffic has consisted primarily of trade with the United Kingdom (accounting for 90 % of total traffic in 2016, and 99% in 2009, with the change mainly due to the Cobbelfret service outlined above). At the beginning of the period Dublin was the market leader, however it faced significant competition due to the relative mobility of RoRo traffic. Competition was strongest with Larne (24% market share) and Belfast (24%) in Northern Ireland and Rosslare to the south (10% market share). Following the recession, there was a large scale restructuring and rationalisation of existing routes and operators particularly on the primary UK –Ireland corridors favouring the ports of Dublin and Belfast. Stena in 2013 transferred a service from Dún Laoghaire to Dublin. In Northern Ireland Stena Line transferred services from Larne to Belfast.

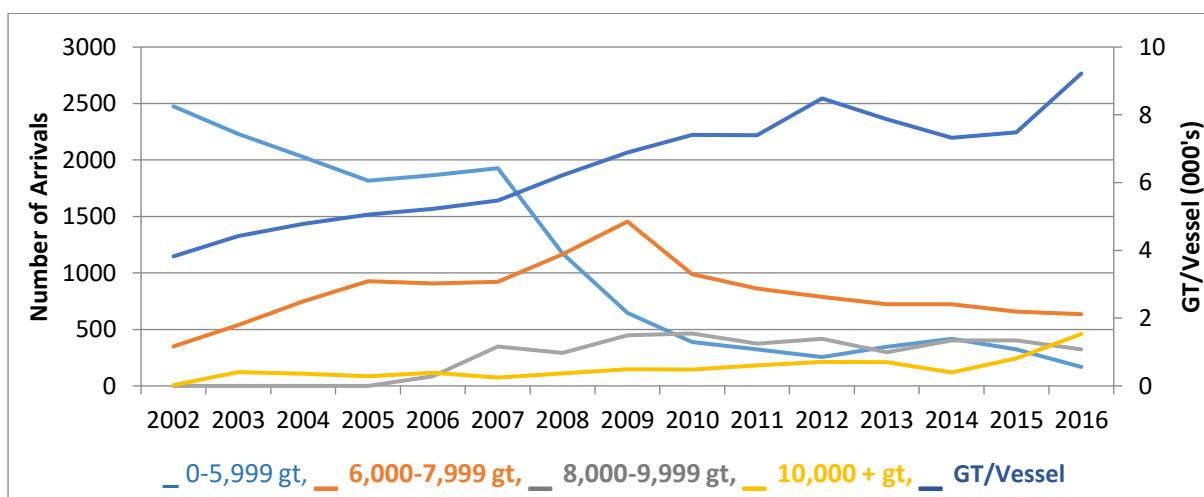
The Lolo sector has followed a similar pattern with increased concentration post-crash. At the beginning of the period, Dublin was also market leader in LoLo traffic at 55% at the start of the period, with sizeable traffic flows also in Waterford and Cork as well as Belfast (17% market share). There was de-concentration prior to the recession given congestion

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<sup>7</sup> This service involves the movement of stackable containers that are driven onto specialised vessels using mafi trailers and is termed colloquially as “ConRO”.

at the larger ports. This trend reversed post-recession with the top three ports, Dublin (55%) Cork (21%) and Belfast (18%), accounting for 94% of the total market in 2016, up from 83% in 2007. Similar to the RoRo market, there was a restructuring following a contraction of demand of almost 2ml tonnes which caused significant over-capacity in terms of port and carrier capacity. In response, carriers responded by rationalising routes and increasing the use of Vessel Sharing Agreements (VSAs) to improve utilisation rates. The IMTE (2010) estimated that fourteen routes were rationalised in 2009, while by 2011, the three largest VSAs on the market accounted for 70% of total market traffic (Murphy, 2013). The move toward VSAs led to an increase in ship size and reduction in the number of calls as evidenced in Figure 3-4. Larger vessels and less frequent call favour the competitiveness of the larger ports. Firstly, there is greater depth available at the larger ports of Dublin, Belfast and Cork. Secondly, given their location, they have a greater proximity to the larger hinterland markets so they have a better potential for achieving utilisation of larger vessels (O'Connor et al., 2018).

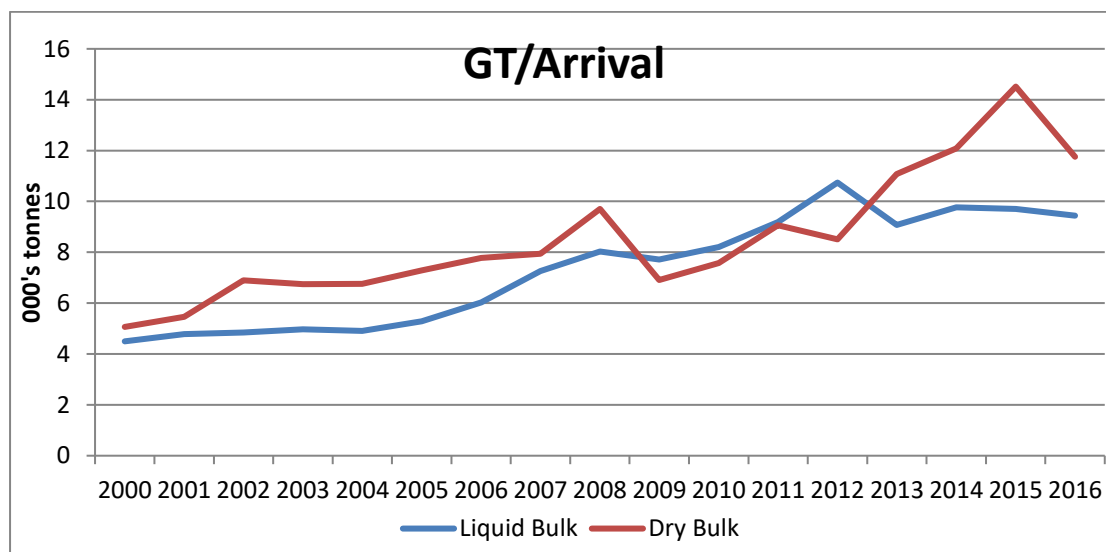
Figure 3-4 Change in LoLo Vessel Profile



Source (authors compilation based on Eurostatt data)

In the bulk sector concentration, trends in liquid and dry bulks have followed that of the unitised sector. In both sectors, similar to Lolo there has been an increase in the size of vessel utilised as displayed in Figure 3-5. Noticeably the break bulk sector has become deconcentrated. Vessel sizes in this sector tend to be smaller, therefore are possibly better suited to regional ports. In addition, break bulk cargos typically consume a relatively large amount of land space within ports, thus given competition from other modes, break bulk may be deprioritised. This is the case in Dublin as per the ports masterplan ports ‘break bulk, which is the most land intensive cargo mode, has largely disappeared from Dublin Port due to unitised trade and use of smaller east coast ports’ (Dublin Port, 2018, p. 38).

Figure 3-5 Change in Bulk Vessel Profile



### 3.2 - Methodology

A case study approach involves an in-depth analysis of a limited number of cases that involve generally more variables than large sample studies (George and Bennett, 2005; Yin, 2013). The advantage of the approach is that through not restricting the analysis to a chosen set of ex-ante variables (which by design are necessary for a large sample study), probability of new variables and critical relationships among them being discovered is increased (Eckstein, 2000).

### *Analytic Approach*

The analysis consists of a quantitative summary of the evolution of performance among the sub-units from 2000-2016. In completing the quantitative summary a mixed methods approach is employed. Gertler et al. (2016) assert that this approach involves qualitative data providing context and explanation for the quantitative results. Gertler et al. (2016) further contend that this approach allows the researcher explore outlier cases of success and failure. Enabling the development of systematic explanations of the policy program's performance as measured by the quantitative results.

### *Measuring TFP and Profitability*

The main metric employed is a measure of Total Factor Productivity (TFP). Productivity relates to the process by which a production unit converts inputs into outputs. Total Factor Productivity measurement, as distinct from Partial Productivity measurement, relates all inputs in the production process to outputs. Changes in TFP, therefore, provides a good approximation to how effectively the port enterprise is managing its resources. Increases in Productivity occur when the ratio of output produced to input consumed increases (Coelli et al., 2005).

There are two approaches to measuring TFP; the index price approach that uses input and output prices to weight the relative contribution of respective outputs and inputs to TFP; and the frontier approach which uses statistical approaches to estimate a production possibility frontier. In the port context, the latter has been almost exclusively employed in studies (see Medal Batrul et al. (2016) for an extensive review). The major advantage of a frontier approach is that through estimating a production possibility frontier, it allows for the decomposition of productivity change into its constituent parts. Namely, TFP change due to shifts in the production possibility frontier (technical change), TFP change due to increases in technical efficiency and TFP changes owing to increases in scale. Frontier approaches are widely

preferred as they allow for the generation of more information than index number approaches and if estimated properly present a better representation of productivity.

Nevertheless, there are significant challenges in the current case in estimating the production frontier. To estimate the production possibility frontier reliably, either parametrically or non-parametrically, there is a requirement to have a sample of homogenous producing units. In the Irish case, the number of firms in the set is quite small and in addition, there is a high degree of heterogeneity between relatively small break bulk and large multimodal ports. This limits our capability to properly estimate the production frontier. For that reason, a Tornqvist index approach is chosen to measure TFP change over time.

Using price information, the Tornqvist index calculates productivity as a simple calculation of an output index over the input index. Input and output indexes are generated using cost/price shares to weight the relative contribution of inputs of outputs. Productivity change is then calculated relative to a base year as follows:

$$\text{Tornqvist TFP Index} = \frac{\text{Tornqvist Output Index}}{\text{Tornqvist Input Index}} \quad (1)$$

$$= \frac{\prod_{j=1}^m \left[ \frac{y_{jt}}{y_{js}} \right]^{\frac{\tau_{js} + \tau_{jt}}{2}}}{\prod_{n=1}^n \left[ \frac{x_{nt}}{x_{ns}} \right]^{\frac{\omega_{ns} + \omega_{nt}}{2}}} \quad (2)$$

Here  $y$  represents output  $j$  at time  $t$ , while  $\tau$  represents the output price. Similarly,  $x$  represents input  $j$  at time  $t$  while  $\omega$  represents input cost. In this way taking year  $s$  a reference year productivity change is simply interpreted as a result of a change in input consumption relative to output production. In this way the change in respective output is easily related to the qualitative data describing the consumption of inputs in a given year and major factors that have influenced output generation.

The drawback of using an index number approach is it is not possible to decompose the source of productivity change as described above. Secondly, any interpretation of productivity is relative to the firm in the base year chosen, and as such, comparisons between the productivity of two firms are not possible. All that is possible is a comparison of rates of productivity changes over time.

To select inputs for the index, an approximation of labour and capital were chosen as the two inputs. Labour was measured as the number of full-time employees of the respective port companies. Cost-share was calculated as the staff cost in a given year as reported in the financial accounts<sup>8</sup>. Capital is typically more complex to measure. As information on capital assets is available from vesting day in each port company the perpetual inventory method was chosen following the method outlined in See and Coelli (2013) and also employed in the Irish context in Cahill et al. (2017). Measuring capital in this way allows for control for the use of different depreciation methods across companies, which can affect the true value of tangible assets, represented in the company's accounts. The quantity of capital is measured as follows:

$$K_t = K_{t-1} + I_t - \theta_t - R_t \quad (3)$$

Where  $K_t$  is the real depreciated capital stock in period t and t-1.  $I_t$  is the real investment in period t,  $\theta_t$  is a real value of disposals in period t and  $R_t$  represents real retirements<sup>9</sup>. Cost of capital was calculated following Cahill et al (2017) as follows:

$$CK_{kt} = \sum_{K=1}^N (i_t + \delta_{kt}) NomFA_{kt} \quad (4)$$

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<sup>8</sup> Labour costs were converted to constant prices using the consumer price index at base year 2000.

<sup>9</sup> Real capital stock was calculated by taking the deflated nominal capital level in vesting year. The Gross fixed capital formation deflator was used to convert capital to constant prices at base year 2000. To account for different asset classes two groups of assets were formed, land, terminals and quays, which were depreciated at 3% and plant and equipment which was depreciated at 12%.

where:  $k$  = each asset group;  $i$  = ten year bond yield on government securities;  $\delta$  = depreciation rate; NomFA = Nominal value of each group of fixed assets. In terms of outputs, while it is desirable to use all possible outputs of the firm, a lack of price data means analysis is restricted to the use of a single output<sup>10</sup>. In addition to TFP, the operating margin was measured to account for profitability. While there should be a positive correlation between profitability and productivity as an increase in productivity means that a firm is now producing output with proportionately less input. In practice it is not always the case. Often factors related to external to operations can affect profitability (Bai et al., 1997). For that reason, the operating margin (ratio of operating profit to revenue) is measured to examine whether increases in productivity are translated to profit.

#### *Other Measures*

The use of an aggregated measure such as revenue, facilitates measurement however it doesn't reflect the multi-output nature of PAs as productive units (Gonzalez and Truijio, 2009). To further examine the source of output growth tonnage growth is additionally considered. To achieve this, absolute growth and growth relative to the market is examined for each major cargo market the respective ports are involved with. To measure relative growth in respective markets, the percentage of which actual growth in a period is above expected growth if the tonnage in the port grew at the same rate as tonnage growth in the period is measured. This measure is an adapted form of the shift-share analysis introduced by Notteboom (1997) and as such is termed the ports shift share margin (percentage of actual growth above expected growth)

$$shftsharemg_{im} = \frac{\left( tng_{imt_1} - \left( \frac{\sum_{i=1}^n tng_{imt_1}}{\sum_{i=1}^n tng_{imt_0}} \right) * tng_{imt_0} \right)}{\left( \left( \frac{\sum_{i=1}^n tng_{imt_1}}{\sum_{i=1}^n tng_{imt_0}} \right) * tng_{imt_0} \right)} \quad (5)$$

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<sup>10</sup> Revenue was also converted to constant costs using the consumer price index at base year 2000.

Here  $i$  represents port  $i$  and  $m$  represent the cargo mode. In this way, the shift-share margin is a normalised measure of growth relative to the market for each cargo market. A positive shift share indicates a relative growth in competitiveness of services running through the port. The shift-share analysis is examined over two periods, firstly the pre-crash boom period from 2000-2007 and secondly the post-crash inclusive of the recessionary (2008-2013) and recovery periods (2013-2016).

#### *Data Sources*

The above measures were constructed using data extracted from various sources. All measures of inputs, outputs and profitability were obtained from the audited financial accounts reported in the annual reports of the respective Port Companies. Data on the ten-year bond yields, the consumer price index, and Gross Fixed Capital Formation deflator were obtained from the Ameco database. Port traffic statistics were obtained from Eurostat. Qualitative sources utilised in the completion of the analysis include; periodic policy reports; the annual industry statistical bulletin the Irish Maritime Transport Economist (IMTE); and available corporate documents of the individual port companies (including a full series of annual reports and available master-planning documents).

### 3.4 - Results

#### *Dublin Port Company*

TFP growth in the pre-crash period was staggered. TFP initially fell, largely driven by a reduction in the output index, with TFP dropping to a low of 79 in 2002. Subsequent to 2002, TFP began to recover as a decline in the input index was matched with an increase in output, with TFP peaking at 108 in 2006. There were two major factors influencing TFP change over the period. Firstly, the port implemented a series of reforms in the early part of the decade to reduce operating costs by withdrawing from the provision of non-core services, mainly

warehousing and crane operations. As reported in the annual reports, non-core service provision had become loss-making activities and withdrawal from such activities in a programme of modernisation was intended to allow the port to focus on developing infrastructure. This represented a further move toward the landlord model, as the port replaced the PA provision of these services with a system whereby private third parties compete to provide these services.

Figure 3-6 Dublin TFP and Profitability Change

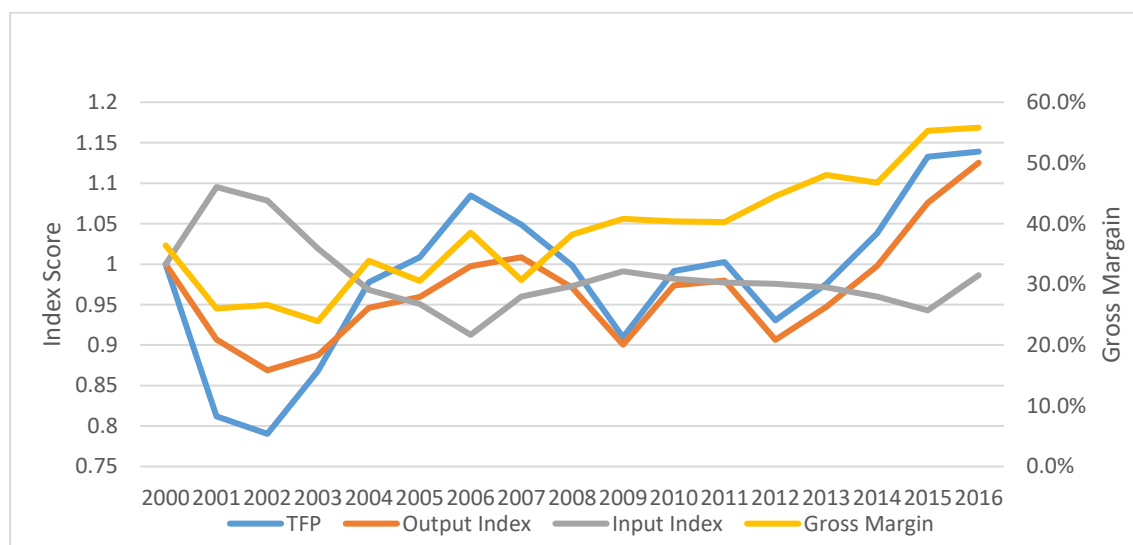


Table 3-2 Dublin Tonnage Growth

Traffic Sector	Tonnage		Shift Share Margin	
	2000 (Mrkt share)	2016 (Mrkt share)	2000-07	2008-16
RORO	6,536 (35%)	12,667 (48%)	14%	21%
LOLO	4,176 (54%)	5,062 (55%)	-5%	7%
Dry Bulk	1588 (11%)	2053 (13%)	27%	-14%
Liquid Bulk	3342 (24%)	4017 (36%)	19%	16%
Break Bulk	250 (16%)	50 (4%)	4%	-72%

The major effect of these reforms was a reduced level of staffing with the PA employees dropping from 416 in 2000 to 208 in 2006 a drop of over 50%. The shift in business model appears to have been highly successful in terms of allowing for a focus on capital investment. In 2000, labour costs accounted for 48% of total input shares. In contrast, by the year 2011 at the height of the recession, input shares accounted for 18% of total input shares. Furthermore, since 2008, capital has accounted for approximately 80% of total input costs every subsequent year, up from just over 50% at the turn of the millennium. The port has thus been able to significantly increase the capital stock (up 66% over the period), while keeping its overall input shares relatively constant.

The second major factor affecting TFP growth in the pre-crash period was a loss in revenue due to the movement away from non-core activities and an initial loss of market share in the LoLo market as the port suffered from the effects of congestion. There was a significant loss of volume in 2001 where LoLo traffic declined by from 4.2 ml tonnes to 3.3 ml tonnes in 2000. Traffic volume did not recover to 2000 levels until 2005. This period coincided with growth in all other ports in the network, resulting in Dublin Ports market share dropping from 54% in 2000 to 45% in 2005. This trend had begun to reverse in the years immediately prior to the recession, however, with Dublin's market share recovering to 51% in 2007 due to an expansion of routes through Dublin and increase in capacity in two of the ports three terminals. Coupled with the recovery, the port saw the continued rise of RoRo traffic through the port. This continued a trend that began in the 1990s as Dublin Port won market share from the major ports in Northern Ireland (Brunt 2000).

TFP change following the crash followed a similar trajectory to pre-crash TFP growth, with an initial decline followed by a gradual increase, peaking at 1.13 at the end of the period. In the pre-crash period, input change was constant. TFP growth was largely driven by an

increase in output. Output growth was driven by the RoRo sector, with the port benefiting from increased concentration in the market and the success of the ConRo service. Profitability, as measured by the operating margin, has shown stronger growth in the post-crash period than the pre-crash rising. This is despite revenue only returning to pre-crash levels in 2014. Further examination of the port company accounts provides an indication as to what caused this rise in relative profitability rate. Initial improvement in the profitability rate was driven by a lower cost of sales which fell owing to rationalisation within the company, with the cost of sales to revenue ratio dropping from 50-34% from 2000 to 2007. This ratio, however, has been relatively stable, averaging 33% percent from 2008-2016. The major driver in the gross margin in the subsequent years has been a decrease in admin and exceptional costs, which dropped from 25% of total revenue in 2007 to 13% in 2016.

#### *The Port of Cork*

There was limited growth in the port in TFP during the pre-crash period. While there was growth in output, it was closely matched by growth in the input index. This is largely explained by a rise in input consumption as the port underwent a period of capital expansion coupled with a period of rising labour costs. Most significantly, the port had net investment of 22ml in 2004 as it net purchased land at the former Buckeye manufacturing facility adjacent to the ports Ringaskiddy Terminal.

Figure 3-7 Port of Cork TFP and Profitability Change

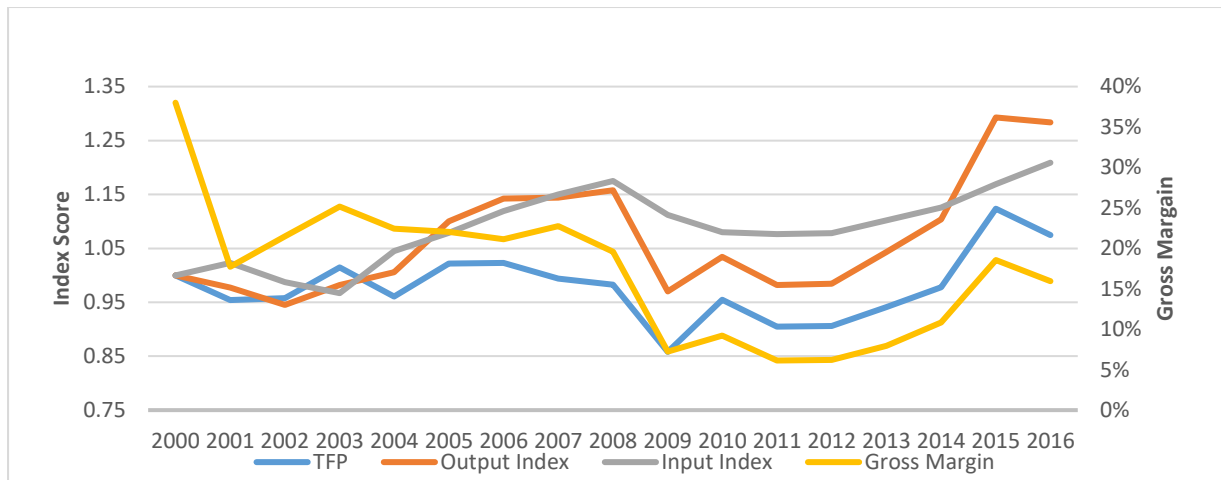


Table 3-3 Port of Cork Tonnage Growth

Traffic Sector	Tonnage		Shift Share Margin	
	2000 (Mrkt share)	2016 (Mrkt share)	2000-07	2008-16
RORO	191 (1.01%)	84 (0.3%)	-64%	72%
LOLO	968 (14%)	1,889 (23%)	15%	39%
Dry Bulk	1556 (11%)	1435 (9%)	3.00%	-19%
Liquid Bulk	6365 (46%)	5430 (48%)	-4%	7%
Break Bulk	651 (41%)	139 (10%)	-63%	-36%

In the immediate aftermath of the crash period, TFP fell significantly, hitting a low of 86, as output dropped 16% in 2009. Subsequent to the year 2009, the ports TFP has gradually recovered, driven by a reduction in the ports input index and recovery in output. Influencing this was dock labour reform initiated in 2009, which improved competitiveness in the LoLo sector. The port bought out the pre-existing casual labour force and assumed responsibility for stevedoring (through the ports subsidiary Cork Port Terminals Services). Finally, TFP has increased significantly in the most recent periods following the integration of what was Bantry

Bay Port Company into the auspicious of the Port of Cork Port Company in 2014. Accordingly, in 2015 and 2016, the ports output and input indexes step changed reflecting its expanded operations.

Profitability at the start of the period, as reported in the annual accounts, was artificially high due to a failure to account for an administrative expense that was accrued in subsequent years. 2001, therefore, acts as a better base from which to compare the change in profitability for the port company in the period. The Port maintained a steady operating margin prior to the financial crisis, despite rising operating costs (increased 51 % tween 2000 and 2007). Following the recessionary period, the port's profitability dropped, corresponding to a drop in output. As revenue has increased however, the ports profit margins have not grown accordingly. This related to an increase in operating costs over the pre-recessionary period (with the cost sales ratio in 2014 at 65% versus 54% in 2007).

Examining the output mix of the port may provide a clue to why this has occurred. At the start of the period, the port was seen as a specialist liquid bulk port (Brunt, 2000). Gradually the activity in this category declined as the container business has become increasingly important for the port. In addition, Dry Bulk activity has declined over the period with its overall market share dropping 2% to 9% in 2016. This drop in the market has been largely in the last number of periods, as the port has suffered a decline in exports owing to a cessation of the exportation of minerals. Profit per euro of revenue generated in the LoLo sector is likely to be lower than the bulk sector, owing to the public rather than private stevedoring and the additional costs of labor.

#### *Shannon Foynes Port Company*

Shannon Foynes Port Company was the last port in the sample vested and was formed as an amalgamation of previously separate harbour companies responsible for the various sites along

the Shannon Estuary. The previous entities had run into financial difficulty reflected in the negative gross margin at the start of the period. The port returned to profitability in 2003, and continued to run profits in the build up to the recessionary period. Similar to Dublin and in contrast to the other ports in the sample, the port's profitability rose rather than declined in the recessionary period. The growth rate in profitability has continued to increase with the gross margin peaking in the last period at 35%.

Figure 3-8 Shannon Foynes TFP and Profitability Change

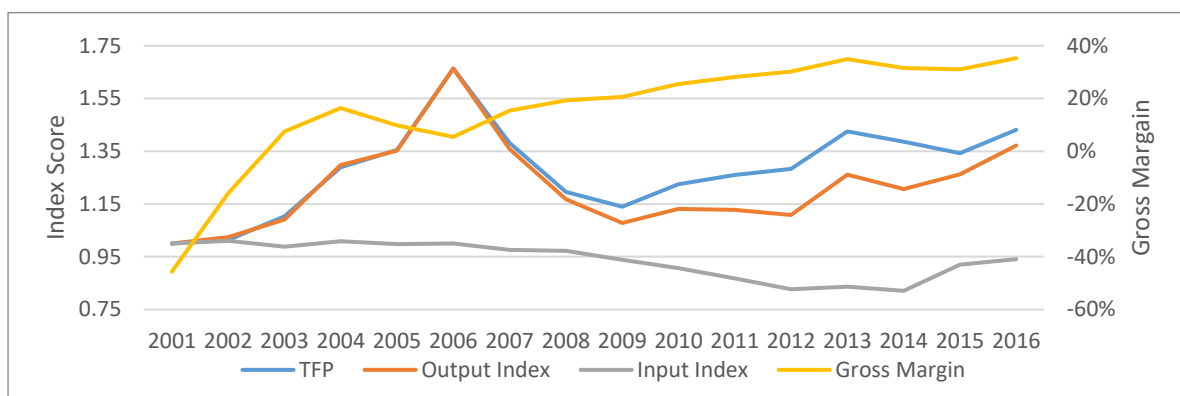


Table 3-4 Shannon Foynes Tonnage Growth

Traffic Sector	Tonnage		Shift Share Margin	
	2000 (Mrkt share)	2016 (Mrkt share)	2000-07	2008-16
Dry Bulk	8,230 (57%)	9,714 (61%)	1%	7%
Liquid Bulk	1,903 (14%)	1,050 (9%)	-22%	-16%
Break Bulk	150 (9%)	184 (13%)	58.00%	-2%

TFP has similarly risen over the period. In the run up to the recession, this was mainly attributable to rising outputs as inputs remained stable between 2000 and 2008. Notably, there is a strong divergence between profitability and TFP growth in 2006. TFP is measured at a peak of 80% over the base period owing to growth in revenue to over 16ml euro. In contrast,

the operating margin dropped to 6% from 16% in 2004. Referring to the annual reports, much of this sudden rise is attributed therein to the launching of a LoLo service, which the port was actively involved with running. This rise in income is subsequently matched by exceptional costs, again attributed to the launching of the LoLo service but also court cases the port was engaged in at the time. Such exceptional costs, while affecting profitability, do not factor into the input index.

Aside from this anomaly, TFP growth largely mirrored that of profitability with consistent increases from 2010 to 2016. This increase in TFP has been driven by both growth in output and rationalisation in inputs. Much of the ports business is related to large industrial clients and sector specific production particularly agriculture. It is possible therefore that the ports output level was less affected by in the downturn in the domestic economy than in other ports which largely serve markets more closely related to domestic consumption. Rationalisation of input began in 2007, with the initiation of a programme to improve manning efficiency, including a scheme to introduce annualised operating hours to increase working flexibility. This process accelerated during the recessionary period, with the ports input index reaching a low of 80% of base value in 2014. Subsequent to this, in the last two years of the period, there has been an increase in input consumption as the port has begun its most significant programme of capital expenditure over the period.

Output growth over the period has largely been driven by dry bulk traffic as evidenced in Table 3-4. In examining traffic patterns in Shannon Foynes, it is important to segment between traffic serving single user large-scale industrial clients with processing sites along the Shannon estuary and bulk traffic that serves demand that occurs in the immediate hinterland at multi user terminals in Foynes and Limerick. Evidence from the ports corporate documents allows us to examine the evolution of traffic in the two categories at varying points

in time. As per the 2007 annual report, peak, traffic at the port reached 11.35 ml tonnes of which 2.4 ml tonnes (approximately 21%) were handled at multi-user terminals. In 2011 during the recessionary period at the time of the ports master planning exercise, traffic had declined 9.9 ml tonnes of which 1.66 ml tonnes (approx. 17%) were handled at multiuser facilities. Finally, in 2016, traffic volumes increased to 11.1 million tonnes of which 2.4ml tonnes (approximately 22%) were handled at multi-user facilities.

*Port of Waterford*

Waterford Port company, in direct contrast to the position of Dublin, decided to assume responsibilities for container operations at the newly developed Bellview container terminal at the start of the period. In the run up to the recessionary period, this move was initially very successful. Between 2000 and 2008 the ports output grew by 112%, largely driven by an increase in container volume and subsequent revenues from port dues and terminal handling charges (container volumes peaked at 1.3ml tonnes in 2007 up from 1ml tonnes in 2000). The ports input index over the same period was subject to a step change as expected, however, the rise in input consumption was relatively more modest at 55%, enabling overall TFP to increase by 56%. This strong performance was reflected in the port’s profitability with the ports operating margin rising to 46%.

Figure 3-9 Port of Waterford TFP and Profitability Change

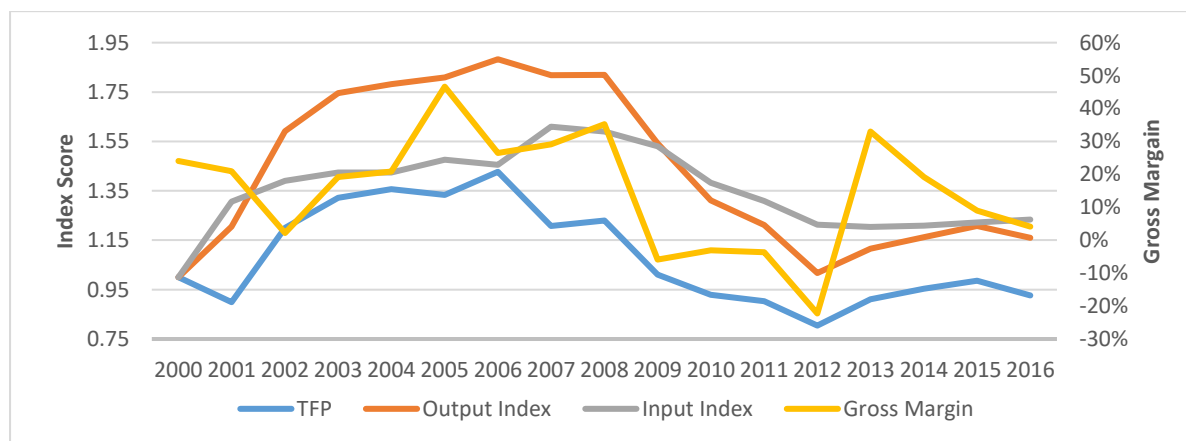


Table 3-5 Port of Waterford Tonnage Growth

Traffic Sector	Tonnage	Tonnage	Shift Share Margin	
			2000-07	2008-16
	2000 (Mrkt share)	2016 (Mrkt share)		
LOLO	1014 (14%)	279 (3%)	-10%	-74%
Dry Bulk	498 (3%)	970 (6%)	42%	37%
Liquid Bulk	245 (1.8%)	0 (0%)	-94.00%	-100%
Break Bulk	115 (7%)	76 (5%)	-19%	-41%

As outlined, the effect of the recession and changing structural demand conditions particularly affected the container trade through Waterford, with container traffic dropping from the high of 1.3ml tonnes in 2007 to a low of 268 ml tonnes in 2014. Prior to the recessionary period, LoLo volume was served by seven weekly services, four by operator C2C, and three by DFDS. C2C subsequently pulled out of the port, consolidating its operations through its sister ConRo service in Dublin. DFDS reduced the number of services to two, operated on a VSA with Samskip. Initially, the port struggled to readjust inputs to account for the fall in output level, with TFP and profitability significantly affected. Most recently, however the port has been able to decrease its cost base with inputs dropping from 1.53 in 2008 to 1.2 in 2013. In addition to a rationalisation in the consumption of inputs, there has been a rise in output in recent years driven by a rise in dry bulk traffic with a shift share of +37% in the post recessionary period. These developments have led to an increase in TFP and return to positive profit margins for the port Company since 2013 (note the high gross margin of 2013 is attributable to exceptional income accrued to the port company).

### 3.5 – Discussion

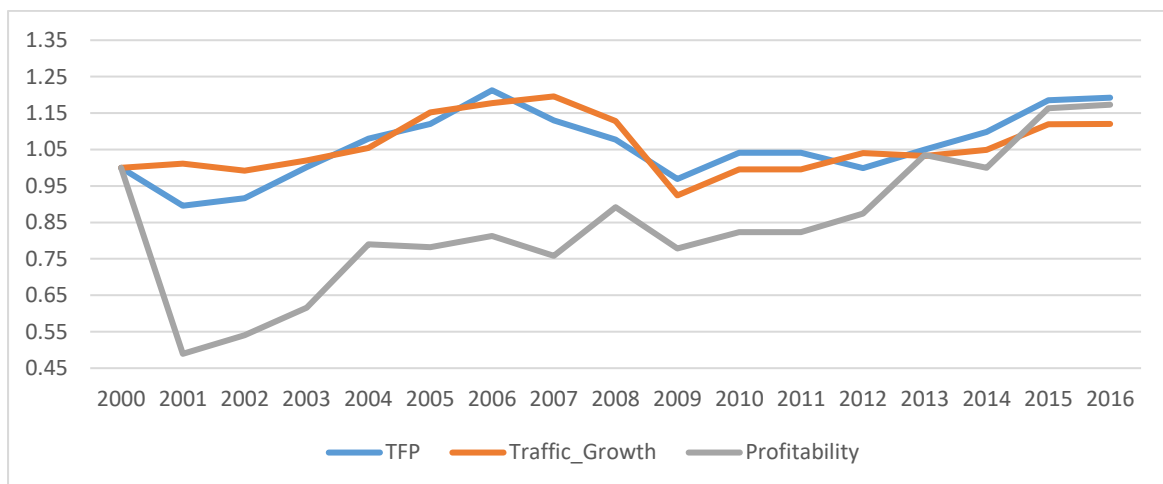
In this section, results presented in section 4 will be examined through a cross-case analysis of performance change across the ports. The results will first be examined in the context of external macro and meso level environmental changes that affected performance across the ports. Secondly, the effect of managerial decisions on performance change across the ports will be discussed. This section concludes with a discussion of policy implications.

Examining macro-level change performance in the sector was cyclical and closely related to the underlying Irish economic business cycle. This is clearly demonstrated by the close correlation between network traffic and TFP growth as demonstrated in Figure 3-10. Across the ports however, there was a divergence in the effects of the major macro environmental changes. This is particularly apparent when the performance is compared before and after the recessionary period. All four ports saw declined performance post-2007. However, the duration of the decline and subsequent recovery varies from port to port. Shannon Foynes Port Company returned to 2007 productivity levels in 2013. The ports of Cork and Dublin returned to 2007 levels in 2015. Finally, the port of Waterford is still 23% below 2007 levels of performance when measured in terms of productivity change.

The varying rates of recovery in the respective ports have most likely been affected by the longer term meso level changes identified in section 2, specifically, the trend toward concentration in the major cargo markets identified in section 2. This is most clearly illustrated when examining productivity change in Dublin and Waterford over the period as both ports had similar growth trajectories preceding the recession. Pre-recession, both ports experienced similar increases in productivity, as the output of the port grew through increases in unitised trade. In addition, both ports had increased capacity through capital investment. Post-crash however, the shift in demand and acceleration in the centralisation process favoured Dublin

and greatly worked against Waterford. Dublin Port, in the post-crash period managed to grow its output largely through attracting new services in the RoRo sector, while keeping its cost base low. Hence, its productivity grew significantly. In contrast, the port of Waterford saw its throughput fall unexpectedly. The port suffered a significant fall in productivity in the immediate years following the crash as it took a number of years to adjust its input consumption. Subsequently, the port has managed to recover its productivity somewhat as both its input level had reduced, but also the growth in Dry Bulk business has substituted to a degree for the loss in its LoLo business.

Figure 3-10 Network TFP and Profitability Change



Focusing on the initiatives of managers, a notable feature of port company activity has been a trend toward rationalisation of labour across the ports. In Dublin this began at the beginning of the period as the port moved to divest itself from non-core operating activities. In the Port of Shannon-Foynes and Cork, there were dock labour rationalisation schemes aimed at improving the competitiveness of port services. In the Port of Waterford a rationalization in response to the loss of business has allowed the port to recover from a difficult period. There have, accordingly, been active attempts on the part of the major companies to control the cost base of operations.

A sector factor identified that influenced the performance of the ports is the choice of business model and degree to which operating activities are outsourced to the private sector. In the bulk sector, the operating structure employed across the ports closely followed that of the landlord model with mainly private provision of stevedoring. In the unitised sector however there was a divergence between Dublin, who moved closer to the Landlord model and the ports of Cork and Waterford who both fully assumed responsibility for terminal operations. This appears to have had an effect on productivity. In Dublin, after the initial change in business model, increases in scale were largely unmatched by the input index. In contrast increases in unitised trade in Waterford (pre crash), and Cork, have been matched by increases in the input index. This points toward differing marginal returns to scale depending on the model employed. In the Landlord model, the effective outsourcing of operations to the private sector, reduces the marginal cost of additional output (with the exception of expansion that requires capital investment). In the public provision model, the port company potentially has scope for greater returns based on its capacity to charge for the full terminal handling service; however, the port company also faces the full additional cost of providing services in labour.

The divergence in operating model activity is mainly attributable to the scale of operations outlined in the Competition Authority Report (2013). Dublin operates at a higher volume than the other two ports and as such sustainably manages to maintain a number of separate terminals. The reduced scale of the LoLo business in the smaller ports is viewed to impact the commercial feasibility of having more than one operator provide services from the port. Private participation in a single operating terminal runs the risk of the creation of a private monopoly. Without the regulating force of intra-port competition, it is feared that private monopolies with little commercial incentive to invest and innovate will produce poorer quality services. Discussing this directly, the Port of Cork outline that the challenge for the port sector

arises from the fact that the sector is small in scale, scope and profitability, and there is little benefit or attraction for the private sector to invest in local facilities (Port of Cork, 2010). Port Company provision, therefore, mitigates this risk and helps ensure quality of service.

Outsourcing may result in a cost reduction but if this is matched by a deterioration in the quality of output, the initiative may not result in a reduction in output (Grönroos and Ojasalo, 2004). This is not desirable particularly as many Port Companies, as public organisations typically have an economic facilitation mandate. Examining the Port of Cork the strong growth in container trade is noted, with a shift-share margin of +36%. This would suggest growing competitiveness. Waterford also had particularly strong growth in traffic and productivity in the pre-crash period. Currently, the port has excess capacity, however it is in a strong position to take on extra services if demand arises. It is questionable if this would have been the case if a private sector operator had continued to operate the terminal.

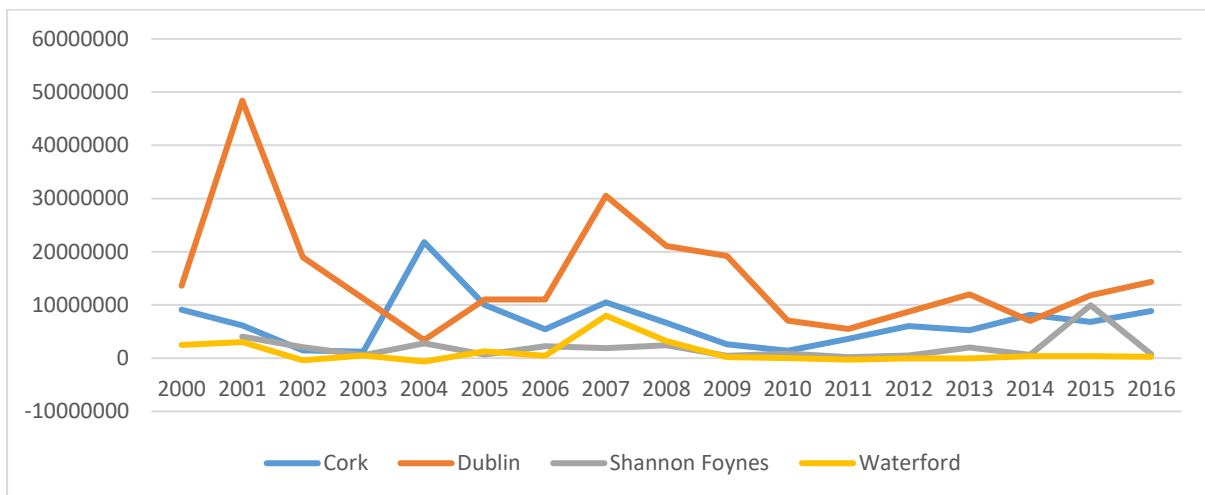
While ports have been reactive in adapting to trends, there is also evidence that ports have been proactive in prioritising certain cargoes over others in attempting to optimise the value of cargo moving through the port. This is best illustrated through the relative de-concentration of break particularly away from Dublin. Addressing the future of bulk business states, reflective of land constraints, the port has stated that it ‘will not seek to replace declining bulk commodities with other bulk commodities and will instead look for opportunities to redevelop bulk facilities to provide additional land area for unitised trades (Ro-Ro and Lo-Lo)’(Dublin Port, 2018, 49) . The relative growth of a particular mode may be influenced by strategic specialisation in a particular port. Most ports operate with finite resources affecting their capability to serve all types of cargo. Port managers therefore, are faced with a cargo mix choice. A loss in cargo volume through a port may be due to a de-prioritisation of that cargo type rather than a loss of competitiveness of the port, per se. There is further evidence that the

choice in cargo mix in the dominant ports is having an effect on how smaller ports within the Irish port system are attracting traffic. In the sample Waterford has managed to recover its output index through attracting more dry bulk business compensating somewhat for its loss in container traffic. Further evidence is apparent of de-concentration in the break bulk, discussed in section 2. Across the system as a whole, there is a noted increase in de-concentration in the break bulk sector.

### *Policy Implications*

The purpose of the initial reform in the sector as outlined in section 2, was to create commercially responsive port companies. It is difficult to say with certainty whether the reforms were successful without access to data regarding the performance of the ports prior to reform, or to an adequate counterfactual of sample of non-commercialised ports with which to compare Irish performance. However, there is evidence of responsiveness on the part of the ports that would suggest some degree of success. Across the ports there was labour rationalisation in an effort to improve efficiency. Albeit, this occurred in Shannon Foynes and Cork substantially later than in Dublin port. Reform in Waterford was largely in response to the changed economic circumstances. In addition, all ports sampled showed a responsiveness to recovery from the negative effect of market contraction due to the recession. Alternative choices in business model across the ports displays further evidence that ports are adapting to the specific operational challenges of their respective environments. Lastly, net investment is easily derived from the change in capital stock and can be seen displayed in Figure 3-11. Here it can be seen that there was positive investment across all ports over the period.

Figure 3-11 Net Investment Across Sampled Ports



\*Note: Net investment includes net investment in assets accruing to the port company. Investment therefore does not include investment by private operators.

National Ports Policy (2013), represented a departure from the previous policy position through a move to concentrate state support in the largest ports. The decision to tier the ports in National Ports Policy (2013) appears to be largely consistent with meso level dynamics toward concentration and relative performance of the largest ports. The tier 1 ports appear to be better positioned, both in terms of access to deep water and financial resources to develop capacity in line with changing trends. Ports require sustained traffic flows to make the necessary capital investments to remain competitive. The market for port services in Ireland is limited by the size of the Irish hinterland and relative peripherality of Irish ports to the major trade lanes which make it unsuitable for transshipment traffic. There is a strong case to be made, that with limited traffic, there is not a sizeable enough market to support multiple competing ports. The increasing concentration in all sectors except break bulk would support this conjecture. In addition, in Figure 3-10 it is clear that Dublin port has invested far more over the period than any other port.

Looking to the future, potential constraints to development in Dublin Port, given land restraints, may provide a threat to future development of system Traditional port system

development models point to limits to concentration (Notteboom and Rodrigue, 2005). Notteboom and Rodrigue (2005)s popular framework suggests for example, that as central ports continue to expand, space constraints lead to diseconomies of scale leading to a period of de-concentration. While there may not be immediate concern regarding space constraints in the long run this may become an issue. A growing gap in size and performance between the large and small ports creates doubts as to whether smaller ports may be able to adequately develop to provide substitute capacity should capacity constraints occur in Dublin. One potential may be amalgamating ports as proposed by the *Report of the Review Group on State Assets and Liabilities* (McCarthy et al., 2011). Here it is proposed that ports are amalgamated into three port companies representing east, south and west coast ports.

### 3.6 - Conclusion

Through applying a case study approach, this chapter provides a descriptive account of the evolution of performance change throughout the Irish Port system over the period 2000-2016. In this way, the chapter provides the first academic review of Irish port performance since Mangan and Cunningham (2000). It is clear from the analysis that performance was majorly effected by the macro-economic changes of the period. Through the in-depth case study it was possible to identify how port management adapted in respect to the short term shock of an unexpected reduction in traffic following a period of unprecedented growth. What's clear is that the impact of the recession was divergent across the ports, largely contingent on the scale and nature of operations of the respective ports. This has had an effect on the actions taken and the rate at which productivity has recovered. A longer-term trend at the meso level towards concentration in traffic volumes appears to further favour performance of the larger ports. As identified, a growing gap in performance between smaller and larger ports creates a potential

issue for the future development of port infrastructure should space constraints become an issue at the most dominant ports.

There are however, several limitations to the study. As outlined in the methodology, the productivity measures employed restrict the analysis to relative change in productivity over time in individual ports. This was largely motivated by the small and heterogeneous available sample. In future studies, the employment of frontier methods to measure productivity may enrich the analysis. Similarly, the study does not measure all aspects of port performance. The effectiveness of service delivery and environmental performance are increasingly important in port performance studies. (Brooks and Pallis, 2008b; O'Connor et al., 2016). Historical data to measure the performance on such dimensions was not available to this study. Similarly, in future studies, including such measures would further enrich any future performance analysis.

From a policy evaluation perspective, the results show the importance of contextualising the effects of macro-environmental changes and demand-side dynamics when considering supply-side performance factors. It is argued that the study demonstrates the potential of in-depth case study analysis for uncovering insights into the drivers of performance across a number of dimensions, thus allowing for the contextualisation of results. The study of a small number of cases enables the use of rich qualitative sources to create strong narratives which combined with quantitative measures of performance, can lead to new insights. This form of case study approach has been used recently to examine performance in a number of other sectors including energy (See and Coelli, 2013), food production (Palcic and Reeves, 2015) and airports (Cahill et al., 2017). It is proposed that this form of approach has particular potential for use in conjunction with large sample studies that are more typical in the port performance literature. Here case studies can be used to generate insights and propositions that can be more formally examined in large sample studies. For example, the results of this study

would suggest that larger ports have advantages relative to smaller ports, in regions limited by low volumes of demand for port services.

# Chapter 4 - Examining the relationship between relative size and technical efficiency in peripheral port markets: Evidence from Irish and North Atlantic Spanish Ports.

## 4.1 – Introduction

Achieving efficiencies in the production of port services is recognised as a key goal of regional and national policy makers around the world due to the importance of maritime transport in international trade (Brooks and Cullinane, 2006). A key mechanism for achieving efficiencies has been the reform of Port Authorities who are responsible for the regulation and development of port infrastructure. The dominant paradigm has been the corporatisation of PAs, with public ownership retained and responsibility devolved to commercially orientated semi-state bodies (de Langen and Heij 2014; Brooks et al. 2017). Private sector participation under this approach is facilitated by public-private partnership mechanisms (most frequently involving licensing and concession contracts).

The promotion of competition between autonomous PAs and the intended associated benefits are a key component of reform in many jurisdictions (Ng and Pallis 2010).<sup>11</sup> Amongst the major European hub ports, increased competition and its associated effects on port company strategy have been widely documented (Notteboom, 1997; Notteboom and Winkelmanns, 2001; Gouvernal et al., 2005; Notteboom, 2010). The largest hub ports act as load centres in hub and spoke networks competing for transshipment traffic. Increasing interdependency amongst nations and improvements in both technology and intermodal transport infrastructure have improved the capability of these ports to serve distant regions (Haralambides, 2002, 2017).

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<sup>11</sup> In Spain for example the Royal Legislative Decree 2/2011 set objectives for the self-financing of State PA's. In addition, the decree relaxed the tariff system to increase the autonomy of the PAs to set their own fees (Coto-Millán et al., 2016).

On the other hand, ports situated in regions that are relatively peripheral to major traffic lanes struggle to compete with the larger hub ports for contestable traffic. This restricts the spatial extent to which peripheral ports can compete for traffic, in most cases to the local hinterland. In peripheral regions, it is questionable if the size of the market for port services can support multiple, independently competing PAs (Brooks et al., 2010). Port operations are capital intensive, requiring large fixed asset specific installations. PAs need sustained traffic flows to attract the capital necessary to develop infrastructure and increase their competitiveness. With limited traffic flows, the capability of multiple PAs -operating in proximity- to attract adequate capital so as to remain competitive is highly challenged.

Recent national reforms in specific European jurisdictions have seen initiatives to boost the competitiveness of peripheral ports and avoid unnecessary duplication of resources in neighbouring competing ports. In Ireland, the National Ports Policy (2013) categorised ports into three tiers based on their capability to serve national traffic requirements. The National Ports Policy (NPP) is a move away from the previous policy of multiple independent competing ports. The NPP cites the wider trend toward consolidation in the shipping market and the use of larger ships as influencing factors. NPP states that Tier 1 ports are mandated to ‘lead the response of the State commercial ports sector to future national port capacity requirements’ with Tier 2 ports also recognised as having a responsibility to develop additional national capacity. The remaining commercial ports are categorised Tier 3 ports of regional significance. The NPP also points out that all future state support for major infrastructure developments will respect this mandate, a position which has been reiterated in the National Development Plan 2040.<sup>12</sup> Similarly in France, most recent reform has decentralised regional ports, while the largest ones, the ‘Grands ports Maritimes’, are retained under state ownership (Debie et al.,

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<sup>12</sup> Under the NPP there is no exchequer funding available for port infrastructure development. Instead state support will prioritise the development of intermodal infrastructure for Tier 1 and Tier 2 ports.

2013; Cariou et al., 2014). In Italy, the 2016 reforms went a step further. There, 24 independent PAs have been consolidated to 15 in a series of mergers, aimed to boost the capabilities of the newly formed PAs (Ferretti et al., 2018).

While the above refers to relatively policy-driven or top-down reforms, there are also strong examples of PAs themselves acting to pool resources (Notteboom et al., 2018). Most prominently, the ports of Copenhagen and Malmö merged to become a single entity in 2001. Similarly, in 2017, the ports of Ghent and Zeeland Ports merged to become the North Sea Port. Prioritisation of larger ports through tiering, or amalgamating smaller ports through mergers, should lead to efficiency gains. This assertion is explored by examining the relationship between the relative size and the technical efficiency of PAs in peripheral regions.

#### 4.2 - Investigating the relationship between size and technical efficiency

Previous studies on the relationship between port size and technical efficiency have shown mixed results regarding the significance of this relationship. Barros (2003), applying a second stage tobit regression, found that market share had a positive effect on technical efficiency in Portuguese PAs. Similar results were found in Barros and Athanassiou (2004), with the analysis extended to Portuguese and Greek Ports. Tovar and Wall (2017) found that relative size typically had a positive effect on the technical efficiency of Spanish PAs, between 2000-2012. Hidalgo Gallego et al. (2015) found a positive relationship between size and port utilisation, also in Spanish PAs. In contrast, Coto-Millán et al (2000) found that, amongst Spanish PAs, it is the smallest ports that have the highest technical efficiency, while Inglada and Coto-Millán (2010) found a negative association between size and efficiency (technical and scale efficiency). Bonilla et al. (2002), Tongzon (2001), Gonzalez and Trujillo (2008) and Zahran et al. (2017) found no significant effect of size on efficiency in PAs.

An issue with drawing conclusions from these studies is that, in sampling PAs for analysis, major hub ports with a substantial amount of transshipment traffic are included alongside smaller ports serving regional demand. The relative size of the hub ports, compared to the small to medium sized ones that are the focus of the analysis, complicates the research. In this chapter, ports sampled are exclusively from peripheral regions. Specifically, the chapter looks at Irish state owned ports and Spanish North Atlantic ports over the period 2000-2015. Ireland, as an island, has a limited hinterland while its relative distance from the major European markets and major trade lanes make it relatively uncompetitive in terms of major transshipment activity. Similarly, the North Atlantic Spanish region is limited in size. While the Spanish North Atlantic ports are less peripheral than the Irish ports to the major east-west and north-south trade lanes. The relative lack of transshipment activity in this region indicates a lack of competitiveness of ports in the region in attaining hub status. This is clear from Table 4-1 where it can be seen that the volume of transshipment traffic in the largest port in the region (Bilbao) is far below the major hub ports in Europe.

Table 4-1 Transshipment Incidence of Major Western Mediterranean and North West Atlantic Ports

Port	TEU	Transshipment (%)
Bilbao	610,131	2
Algeciras	4,070,701	91
Valencia	4,469,754	51
Barcelona	1,749,974	25
Antwerp	8,635,169	29
Le Havre	2,303,750	17
Rotterdam	11,865,910	36

Source: Notteboom et al. (2014)

In this chapter, the sample consists of fifteen ports, varying in size, as displayed in Table 4-2. To examine the relationship between size and a port's technical efficiency, the well-known two-step Simar-Wilson approach is applied (Simar and Wilson, 2007). The first step involves the measurement of a port's technical efficiency by using bootstrapped Data Envelopment Analysis (DEA), followed by a bootstrapped truncated regression (second step) to capture the relationship between contextual variables and technical efficiency measures. A major contribution of this study stems from the data set, covering as it does, a long period of port activity before and after the 2008 economic crisis. In both regions analysed, the effects of the crisis resulted in a large scale contraction in market demand. Utilising the dataset it is possible to measure the interaction effect between the contraction in ports system volume and size on technical efficiency. To achieve this a second interaction-based model is employed.

Table 4-2 Irish and North Atlantic Spanish Ports

<b>Port</b>	<b>Traffic (tonnes)</b>	<b>Revenue (€)</b>
Avilés	5,108,851	17,273,601
Bilbao	32,399,823	66,511,912
El Ferrol	12,759,526	18,632,334
Gijón	21,178,589	46,936,764
A Coruña	13,764,237	27,871,516
Pasaia	3,738,537	14,798,088
Marin-Pontevedra	2,114,083	9,634,104
Santander	5,559,820	20,417,982
Vigo	4,027,462	27,496,589
Vilagarcía	1,024,904	5,365,487
Dublin	22,204,000	79,508,000
Cork	9,708,000	29,956,316
Waterford	1,497,000	6,903,614
Shannon Foynes	10,871,000	12,151,864
Drogheda	1,227,000	3,196,536

Source: Eurostatt

The chapter is structured as follows: Section 3 outlines the methodology in more detail while section 4 discusses the port data employed. Section 5 presents the analysis, beginning with a qualitative analysis of efficiency scores before presenting the results of the second stage estimation procedure. Finally, section 6 consists of conclusions drawn.

### 4.3 - Methodology

To measure the relationship between technical efficiency and relative size that chapter employs the two-step double bootstrap DEA Approach outlined in Simar and Wilson (2007)<sup>13</sup>. DEA is one of two prominent approaches to estimate a production possibility frontier (or an input requirement frontier) and to analyse efficiency<sup>14</sup>. The DEA method was developed by Charnes et al. (1978), based on Farrel (1957), and it has been widely applied in port efficiency measurement. (Barros, 2006; Wu et al., 2010; Schøyen and Odeck, 2013; Zahran et al., 2017; Nguyen et al., 2018). The method takes a set of  $n$  inputs ( $x_{in}$ ) and  $m$  outputs ( $y_{im}$ ), for a set of  $i$  decision making units (DMUs) -in our case *ports*, and estimates an efficiency frontier by creating a piece-wise surface that envelopes the data. This is done by solving a linear programming problem for each data point  $i$ , commonly represented for an output-orientated model in its dual form:

$$\hat{E}_i(y, x) = \max_{\theta, \lambda} \theta \quad (1)$$

s.t.

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<sup>13</sup> Efficiency measurement is primarily based on the concept of efficiency introduced by Farrell (1957). Farrell (1957) decomposes overall productive efficiency into two elements; technical efficiency and allocative efficiency. Technical efficiency measures the ability of a firm to obtain maximum outputs from a certain quantity of utilized inputs, and typically refers to physical quantities. Allocative efficiency relates to the optimal choice of input bundle to produce outputs given prevailing market prices of inputs and outputs. It is desirable to measure both, however as outlined in Gonzalez and Trujillo (2007), the lack of factor price information has frequently forced researchers to focus on technical efficiency. Similar data constraints limit the current study to the analysis of technical efficiency.

<sup>14</sup> The other approach is parametric stochastic frontier analysis (SFA).

$$\sum_{i=1}^I \lambda_i y_{im} \geq \theta_m y_{im}, \quad m = 1, \dots, M$$

$$\sum_{i=1}^I \lambda_i x_{in} \leq x_{in}, \quad n = 1, \dots, N$$

$$\lambda_i \geq 0$$

Where  $\widehat{E}_i$  is the efficiency estimate of the  $i^{\text{th}}$  DMU ( $\widehat{E}_i \geq 0$ ),  $\lambda_i$  is a non-negative intensity vector used to scale individual observed activities for constructing the piece-wise linear technology and  $\theta$  is the actual unobserved efficiency score. With an output oriented frontier, a port  $i$  is considered as technically efficient when  $\widehat{E}_i = 1$ , and as technically inefficient when  $\widehat{E}_i > 1$  with  $\widehat{E}_i - 1$  representing the proportional increase in output required to project DMU  $i$  to the frontier, holding inputs constant. The DEA programme given by Eq. (1) represents the DEA-Charnes-Cooper-Rhodes (CCR) or DEA constant returns to scale model; to assume variable returns to scale, or the DEA-Banker-Charnes-Cooper (BCC) model, the constraint the constraint  $\sum_{i=1}^I \lambda_i = 1$  is added.

The main advantage of DEA is that it does not require the specification of a production function and it performs better with smaller samples relative to SFA (Panayides et al., 2009). As mentioned above, the estimation procedure may assume an output orientation, whereby output is maximised holding inputs constant or, alternatively, an input orientation can be assumed where input requirements, rather than the production possibility frontier, are estimated. Typically, an orientation should be chosen based on the production units' capability to adjust inputs/outputs (Coelli et al., 2005). Given that the provision of port infrastructure is highly capital intensive, the capability of PAs to adjust inputs is restricted. In choosing an

output orientation we therefore follow Gonzalez and Trujillo (2008), Tovar and Wall (2017) and Zaharan et al. (2017).

A number of approaches have emerged to examine the effect of contextual variables on efficiency scores generated by DEA. These approaches typically employ a second stage regression procedure, often using a censored or a truncated regression model to account for the bounded nature of the dependent variable; i.e. the estimated efficiency scores  $\widehat{E}_i$  (Simar and Wilson 2007, 2011). Such models can be represented by:

$$E_i = z_i \beta + \varepsilon_i \quad (2)$$

where  $z_i$  represents contextual variables. The error terms  $\varepsilon_i$  are assumed to be independent and identically distributed  $N(0, \sigma_\varepsilon^2)$  with left truncation at  $1 - z_i \beta$  (Balcombe et al., 2008). Thus,  $E_i$  cannot take values smaller than unity, irrespective of the values that the elements in vector  $z_i$  may take (Badunenko and Tauchmann, 2018a). Inferences in the second stage process relate the contextual variables as covariates to technical efficiency estimates that are assumed to be derived from some underlying Data Generating Process (DGP) based on a representative production technology. As outlined in Simar and Wilson (2007), replacing efficiency scores generated by the true DGP with estimates generated by DEA poses issues that make inference in ‘naïve’ two-step approaches invalid.

Simar and Wilson (2007) stress the major shortcomings of naïve two-stage approaches. The first issue arises due to replacing  $E_i$  in Equation 2 with  $\widehat{E}_i$ ; the DEA estimated efficiency scores. Although the error terms in Equation 2, where  $E_i$  is regressed on  $z_i$ , are assumed to be statistically independent across ports; the errors terms in a regression of  $\widehat{E}_i$  on  $z_i$  cannot be treated as independent of  $\widehat{E}_i$  since the latter are derived from the same sample. Thus the error terms of  $\widehat{E}_i$  for each firm (port)  $i$  can be serially correlated. Secondly, conventional DEA results

will, by construction, estimate some efficiency scores to be equal to one (i.e. full efficiency). However, according to Equation 2 the probability of a DMU achieving full efficiency ( $E_i = 1$ ) is null and the aforementioned scores are an artifice of the finite sample. This is particularly a problem in large samples where multiple DMUs will achieve full efficiency.

Simar and Wilson (2007) suggest the use of a parametric bootstrap procedure to address the issue of serially correlated error terms. In this parametric bootstrap procedure standard errors and confidence intervals for  $\hat{\beta}$  are estimated in which pseudo errors are drawn from the truncated normal distribution with left truncation  $1 - z_i \hat{\beta}$  (Badunenko and Tauchmann, 2018a).

The latter issue of unitary efficiency can be tackled by adopting one of the two following approaches proposed by Simar and Wilson (2007). In the first approach, observations with unitary efficiency are excluded from the truncated regression model. The estimated  $\hat{\beta}$ s and variance parameters of the remaining observations could be used further in the parametric bootstrap procedure mentioned above to eliminate the bias of serially correlated error terms. The second approach dealing with the problem of unitary efficiency, uses all observations in the truncated regression model and replaces the initial estimates using conventional DEA with bias-corrected scores, produced through a bootstrapping procedure, and as such is termed a double bootstrap approach. The second approach addresses the issue of serial correlation in a similar manner to the first approach.

Since its introduction, the Simar Wilson approach has become the most commonly used approach in two-step DEA regression analysis (Badunenko and Tauchmann, 2018b). The Simar Wilson approach has also been applied by scholars to analyse the efficiency of PAs. Recent examples include Yuen et al. (2013), Bergantino et al. (2013), De Oliveira and Pierre Cariou (2015), Wanke and Barros (2015), and Tovar and Wall (2017). This chapter uses the

double bootstrap approach of Simar and Wilson (2007) and the truncated regression for the second stage procedure. A bootstrapping procedure is subsequently used, to create confidence intervals through drawing from a truncated normal distribution with truncation at  $(1 - z_i \hat{\beta})$  where  $\hat{\beta}$  is the estimate of  $\beta$  in Equation 2. The authors show how, under a number of assumptions, this procedure produces consistent estimates of  $\beta$ . Most important is the assumption of separability, where the shape of the frontier is not dependent on  $z_i$ .<sup>15</sup>

#### 4.4 - Data

The sample consists of the five largest Irish state owned ports and the ten Spanish North Atlantic ports (Table 4-2). Importantly, the ownership and governance structure across both jurisdictions are highly comparable. The Spanish ports were decentralised under Law27/1992 and Law62/1997. Similarly, in Ireland, the Harbours Act of 1996 corporatised the former harbour authorities, creating decentralised autonomous port enterprises.<sup>16</sup> In both systems, therefore, PAs are decentralised and autonomous and while there is private sector participation in all ports, the state retains ownership of the infrastructure. PAs are therefore responsible for

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<sup>15</sup> See section 3 of Simar and Wilson (2007) and Simar and Wilson (2011) for more details.

<sup>16</sup> In Ireland, the Harbours Act corporatized the 10 largest state owned ports, creating commercial state-owned enterprises. The government retained ownership as the sole shareholder with the resulting “port companies” given a largely commercial mandate. Most operating restrictions were removed except the requirement of ministerial approval for large-scale borrowing and the establishment of subsidiary companies. New boards of directors were established to be responsible to the minister for transport for the conduct and operation of the port companies. The Spanish State Port System consists of 46 ports, managed by 28 Port Authorities. In the terms established under Spanish Law27/1992 and Law62/1997, the Port Authorities are responsible for the management of the ports under their autonomy regime and the State Ports Authority (Puertos del Estado) is then responsible for the overall coordination of the 28 Port Authorities and for the execution of the port policy of the Government.. Puertos del Estado define the objectives of the whole state port system, as well as the general management of the Port Authorities, through the Business Plans agreed with them. When a Port Authority considers it necessary to establish objectives with a time horizon of more than four years, it must formulate a plan that must also be agreed with Puertos del Estado. In addition, Puertos del Estado approve the financial and investment programming of the Port Authorities, derived from the Business Plans agreed with them, and the consolidation of their accounts and budgets (Royal Decree 2/2011). While there have been further reforms in both jurisdictions in the intervening period, the fundamental structure of the PAs, as decentralised autonomous units, has been preserved.

the development of infrastructure while ensuring that that infrastructure is operated efficiently and effectively, (in most cases through the appropriate regulation of private sector partners through the use of concession contracts and licensing).

The selection of inputs and outputs is a key element in any efficiency measurement exercise. There is significant diversity in the literature regarding what constitutes a port's output. This is often explained by the subject of analysis, i.e. a container terminal, a PA, etc., but also by the availability of data (Gonzalez and Trujillo, 2007; Panayides, 2009). There has been extensive literature measuring Spanish PAs technical efficiency. The major categories of cargo have been widely used as outputs, as well as the number of passengers (see Gonzalez and Trujillo (2007) for an extensive review), reflecting the multi-output nature of a port's production process. This however, creates a certain difficulty, as discussed by Panayides (2009), when it comes to estimating an efficiency frontier using DEA; increasing the number of outputs results in a loss of discriminatory power and overestimation of efficiency when there is significant heterogeneity in the output mix. As Panayides (2009) notes, as the number of dimensions increase, the opportunity to differentiate one DMU from its peers also increases and as a result the DMU may be deemed efficient only due to the lack of comparator observations.

In order to develop a parsimonious model and avoid estimation complexities a single aggregate output was used. We examined various means of aggregating outputs, based on cargo types and port activity. Given a lack of historical output price information, an issue arose in representing the relative value of different cargoes.<sup>17</sup> For that reason, Zahran et al. (2017) was followed and the revenue generated by the PA was chosen as a single output. A production

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<sup>17</sup> The ports of Cork and Waterford do not disclose the prices that they charge. In addition, this data is not available on a historical basis for the Irish ports.

process assuming an output orientation can be characterised as follows: the DMU, through available technology, transforms available resources (inputs) into output measured by the revenue generated by the PA.

As regards inputs, the standard factors of production, i.e. land, labour and capital, are employed. Land is measured by the surface deposit area of the port domain in square metres (m<sup>2</sup>). Labour is measured by total labour costs, obtained from audited annual reports, and deflated using Eurostat's Harmonised Index of Consumer Prices (HICP) in 2015 prices<sup>18</sup>. Following Medal-Bartual et al. (2016), capital is approximated by the total stock of net assets. Again, this measure was taken from the audited annual accounts and deflated by using the HICP index in 2015 prices<sup>19</sup>.

The next set of variables of interest are the contextual or *z* variables, as presented in equation (3). To measure the (relative) size of a *PA* we follow Tovar and Wall (2015) and measure the throughput of the port, relative to the total throughput of the port system measured in tonnes as follows<sup>20</sup>:

$$Relsize_i = \frac{tonnage_i}{tonnage_{sysj}} \quad (3)$$

Other variables considered in explaining efficiency were specialisation and rate of unitisation. Specialisation refers to the degree to which a *PA* concentrates in a particular output, relative to a differentiated output mix; the variable has been found to be a significant in Tovar

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<sup>19</sup> Labour includes the wage bill for all direct employees and managers of the respective PAs. This information is taken from the annual accounts of the PAs. The value of the stock of net assets for each port were taken directly from the annual accounts of the PAs. The value of fixed assets in a given year reflect cost minus accumulated depreciation.

<sup>20</sup> Tonnage is used to reflect cargo output as it allows for the aggregation of different types of cargo for comparative purposes.

and Wall (2017). To measure specialisation, we adopt the common normalised Herfindahl-Hirschman index (NHHI) given by:

$$NHHI_i = \frac{\sum_{m=1}^M \left( \frac{y_{mi}}{\sum_{m=1}^M y_{mi}} \right)^2}{1 - \frac{1}{M}} \quad (4)$$

where  $y_{mi}$  represents the  $m^{th}$  cargo output of port, *measured in tonnes*.

The unitisation rate is similar to the containerisation rate, commonly used as a measure of the type of output produced. We use unitisation rather than containerisation<sup>21</sup> to reflect the prevalence of RoRo (Roll-on/Roll-off) cargo in the Irish market and therefore aggregate LoLo (Lift- on/Lift-off) and RoRo cargo. RoRo cargo, similarly to containerised cargo, is parcelled and designed for easy transfer to other modes of transport. Unitised cargo is in direct contrast to bulk cargo, the latter consisting of goods that are primarily of low value and high volume, of a granular consistency and typically loaded en masse. Here, unitisation is measured simply as the percentage of traffic within the port that is unitised.

As mentioned above, we were also interested in examining the effect of the economic recession, in terms of demand side shock and subsequent market contraction. To capture this effect, the chapter initially considered dummy variables. An issue arose however with regard to the varying intensity of the recessionary effect, following the initial shock and recovery. To capture this, a Market Contraction Index (MCI) was constructed, whereby the effect of the recession is approximated by the amount of cargo, measured in tonnes, in the port system  $j$  in

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<sup>21</sup> Unitization reflects both RoRo and LoLo traffic. Containerisation refers to traffic that is loaded in 20ft or 40ft containers for shipment.

the given year ( $cargo_{sysjt}$ ) relative to the previous maximum level of cargo attained within the port system ( $max_{ij}^{t-1} cargo_{sysij}$ ); i.e.,

$$MCI_{sysij} = \frac{cargo_{sysjt}}{max_{ij}^{t-1} cargo_{sysij}} \text{ where } j = 1, 2 \quad (5)$$

Lastly, three classes of control variables were included. Firstly, a spatial variable to account for the size of the natural hinterland, measured in terms of population. Secondly, following Tovar and Wall (2015), dummy variables were included for each year, to account for the evolution of efficiency over time. Finally, a regional dummy variable to account for any systematic variation resulting from being in either jurisdiction was added. Descriptive statistics for the control variables are presented in Table 4-3.

Table 4-3 Summary Statistics

Variable	Unit	Obs	Mean	Std. Dev.	Min	Max
<b>Outputs:</b>						
Revenue	€ (2015 prices)	240	25,659,023	21,388,328	1,877,855	98,816,828
<b>Inputs:</b>						
Land	$m^2$	240	956,310	834,984	100,443	3,132,019
Labour	€ (2015 prices)	240	6,699,467	4,646,796	463,188	26,400,000
Capital	€ (2015 prices)	240	271,718,536	279,123,174	25,022,409	1,210,969,087
<b>Contextual Variables:</b>						
Population	People	240	1,868,926	738,844	531,159	2,797,653
Relative Size	%	240	12%	11%	1%	44%
NHHI	%	240	32%	20%	0%	80%
Unitisation	%	240	17%	22%	0%	74%
MCI	Index value	240	94	7.05	78.5	100
Legend:						

Relative Size: Cargo output in port relative to the market, equation (3)  
NHHI: Normalised Herfindahl-Hirschman index, equation (4)  
Unitisation: percentage of cargo that is unitised  
MCI: Market Contraction Index, equation (5)

## 4.5 - Results

To present the results of the efficiency analysis, it is necessary to firstly examine the efficiency scores generated through the initial step, and then proceed to the results of the second stage (regression).

### 4.5.1 - Efficiency Estimates

Applying the double bootstrap methodology of Simar and Wilson (2007), bias corrected efficiency scores are estimated (Table 4-4). Efficiency scores are estimated both under constant returns to scale (CRS) and variable returns to scale (VRS) in order to ascertain the appropriate technology. Following Coelli et al. (2005), scale efficiency in an output orientated technology equals:

$$SE_i = E_{ci}/E_{vi} \quad (6)$$

Where scale efficiency  $SE_i$ , is given by the ratio of efficiency under constant returns to scale ( $E_{ci}$ ) to efficiency under variable returns to scale ( $E_{vi}$ ). The CRS assumption is valid only if  $SE_i = 1$  globally ( Coelli et al., 2005). As can be see in Table 4-4, several DMUs exhibit scale inefficiency. Thus for qualitative analysis of efficiency scores, and the second stage estimation procedure, VRS is assumed.

Table 4-4 Average Technical Efficiency Scores

Port	Pre-Recession			Post-Recession		
	CRS	VRS	Scale	CRS	VRS	Scale
Avilés	1.62	1.52	1.07	1.49	1.46	1.02
Bilbao	1.32	1.29	1.02	1.41	1.37	1.03
El Ferrol	1.48	1.48	1	1.55	1.49	1.04
Gijon	1.24	1.25	0.99	1.27	1.3	0.98
A Coruña	1.27	1.25	1.02	1.27	1.25	1.01
Pasaia	1.9	1.91	1	1.87	1.82	1.03
Marin-Pontevedra	1.45	1.3	1.11	1.61	1.46	1.11
Santander	1.49	1.49	1	1.92	1.9	1.01
Vigo	1.31	1.34	0.98	1.59	1.63	0.98
Vilagarcía	2.07	1.5	1.39	2.18	1.84	1.19
Dublin	1.15	1.13	1.02	1.11	1.12	0.99
Cork	1.41	1.38	1.02	1.56	1.49	1.05
Waterford	1.39	1.37	1.01	1.67	1.48	1.14
Shannon Foynes	1.66	1.66	1	1.47	1.46	1.01
Drogheda	1.99	1.36	1.47	1.78	1.72	1.02
<b><i>Ireland</i></b>	<b>1.52</b>	<b>1.38</b>	<b>1.1</b>	<b>1.52</b>	<b>1.45</b>	<b>1.04</b>
<b><i>Spain</i></b>	<b>1.52</b>	<b>1.43</b>	<b>1.06</b>	<b>1.62</b>	<b>1.55</b>	<b>1.04</b>
Legend: CRS: Technical efficiency measured under constant returns to scale VRS: Technical efficiency measured under variable returns to scale Scale: Scale efficiency						

The evolution of efficiency scores over time is considered. To achieve this, average technical efficiency scores, for ports and jurisdictions, are reported for the pre-recessionary (2000-08) and (2009-15) periods. Here, it can be seen that average technical inefficiency across jurisdictions has decreased from the first period to the second. Illustrating annual efficiency changes (Figure 4-1), inefficiency was largely cyclical and strongly correlated to economic growth over the period. This is not surprising, as ports are nodes in a transport network that exists to serve international trade. Furthermore, ports are capital-intensive infrastructure

systems that require large, fixed, asset specific installations. As a result, given a sudden reduction in demand, ports will typically be subject to over-capacity as they cannot easily reduce their rate of input consumption, notably capital. Interestingly, a divergence was observed between North Atlantic Spanish and Irish Ports, with regard to the effects of the recession. The initial effects of the recession were stronger in Irish ports, with a much sharper decline in efficiency, following the financial crash, with the strongest effect observed in 2009. Nevertheless, efficiency in Irish ports has largely recovered while it has continued to decrease in Spain. The relative improvement in efficiency in Irish ports compared to Spanish ports may be influenced by the faster rate of recovery in the Irish economy as illustrated in Figure 4-2.

Examining differences across jurisdictions overall, it can be seen that average inefficiency in Irish ports has been slightly lower in both periods as measured under VRS technology. It is important to note however, that the larger number of Spanish ports in the sample may have influenced this result. Examining efficiency at the individual port level, there appears to be no obvious advantage to being in either jurisdiction. Dublin is the best performing port in both periods, with efficiency scores well above the most efficient Spanish ports, A Coruña and Gijon. The remaining Irish ports however are rather dispersed in terms of efficiency rankings in both periods.

Figure 4-1 Technical Efficiency (VRS) Over Time across the Port Systems

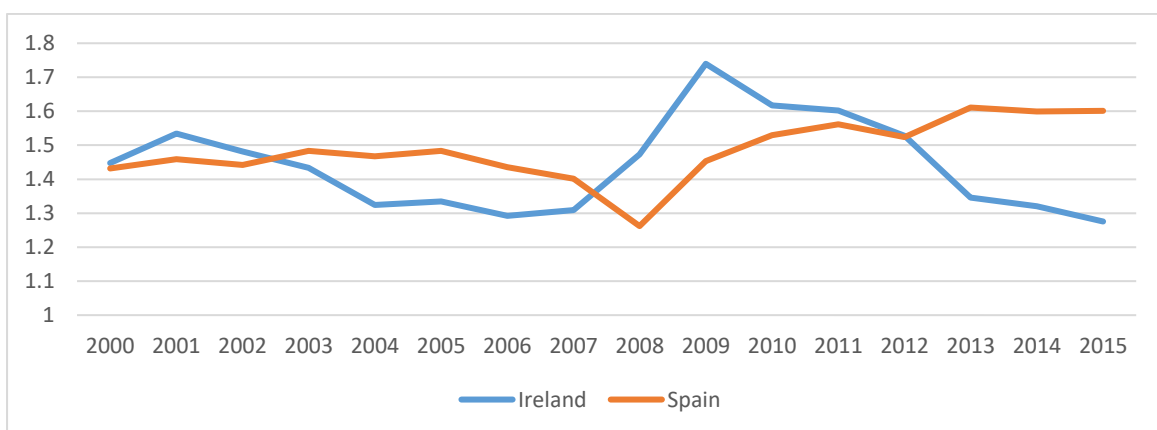
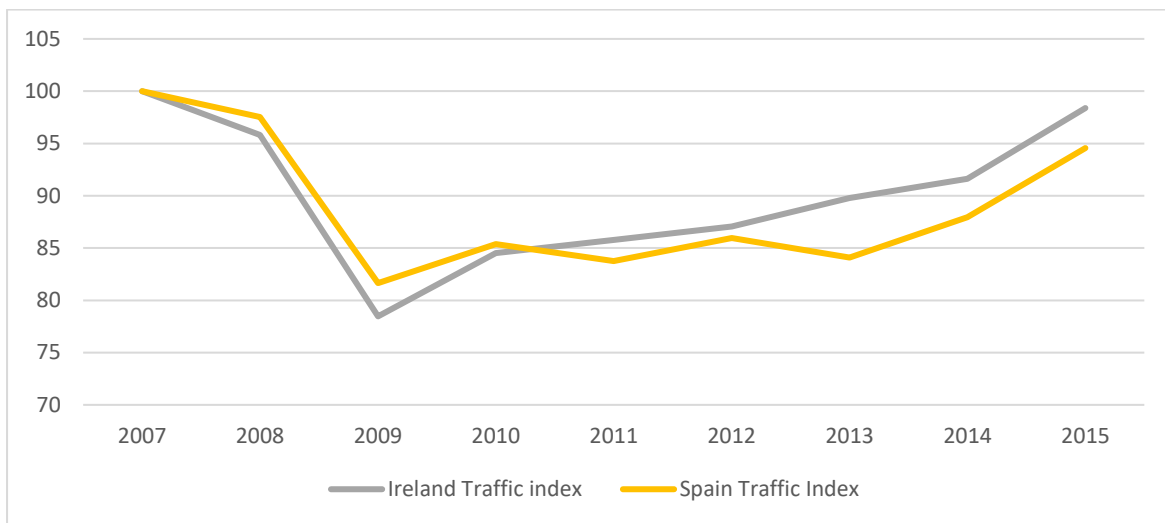


Figure 4-2 Post Recessionary Market Concentration Index change



To qualitatively examine the relationship between efficiency scores and the variables of interest identified in section 4, in Figure 4-3 we plot the average technical efficiency score against the average variable levels. A clear pattern emerges for relative scale, as those ports with higher efficiency are also those with the larger scale. There is no such pattern for the remaining variables, including, notably, NHHI: One can see no clear pattern, with highly concentrated ports tending both towards higher and lower efficiency. The same applies in the case of less concentrated ports. While this is explored formally in the next section, this result indicates that scale is likely the best predictor of technical efficiency scores. To examine this relationship over time in Figure 4-3, the average efficiency of the top twenty per cent of our ports, in terms of size, is plotted against the bottom twenty per cent. It can be seen that the efficiency gap between the larger and smaller ports increased considerably after the recession.

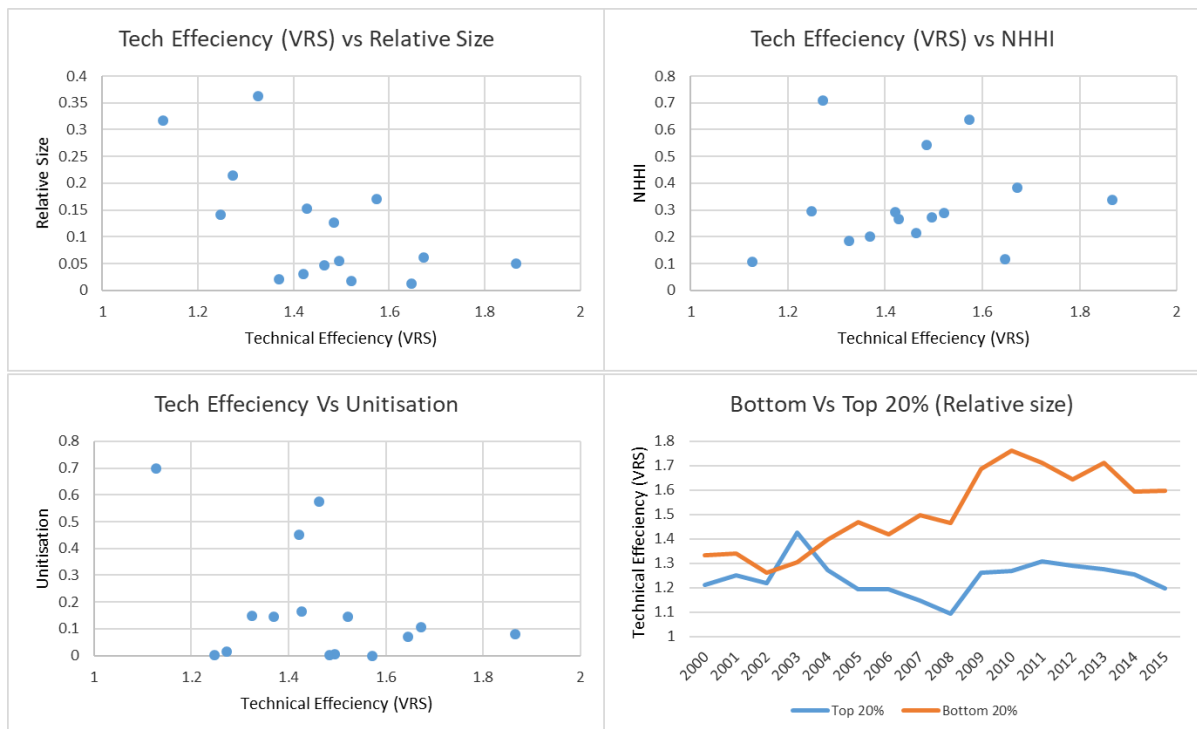
As displayed in Table 4-4, scale efficiency decreased from the pre- to the post-recessionary period. Notably the ports with the highest rate of average scale inefficiency, such as Marin Pontevedra, Vilagarcía, Waterford and Drogheda, were also the ports with the lowest average tonnage per year.

It is possible to examine whether scale inefficiency is caused by increasing or decreasing returns to scale. This may be achieved through further exploration of the relationship between efficiency scores generated by a VRS assumption versus those generated by assuming non-increasing returns to scale. This is done by employing the indicator:

$$SEIN = E_{ni}/E_{vi} \quad (7)$$

Here, SEIN indicates the degree to which there are increasing returns to scale available and is determined by the ratio of efficiency under the non-increasing returns to scale assumption ( $E_{ni}$ ), to efficiency under the variable returns to scale assumption ( $E_{vi}$ ). Calculating SEIN for the four ports we find average scores of 1.11 (Marin Pontevedra), 1.31, (Vilagarcía) 1.07 (Waterford) and 1.28 (Drogheda). These scores indicate that the four ports could increase their respective scale efficiency by increasing their scale.

Figure 4-3 Technical Efficiency vs Contextual factors



#### *4.5.2 - Second Stage Process*

In the second stage process, two models are estimated to measure the effect of the variables of interest (namely Relative Size, NHHI and Unitisation) on technical efficiency. The first model estimates the effect of these variables without controlling for the effect of market contraction. In the second model, the MCI variable (5) is included and interacted with the variables of interest to examine if the intensity of effects changes with the size of market contraction. As the truncated regression employed is a non-linear model, the estimated coefficients do not represent the marginal effects of the relevant variables. To derive these, the expected value of the dependent variable is differentiated with respect to the variables of interest, as shown in Table 4-5. Furthermore, in model 2, as the variables of interest are interacted, the interpretation of the effect of variables changes relative to model 1. The effect of a variable in conjunction with the interaction effect must be considered. (Drichoutis, 2011). The marginal effect, as presented in Table 4-5, is the marginal effect of the variable of interest with the MCI at its mean value. To examine how the effect of the variable of interest changes with MCI, the marginal effect of the variable of interest conditional on several values of the MCI is considered. Values of the MCI begin at 75 and continue in intervals of five until 100 is reached. (75 is chosen as a starting value as it roughly corresponds to the minimum value of the MCI as presented in Table 4-5).

Examining the control variables first, hinterland population size has a negative and significant effect on technical efficiency (at the ten per cent level) in both models. As to be expected, this indicates that proximity to a large population centre has a positive effect on the probability of a port achieving technical efficiency in generating revenue. However, the effect of hinterland population size on technical efficiency is not statistically significant at the 5% or 1% level. Examining the year dummies in model 1, it can be seen that none of the years has a

significant effect. However, in model 2, the year dummies corresponding to the post-recessionary period are significant and have negative signs (switching from positive in model 1), indicating a positive effect on efficiency. This result is unexpected, given that average technical efficiency declined in the post-recessionary period, displayed in Figure 4-1. A possible explanation for this could be that the negative effect of the recession in model 2 is captured primarily in the MCI variable introduced in model 2. This variable is negative, indicating that, as MCI rises (i.e. traffic relative to the previous year rises) technical efficiency similarly improves and vice versa. One possible conjecture therefore is that, controlling for the effect of market contraction, efficiency improved following the recession. Finally, the lack of significance of the country dummy variable would support the argument that there is no significant advantage in being in either jurisdiction, as regards the probability of improved technical efficiency.

Moving to the variables of interest, and examining firstly the effects of model 1, it can be seen that the average mean effect for both size and unitisation are positive, albeit more significant for size. This is more evident when we look at the marginal effects in Table 4-6. As both variables are measured on the same scale (i.e. percentage), both effects are directly comparable. It is clear that size has a much higher effect than unitisation. NHHI is not statistically significant; indicating that, on average, there has not been a significant relationship between efficiency scores and concentration of traffic over the period.

Table 4-5 Result of Second Stage Regression

Variable	Model 1		Model 2	
	Coefficient	SE	Coefficient	SE
Hinterland Population	-5E-05*	2.73E-05	-4.76E-05*	(2.56E-05)
RelSize	-1.49***	(0.24)	-7.57***	(2.62)
NHHI	0.11	(0.13)	-0.45	(1.49)
Unitisation	-0.25**	(0.1)	2.07	(1.27)
MCI	NA	NA	-0.09***	(0.02)
(MCI)*RelSize	NA	NA	0.07**	(0.03)
(MCI)*NHHI	NA	NA	0.01	(0.02)
(MCI)* Unitisation	NA	NA	-0.03*	(0.01)
2001	0.08	(0.11)	-0.04	(0.1)
2002	0.05	(0.11)	-0.01	(0.1)
2003	0.05	(0.11)	0.07	(0.1)
2004	0.01	(0.12)	0.01	(0.1)
2005	0.01	(0.11)	0.01	(0.1)
2006	-0.08	(0.12)	-0.06	(0.1)
2007	-0.08	(0.12)	-0.07	(0.1)
2008	-0.16	(0.12)	-0.39***	(0.12)
2009	0.13	(0.11)	-1.49***	(0.36)
2010	0.14	(0.11)	-1.09***	(0.28)
2011	0.17	(0.11)	-1.13***	(0.29)
2012	0.1	(0.11)	-1.03***	(0.26)
2013	0.1	(0.11)	-1.08***	(0.27)
2014	0.09	(0.11)	-0.81***	(0.22)
2015	0.08	(0.11)	-0.27**	(0.13)
Country Dummy (1=IRE)	-0.04	(0.04)	0.03	(0.05)
_cons	1.65***	(0.12)	10.34***	(1.86)

\*\*\* significant at 0.01%, \*\* significant at 0.05%, \* significant at 0.10%

Examining marginal effects in model 2, it can be seen again that size and unitisation have a positive effect while NHHI is insignificant. In Table 4-7, the change in effect as the market contracts is displayed. Examining size first, it can be seen that, as the market contracts, the magnitude of the estimated marginal effect increases significantly. This is largely consistent

with the qualitative analysis of the change in technical efficiency of the top 20% of ports in terms of size, as displayed in Figure 4-3. In contrast, for unitisation, the significance of this effect on the probability of a port being inefficient decreases as the market contracts. The sign further switches as we reach the minimum of the MCI. One possible explanation for this is that unitised trade is more closely linked with the wider underlying activity of a region, relative to bulk trade which is typically concerned with large industrial production and the movement of raw materials. As such, the relative effect of a domestic recession is likely to affect unitised trades to a greater extent than bulk. Finally, the NHHI variable is again insignificant in model 2.

Table 4-6 Mean Marginal Effects

	Relative Size	NHHI	Unitisation
Model 1	-1.14 ***	0.08	-0.19**
Model 2	-1.11 ***	0.07	-0.24 ***

Table 4-7 Interaction effect

With MCI at	Relative Size	NHHI	Unitisation
75%	-2.62***	-0.02	0.15
80%	-2.26***	0.004	0.03
85%	-1.83***	0.03	-0.09
90%	-1.32***	0.05	-0.18
95%	-0.86***	0.06	-0.23*
100%	-0.45***	0.05	-0.22*

## 4.6 – Policy Implications and Conclusions

### 4.6.1 – Policy Implications

Examining the implications of the relationship between size and efficiency for policy makers the evidence as presented suggests that the concentration or amalgamation of resources to

create larger ports within regions with limited traffic flows is likely to lead to greater levels of efficiency. Under systems with multiple independent state-owned ports such as the Spanish and Irish system, Pas, as established under this system, cannot enter or exit the market unless through legislative procedures. In addition, there is no mechanism under this system for acquisition by larger ports of smaller ports or mergers of similar sized smaller ports. Therefore, underperforming ports can continue to operate despite poor efficiency. For policy makers there therefore appears to be benefits accruing to amalgamating underperforming smaller ports, as has been done in Italy.

There is also a strong argument to be made that maintaining multiple small and underperforming ports is likely to lead to unnecessary duplication of infrastructure. This is particularly the case when state funding is allocated for infrastructure development projects. The European Court of Auditors (ECA), in a review of port infrastructure development, found strong evidence of unnecessary investments. The ECA found that “One euro in three spent on the projects examined (€194 million) went on projects which duplicated existing facilities nearby. €97 million was invested in infrastructure which was either unused or heavily underused for more than three years after completion” (European Court of Auditors, 2016,pg 8). Reducing the number of independent PA’s developing infrastructure in proximity is likely to reduce the level of unnecessary investment.

A key motivation for maintaining autonomous and independent PAs is the positive effect of competition, as well as the subsequent effects of incentives, aiming to achieve efficiencies and innovation (Ng and Pallis, 2009). A factor to bear in mind however, is the presence of intra-port competition among private sector participants within the individual ports. Intra-port competition is often seen as a means of mitigating the danger of monopoly pricing and excessive economic rent-seeking in ports that are subject to limited inter-port competition

(De Langen and Pallis, 2006). The Irish competition authority (2013) and the Spanish Royal Decree 2/2011 promote intra-port competition as a means to introduce more competition into the sector, in the face of limited scope for inter-port competition. While concentrating on reducing the number of PAs may seem on the surface anti-competitive, intra-port competition once suitably regulated and promoted may help mitigate this risk.

#### *4.6.2 – Conclusions*

In this article we employed the DEA double bootstrap procedure of Simar and Wilson (2007) to examine the relationship between technical efficiency and port size in peripheral regions over the period 2000-15. Purposely sampling Irish and North Atlantic Spanish ports of various sizes that compete in limited markets, we find evidence of a positive relationship between technical efficiency and size. The magnitude of the positive effect of a port's size on technical efficiency becomes stronger when we account for potential interactions between post-recessionary market contractions (MCI) and size.

The evidence put forward, both qualitatively and quantitatively, clearly points toward a positive relationship between scale and technical efficiency across the two port systems. As discussed in section 2, this is not necessarily consistent with the literature, which provides mixed evidence of a positive relationship between scale and technical efficiency in PA operations. The discrepancy between the strong evidence in this study and contrary evidence elsewhere is likely to be a question of scope in terms of the type of ports under analysis. This study has considered a range of small- to medium-sized gateway ports from two peripheral port regions. Other studies have included transshipment hubs which, as discussed in Notteboom et al. (2000), have a different operational model from ports without transshipment operations.

Higher degrees of technical efficiency imply a competitive advantage for larger ports within peripheral regions relative to smaller ports. The scale efficiency analysis in section 5 indicates that the smallest ports in the sample are scale inefficient and facing increasing returns to scale. With a limited volume, it is questionable as to whether there is scope for these ports to increase scale and achieve higher efficiencies. While the results of this research indicate that a positive relationship exists between port size and technical efficiency across the peripheral traffic regions of Ireland and North Atlantic Spain, a broader analysis would be required to ascertain if these findings can be generalized to small ports in other peripheral areas.

# Chapter 5 - Examining demand and substitutability across terminals in a gateway port network: A discrete choice model of Irish ports.

## 5.1 - Introduction

Examining demand for services across the nodes in the network through port choice modelling can play a crucial role in helping policy actors shape future policy actions to improve the future functioning of the port network. Given the trend toward digitalisation in container shipping, there are increased opportunities for researchers to investigate and model demand using previously unavailable sources of data. Given its prevalence, automatic identifier system (AIS) data represents an important source of such data. This paper aims to contribute to the literature through a novel application of discrete choice analysis using AIS data.

To achieve this, a case study of the Irish container terminal network is carried out. The Irish LoLo terminal network is a good example of a system of gateway nodes that combine to provide capacity for a region (the island of Ireland). To model demand across the terminal network the probability of a shipping line choosing a node/terminal in the network is estimated using a number of discrete choice models. Substitutability between nodes is then examined through simulation exercises, thus following Brownstone and Train (2000). These simulations are based on real events that are likely to impact demand across the terminal network. Namely, potential congestion at the dominant port of Dublin given constraints on land for development; the impact of the movement of container operations in Cork from the Tivoli terminal to a new deep water terminal in Ringaskiddy and finally, the impact of the re-imposition of a hard border between Northern and Southern Ireland following Brexit.

The remainder of the chapter is structured as follows. Section 2 reviews the literature on port choice modelling. Section 3 introduces the Irish port network, while section 4 specifies the methodology employed. Section 5 presents the data compiled and sets out the attribute measures employed. Section 6 presents the results of the modelling exercise and the policy simulations. Finally, Section 7 concludes with a discussion of results, limitations of the data and outlines avenues for future research.

## 5.2 - Demand modelling for freight transport

Discrete choice modelling is the standard methodology employed in econometric analysis of demand for freight transport options using disaggregated data. The approach has been employed since the 1970's (Winston, 1983). As displayed in Table 5-1, discrete choice models have similarly been widely applied in the port choice literature. Discrete choice models typically vary by form or specification of model used and by the source of data, either stated preference (SP), revealed preference (RP) or joint SP/RP approaches (see Brownstone et al. (2000) for discussion). In the port choice context, a further issue that has emerged as critical in examining choice is accommodating the complexity of the freight logistics chain. As discussed by Talley and Ng (2013), port selection is typically made as part of a wider maritime transport chain selection where different actors combine to determine port choice. Subsequently, what actually determines choice in this context is the capability of a port as a node within the transport system to simultaneously provide enough relative value to shippers, carriers of cargo (both shipping lines and freight forwarders) and the ability of the port themselves to generate a port call.

This poses an issue in choice modelling that is systematic of freight transport demand modelling more generally, in that actually identifying the decision maker is seldom straight forward (Winston, 1983). In a recent review of the literature Martinez and Feo Valero (2017)

discuss this issue in detail. They conclude that while the optimum situation would be to jointly study the decision process of each group of actors, mathematical complexity and difficulty in characterising the relationships that inform a joint decision making process inhibit the feasibility of this approach<sup>22</sup>.

In studying choice between a defined set of alternative ports or nodes, the modeller can employ stated preference (SP) or revealed preference (RP) data. SP data is often collected via choice experiments where respondents indicate their choices across a number of choice options with varying attribute levels (Nir Lin, and Liang 2003; Stithou et al., 2012). Actual choices in RP data reveal preferences for the chosen node relative to all other nodes in the set irrespective of the actual decision making process. RP relies on the assumption that given a choice between a set of alternatives, the decision maker, through choosing a particular alternative is revealing her preference for that alternative over all others in the set (Samuelsson, 1948). For uncovering actual preference structure and substitution between a set of alternatives, RP approaches thus avoid much of the issues associated with misrepresenting the decision making process or not properly surveying the actual decision makers that challenge SP approaches given the aforementioned ambiguity surrounding the true decision making process. The relative suitability of RP over SP approaches is reflected in the literature where studies that model choice in existing systems have tended towards using RP data. As seen in Table 5-1, there have been multiple studies examining choice through the perspective of both the carrier and the shipper.

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<sup>22</sup> While stated preference studies are difficult in the context of port choice, stated preference approaches relying on choice experiments have been applied successfully in a number of mode or route choice studies that encapsulate port choice as part of the decision making process. Puckett et al (2011) is a prominent example of such studies, where the authors examine mode choice in Australia for perspective short sea operators. (Breen et al., 2016) is an example of a similar study in Ireland that looks at route choice in the RoRo sector.

The trade-off in using a revealed preference approach is that the researcher is restricted in both the scope of alternative attributes that can be measured (due to availability of data and capability to introduce variability between attributes and subsequent collinearity), and restricted to examining existing alternatives (Louviere et al., 2000; Hensher et al., 2005; Hynes et al., 2016). The latter restriction relates to the limitation in capturing preferences for alternatives that may be currently absent from the existing market. This is reflected in the extant literature as displayed in Table 5-1, where it can be seen that attributes included are largely a function of what it is possible to measure rather than deriving a full spectrum of what is most likely affecting choice. This also extends to how attributes are measured with latent constructs approximated in various ways across the studies.

For the most part, discrete choice studies that have considered port choice from the shipper's perspective have relied on datasets derived from customs offices or equivalent public trade agencies. This can be restrictive as this type of data is not available in every region; for example in Ireland, disaggregate customs data at the shipment level are not available due to data restriction laws. There is further debate in the literature as to how the choice set from the shipper's perspective is formed. Specifically, shippers will tend to choose a service based on the full cost of the maritime chain, therefore port choice is part of a wider logistics chain choice, with the choice located between alternative transport chains rather than between ports. Cantillo et al. (2018), for example, model the joint choice of ports and countries of origin/destination, rather than ports alone. Similarly as mentioned above, there are a number of studies that have examined shipper or freight forwarders route or mode choice with the emphasis primarily on the full logistic chain operation, rather than choice of port alone (Puckett et al., 2011).

From the carrier's perspective, limited access to disaggregate data has restricted the use of discrete choice modelling to a handful of papers. It is argued in this chapter that AIS data,

which provides detailed information on vessel movements, has the potential to greatly increase the scope for this form of analysis. The European Union’s ESSnet Big Data project concluded that AIS data has proven potential to improve current statistics and generate new statistical products (Consten et al., 2017). AIS is also increasingly used in the ports literature. Two prominent examples include Jia et al. (2017) and Peng et al. (2018) which both use AIS data to measure port connectivity. To the best of this authors’ knowledge however this is the first paper to utilise this form of data to perform discrete choice analysis in the port sector. This is despite numerous studies in other disciplines that utilise RP data for discrete choice modelling, for example Hynes et al. (2016) in fisheries and Broach et al. (2012) in cycling.

Table 5-1 Discrete Choice Applications to Port Choice

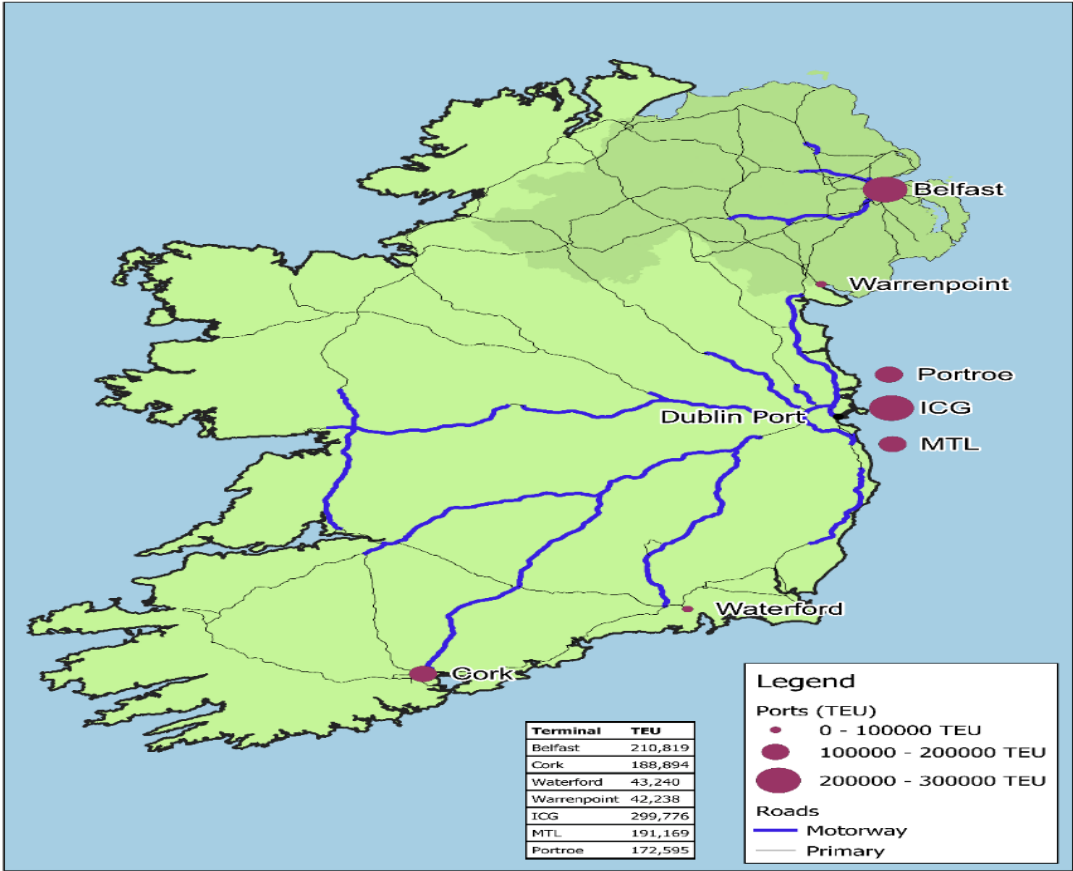
Paper	Methodology	Perspective	Data USED	Port Attribute Measures
Nir Lin, and Liang (2003)	Multinomial Logit (MNL)	Shipper	Questionnaire survey of 309 shippers in Taiwan	Travel cost, Travel Time, Number of routes and frequency of services.
Tiwari Itoh and Doi (2003)	MNL	Shipper	1033 shipments based on the Survey of Cargo Flows in the Yellow Sea rim conducted by The International Centre for the Study of East Asian Development	Berths (number), Water (depth), Cranes (number), Total TEU handled (million), Ship Calls (number), Routes (numbers), Usage Factor (volume/length of quay (1,000 ton/m)
VELDMA N and Buchman (2003)	Multinomial Logit (MNL)	Shipper	Container flows generated by 33 hinterland regions in the Netherlands, Germany and Belgium, and routed through the ports of Antwerp, Rotterdam, Bremen and Hamburg	Differences in transport costs (sourced from operators), transport time, frequency of service and liner service and frequency by seaport and major trade route
Malchow and Kanfani (2001,2004)	MNL, Chamberlain model	Shippers and Carriers	Data on shipments into the US in 1999, broken down by commodity type.	Oceanic distance, Inland distance, Sailing headway, Vessel capacity, Probability that port is the last port visited.
Tongzong & Sawant (2007)	Binary choice logit	Carrier	Survey of 31 shipping lines in South East Asia, concerning chosen hub port	Shipping line Ratings: Adequate infrastructure, Location, Efficiency, Port charges, Cargo size, Connectivity and

				Wide range of port services.
Anderson 2009	Nested Logit	Shippers and Carrier	470,766 shipments Based on the PIERS database of all shipments imported into the top 10 ports in the United States between October 2004 and September 2005	Sea transit time, distance to hinterland destination, freight charges, port reliability, dummy for distances within 175 miles and between 175-375 miles, major market (Asia vs Europe), coast of port
Veldman, Garcia Alonso and Vallejo-Pinto (2011, 2013)	MNL and Nested Logit	Shipper	Spanish Customs Data	Inland transport cost, Maritime, quality mohring effect, transport cost, Choice of coast line, Inland transport cargo balance
Steven and Corsi (2012)	MNL	Shipper	Data on import shipments to the Pittsburgh area derived from Piers data totalling 19,556 observations.	Estimated shipment freight rates, crane productivity, congestion (ratio of total number of vessels to total number of container berths), total number of cranes lifts to crane, Oceanic transit time, Inland transit time, no of Berths
Yang, Wang and Li (2016)	MNL	Carrier	Data obtained from China Shipping Year Book on 1,721 foreign trade routes operated by 80 shipping companies	Hinterland GDP, Speed of delivery, and port capacity
Ko,Shaban pour, and Mohammadian 2016	MNL	Shipper	315,925 records from Carload Waybill Sample in United States between 2007-2012	Distance from origin country ports to the U.S. ports, Distance from the U.S. ports to the states, Capacity Use by ports. Monthly imported container weight over maximum port capacity, Depth of ports. (1 if over 50ft, 0 if less than 50ft)
Veldman Garcia Alonso and Liu (2016)	MNL	Shipper	1,984 import flows and 2211 export flows using Spanish customs statistics.	Inland distance, At sea index, In port index, Feeder dummy, Mohring index (measure of quality of service)
Cantillo, Cantillo and Arellana (2018)	MNL and Mixed Logit	Shipper	Sample of 10,000 records taken from 3,152,765 import records and 1,439,263 export records based on 2014 Colombian Customs data.	Inland Freight Rates, Maritime Freight Rates, Frequency of Shipping Lines, Trade Agreement, GDP per capita

### 5.3 - Irish container terminal network

The container terminal network is composed of seven terminals located across five port locations as represented in Figure 1. Dublin is the only port in the sample year of 2016 to support more than one terminal operator, with three private terminals operated by Dublin Ferry Terminals (DFT), Marine Terminals Limited (MTL) and Portroe stevedores. Belfast previously had two container terminals, but by 2016, all operations had been consolidated to the Belfast Victoria 3 terminal which is operated by the Irish Continental Group, (the parent company of DFT in Dublin). While operations in Dublin and Belfast are provided by private companies, the remaining three terminals are wholly operated by port authorities (Waterford, Warrenpoint and Cork (Tivoli)).

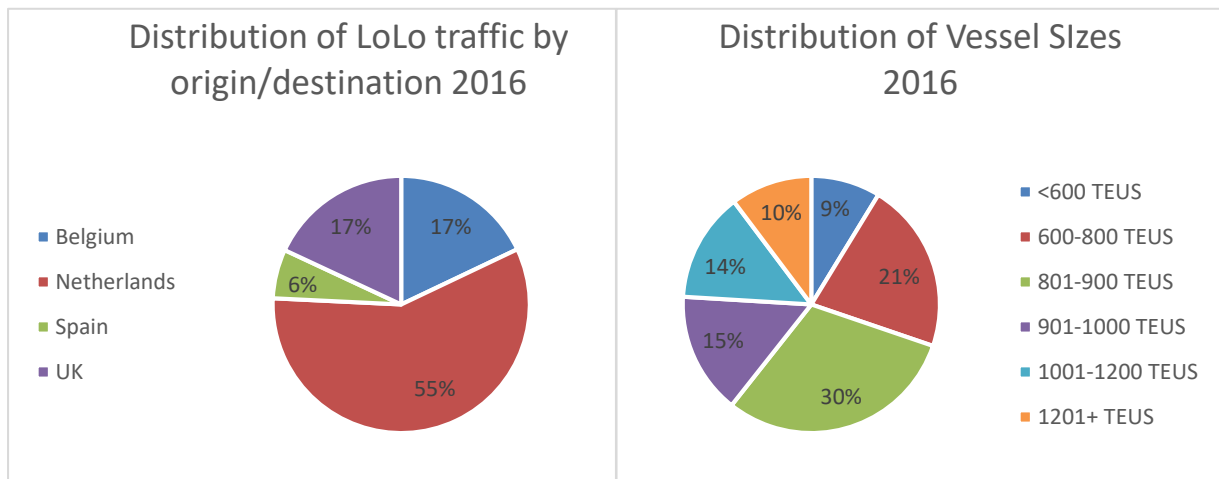
Figure 5-1 Irish LoLo Terminal System



Container services in Ireland have tended to be a mix of short sea and feeder services. The lack of transshipment activity owes primarily to the peripherality of Irish ports with regard to mainline liner routes. In addition, the small size of the Irish market currently inhibits direct sea services with the exception of one service that calls to the Ringaskiddy Deepwater multipurpose terminal operated by the Port of Cork. This service is very much an anomaly in the wider market and as such is excluded from the analysis. As displayed in Figure 2, 72% of services from the island of Ireland serve ports in Northern Europe. Services on this route carry a mixture of feeder and short-sea services and primarily serve the major hub ports of Rotterdam and Antwerp. The 17% of services that call to the UK are comprised of short sea services to ports on the west coast and mixed short sea and feeder services to the hub ports of Southampton and Felixstowe on the east coast. Finally, there is a sustained feed of traffic linking Irish ports and ports in Northern Spain which accounts for 6% of total services.

Lastly, it is worth noting that in 2016, there was no material restriction on traffic moving across the administrative regions of Northern Ireland and the Republic of Ireland. However, this may change following the UK's decision to leave the European Union. Traffic with Northern Ireland is integrated with Lift on Lift off (LoLo) traffic travelling on all island basis (IMTE 2017; Competition Authority of Ireland, 2013). In forming the choice set it was decided to examine choice at the terminal rather than the port level. This was justified on the basis that there are significant operational differences across terminals in Dublin port in addition to significant intra-port competition, as identified by a recent report from the competition authority of Ireland (Competition Authority of Ireland, 2013).

Figure 5-2 Destinations and Vessel sizes



Source: IMDO - Irish Maritime Development Office (2016)

#### 5.4 - Methodology

This study employs a discrete choice methodology to model choice behaviour with regard to Irish terminal or node selection, conditional on choosing to run a LoLo liner service from the island of Ireland. To meet this objective, the random utility model (RUM) framework of McFadden (1973) is applied. RUM models are widely used to analyse choice behaviour and predict choices among discrete sets of alternatives. The RUM model in our case is based on the assumption that a carrier's preferences among the available node alternatives can be described with a utility function and that the shipper selects the alternative with the greatest utility.

More formally, it is assumed that conditional on deciding to run container services, the carrier  $n$  has a choice of seven terminals to route the service through. The choice is made as a function of the relative utility derived by carrier  $n$  which is specified as a function of observed attributes and error term as follows:

$$U_{ni} = \beta X_{ni} + e_{ni} \quad (1)$$

$U_{ni}$  stands for utility of carrier  $n$  for terminal  $i$ .  $X_{ni}$  represents the observable component of the indirect utility function with the attributes of the terminal and  $\beta$  is a matrix of coefficients representing preference for a given attribute. Finally  $e_{ni}$  represents the random error term. Each carrier maximises utility  $U_{ni}$  such that the probability of choosing any given terminal  $i$  for each choice situation can be represented as follows:

$$Pr_{ni} = (\beta X_{ni} + e_{ni} > \beta X_{nj} + e_{nj}). \forall j \neq i \quad (2)$$

Here  $Pr_{ni}$  represents the probability of  $n$  choosing terminal  $i$  and  $j$  represents the set of alternative terminals. In essence therefore, the model is estimating the probability of a carrier routing a service through a given terminal relative to the other terminals, based on observed and unobserved attributes <sup>23</sup>.

There are a number of ways to calculate the choice probability in the discrete choice literature, depending on the treatment of the error term. The most common is the standard conditional logit, which specifies that the error term is identically independently drawn (IID) from a GEV1 distribution. As shown in McFadden (1973), under these assumptions the choice probability reduces to:

$$Pr_{ni} = \frac{\exp(\mu\beta X_{ni})}{\sum_{k=1}^j \exp(\mu\beta X_{nk})} \quad (3)$$

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<sup>23</sup> It is worth noting that within the modelling approach taken it is not attempted to model the process by which decisions are made. The advantage of using revealed preference data is that it allows for modelling choice based on attributes that are observed and unobserved. The approach therefore allows for the inference of the importance of a given attribute in affecting the choice outcome reflective of all attributes. A drawback however is that in the approach taken the capability to derive insight into process by which decisions are made is limited. For example, in theory a carrier may be able to use all terminals, in practice her choice may be limited by contractual obligations. It is not possible to directly observe this from the data, however some degree of control of the effect of such an arrangement may be achieved through the use of appropriate statistical modelling approaches. Specifically, in the current case the use of random parameters to reflect taste heterogeneity and panel data methods that take advantage of repeated choices to account for carrier specific heterogeneity in preferences.

The operator  $\mu$  represents a scale parameter while  $\exp(\cdot)$  represents the exponential function. The conditional logit model is widely popular as it has a number of attractive properties, most prominently it allows for a closed form solution in calculating choice probabilities (Train, 2009). The IID property however imposes several restrictions. Firstly, while a conditional logit model can represent systematic taste variation, it cannot represent random taste variation. Therefore, any difference in taste across the sample not observable through individual specific attributes is disregarded. Secondly, the conditional logit model imposes strict substitution, displaying Irrelevance of Independent Alternatives (IIA), such that the probability of choosing alternative  $i$  over alternative  $j$  depends only on differences between both choices and disregards all other potential alternatives. It also imposes proportionate substitution between alternatives, in that an improvement in the attributes of one alternative reduces the probabilities for all the other alternatives by the same percent. Finally, the conditional logit does not allow for the choices of individuals to be correlated over time, which is particularly restricting, given the panel nature of the data set.

Mixed logit models are an extension of the conditional logit that overcomes the three major limitations described above. Utilising this same random utility approach, the mixed logit can be specified as follows (Hynes et al., 2008; Train, 2009):

$$U_{ni} = \beta_n X_{ni} + e_{ni} \quad (4)$$

The error term, as before, is extreme valued IID distributed. However, in this instance rather than being fixed the coefficients, as represented by  $\beta_n$ , are allowed to vary randomly over the population of  $n$  decision makers. The  $\beta_n$  vary according to some distribution with  $\beta_n \sim f(b|\theta)$ , with  $\theta$  representing the structural parameters of the distribution. As before, the probability of choosing an alternative is calculated as in Equation (3). However, instead of conditioning over

a fixed population  $\beta$ , conditioning is now over each individual  $\beta_n$  in the sample. As  $\beta_n$  is not directly observable, it is assumed that  $\beta_n$  is distributed throughout the population according to the specification of the distribution  $f(b|\theta)$ . As such the random component is portioned into two parts, one IID and another correlated over alternatives. Specifying utility as linear in parameters, choice probabilities can be derived as follows:

$$Pr_{ni} = \int \left( \frac{\exp(\mu\beta X_{ni})}{\sum_{k=1}^j \exp(\mu\beta X_{nk})} \right) f(b|\theta) d\beta. \quad (5)$$

Where the choice probability is the weighted average of the logit formula calculated for different values of  $\beta_n$ , with weights given by the density  $f(b|\theta)$  (Train, 2009). The researcher must therefore specify the distribution  $f(b|\theta)$  (known as the mixing distribution), and estimate the structural parameters. For the purpose of this study, coefficients are specified as being normally distributed with mean  $b$  and covariance  $W$ . As such (5) becomes:

$$Pr_{ni} = \int \left( \frac{\exp(\mu\beta X_{ni})}{\sum_{k=1}^j \exp(\mu\beta X_{nk})} \right) \phi(\beta|b, W) d\beta. \quad (6)$$

The specification is easily extended to account for repeated choices by carriers across multiple choice situations. This is important in the present case as it would be expected that factors captured in the error term i.e. not observable to the researcher, are likely to be correlated over time. Correlation across choices over time is most simply incorporated by calculating the joint probability of a carrier  $n$  in choosing a sequence of alternatives over time. The choice probability is calculated in the same manner as before, with the only difference being that the term between the brackets in equation (6) is replaced by a product of logits for each carrier  $n$ , specified as follows:

$$Pr_{ni} = \int \prod_{t=1}^T \left[ \frac{\exp(\mu\beta X_{nit})}{\sum_{k=1}^j \exp(\mu\beta X_{nkt})} \right] \phi(\beta|b, W) d\beta. \quad (7)$$

In estimation therefore each carriers  $\beta n$  is correlated over alternatives and choices are correlated over time.

The structure of the integral requires the use of simulation methods to estimate the mean and covariance matrix of the normal distribution. The method employed was maximum simulated log likelihood estimation (see Hensher et al. (2005) chapter 4). The simulated log likelihood is specified as follows:

$$SML = \sum_{n=1}^N \ln \left[ \frac{1}{R} \sum_{r=1}^R \prod_{t=1}^T \left[ \frac{\exp(\mu\beta X_{nit})}{\sum_{k=1}^j \exp(\mu\beta X_{nkt})} \right] \right] \quad (8)$$

Here R refers to draws of  $\beta$  from a multinomial normal density, with 1000 draws taken using halton sequences. Estimation was completed using Nlogit5 relying on the Berndt–Hall–Hall–Hausman algorithm. Finally it possible to re-parameterise the mean estimates of random parameters to establish heterogeneity associated with observable influences (Hensher et al., 2005; Hynes et al., 2016). In this way, it is possible to segment the mean to remove some of the heterogeneity from the parameter distribution.

## 5.5 - Data

The sample consists of a census of LoLo/container calls to all Irish ports for the calendar year 2016. The data is obtained by Marine Traffic, which utilises AIS technology. Calls are indexed by arrival and departure and include a unique identifier for each vessel and timestamp indicating the date and hour of arrival/departure allowing for the calculation of time in port. In the case of Dublin, it was also possible to further breakdown calls at the terminal level, using information freely available on Dublin Port’s website through their vessel booking system. This also allowed for a cross checking of arrival and departure times with the Marine Traffic data which was found to be consistent. Finally, vessel specific information for each call

including size, draught, length and operator was obtained from Clarksons Shipping Intelligence Network and matched with the data set. In total the dataset consists of an unbalanced panel of 1765 port-calls. To facilitate modelling, we treat each individual vessel as a decision maker.<sup>24</sup> Statistics regarding the distribution of vessel calls by terminal are presented in Table 5-2.

Table 5-2 Distribution of Vessel Calls by terminal

Terminal Name	Vessel Calls	Average draught of Vessel (meters)	Average loa of vessel (meters)	Average turnaround-time of vessel	Average teu of vessel
Belfast	313	7.6	139	1.0	882
Cork (Tivoli)	210	7.6	142	1.1	911
DFT	351	7.6	145	1.2	949
MTL	379	7.7	141	0.8	929
Portroe	276	7.6	132	0.9	783
Warrenpoint	134	5.9	107	0.8	442
Waterford	104	7.3	140	0.6	807

In modelling alternative service provider’s preferences for routing through a particular terminal, it is assumed that choices are made primarily based on the indirect utility derived from observed and unobserved attributes of the terminals as nodes in the maritime logistics network. As discussed in the previous section, while RP approaches provide significant opportunities to model actual preference structures, the trade-off is that in undertaking a purely RP approach the researcher is restricted to attributes that are directly observable. That said, using the AIS data in combination with publicly available terminal information it is possible to create an array of attribute measures as displayed in Table 5-3 and discussed below:

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<sup>24</sup> It is preferable to model choice at the service rather than vessel level as it better approximates the actual decision process. Based on available data however it is not possible to identify each unique service. Using disaggregate data in this manner is common in freight demand modelling, for example Anderson (2009) and Steven and Corsi (2014) both use disaggregate shipment data to infer the probability of a port being chosen. An advantage of the current approach is that through using vessel level data we can exploit the panel data nature of the data to capture information regarding unobserved heterogeneity from the repeat nature of vessel calls.

## *Congestion*

Congestion occurs when input into the terminal system exceeds capacity to convert such inputs into outputs. In the terminal context this can occur from input entering from the landside using intermodal transport sources (in the Irish context primarily trucks), or the waterside from vessels. In this study and given the nature of the data set, only marine side congestion is considered. While this is potentially a weakness, it is argued that congestion occurring from landside operations will also affect marine side operations. As such, each component is not independent.

It is necessary for each choice situation to have a measure of the level of congestion of each alternative  $j$  relative to alternative  $i$ . Previous measures of congestion in revealed preference studies have tended to use aggregate measures. For example, Steven and Corsi (2012) use the total number of container calls to berths as a measure of congestion. These studies fail however to account for intermitting periods of congestion related to distribution of arrival times of vessels. In particular, and as will be discussed in detail in the results section, demand for LoLo markets in the Irish market is greatest in line with the working week and as such congestion tends to occur at the start and end of the week. Measuring congestion in an aggregated way fails to account for the delays faced by shipping lines at varying points in times across the week. To create a marginal measure of congestion capable of accommodating differing periods of congestion, the indicator was measured as the number of vessels in the system at the time of choice  $k$  relative to total possible capacity. Congestion occurs when the number of vessels in the system approaches or exceeds the capacity limits. Capacity was measured as function of the number of berths and average gross tonnage of vessels served over the year. This allows for the normalisation of the congestion irrespective of the size of the

terminal (for example 3 vessels in a terminal with 4 berths is less of an issue of 2 vessels in a terminal with 2 berths). The final congestion attribute was measured as follows.

$$C_{it} = \frac{\sum_{j=1}^n GT_{jit}}{B_i(GT_{avgi})} \quad (9)$$

$C_{it}$  represents the measure of congestion in terminal  $i$  at time period  $t$ .  $GT_{jit}$  represents the Gross tonnage of vessel  $j$  in terminal  $i$  in time period  $t$  summed over the  $n$  vessels in the system. Finally  $B_i$  represents the number of berths in terminal  $i$  with  $GT_{avgi}$  representing the average gross tonnage of vessel type served in terminal  $i$  for 2016. As represented therefore, congestion occurs when the total Gross tonnage currently in the system approaches or exceeds regular capacity limits. A higher observed congestion measure at peak times will on average contribute more negatively to the probability of a carrier choosing a port compared to a higher observed congestion measure at off-peak times<sup>25</sup>.

### *Terminal Reliability*

From the available data it was possible to isolate ship turnaround time, a commonly used measure of port performance (Slack et al., 2018). While turnaround time can provide a useful benchmark for measuring performance development in a single port setting, it is potentially unreliable as a benchmark across terminals. Turnaround time is heavily contingent on the size of the vessel and requirements of the customers, in addition to the efficiency of the terminal operator. Therefore, the absolute length of time involved in a ships stay in port is likely to vary

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<sup>25</sup> A further measure which is common with AIS data is time at anchorage which can approximate waiting time off berth. At the time of writing this data was not available to the author and thus not included in the modelling exercise. As discussed in Stephen and Corsi (2012) however, this measure is likely to be highly correlated with any other measure of congestion, therefore would have to be included as a composite measure or used instead of the existing measure due to issues of collinearity.

contingent on the particular service being catered for. Reliability of service production is often a better measure for examining the efficacy of service provision for meeting customer requirements. Anderson et al. (2009) used schedule reliability as a key performance indicator in his study of US ports. Container or liner services typically operate on fixed schedules and as such rely on consistent performance to optimise their operations. Consistent deviation in turnaround times is therefore a good indicator of poor performance.

Brooks (2016) discusses reliability and how to measure it in terms of port stay. The author recommends the use of the buffer time index. The Buffer Time Index (BTI) represents the extra time (or time cushion) that travellers must add to their average travel time planning trips to ensure on-time arrival. As such, the BTI is a normalised measure that is consistent across port settings. In calculating the BTI for particular terminals it was noticed however that where multiple services were serving a single terminal, variances in the average turnaround between services was having an impact on the measure. For example, where one service is a direct call to Rotterdam from Dublin, such a call would consistently stay longer in port than a service that called to multiple ports on the way to Rotterdam. The result of this variance across service types is that in terminals that serve multiple types of liner routing structures (point to point, circular, etc.) the BTI is skewed when calculated at the aggregate level. To account for this, a new measure was introduced, where individual BTIs were calculated for each regular service. The individual BTIs for each service were then aggregated using a weighting function based on the proportion of total calls a particular service accounted for. This new measure, referred to here as the *BTI liner*, is specified as follows:

$$BTI_{liner\ i} = \sum_{i=1}^n w_n \left( \frac{\left( \frac{90th\ percentile}{turnaround\ time\ i} \right) - \left( \frac{Average}{turnaround\ time\ i} \right)}{Average\ turnaround\ time\ i} \right) \quad (10)$$

Where  $w_n$  represents the weighting function specified as follows:

$$w_{ni} = \frac{number\ of\ calls\ j}{\sum_{j=1}^n number\ of\ calls\ j} \quad (11)$$

Here *BTI liner* for terminal *i* is calculated as the weighted sum of all regular service calls *j*. The *BTI liner* was compared with the aggregated measure of BTI and found to perform consistently between as an explanatory variable in estimation. In addition, while it would be desirable to include other revealed performance measures of performance such as crane lift rates, incidence of cargo damage, truck turnaround time and preferably some perception based measures, the scope of measures possible were restricted by the availability of data. As such terminal reliability as measured by the *BTI liner* variable was the only performance measure in the study.

#### *Size of vessel capable of Being Handled*

The size of ship capable of being handled by a terminal is an important consideration for carriers when choosing to run a service through a given terminal (Martinez and Feo Valero, 2016). The size of vessel capable of being handled is determined by the physical dimensions of the terminal, including depth of water alongside and in the channel, the length of berth and turning basin. This creates a difficulty in measurement in a revealed preference study as each component is measured on a different scale, for example, berth length (00's of meters) and depth (0's of meters). Choosing a measure or combination of measures that accurately accounts for the relative capability differences between terminals is not necessarily straightforward (Anderson, 2009). To avoid issues of taking multiple measurements of the same variable a simple index was constructed. Here terminals were measured by the percentage of total calls

in 2016 that each port was capable of receiving based on maximum vessel size capable of calling at the port, delimited by allowed depth and length overall. This measure is denoted as the Vessel Size Index (VSI). *Geographic Location*

Proximity to market is a key variable that will affect the probability of a terminal being chosen. Distance creates costs across the chain. Therefore, a terminal that is ‘ceteris paribus’ further away from market is less likely to generate the level of traffic to sustain a container call. Proximity to market can be further subdivided into distance to inland market and distance to offshore market. To measure accessibility from the offshore and inland perspective, a standard accessibility measure common in the regional economics literature is employed (see Vega and Reynolds-Feighan (2016) for more information). The measure is specified as follows:

$$A_i = \sum D_j f(c_{ij}) \quad (12)$$

where  $A_i$  is the accessibility of the node,  $D_j$  is a measure of opportunities and  $f(c_{ij})$  is the impedance function between origin destination pairs. For the impedance function a standard distance decay function was employed. The use of a distance decay function allows for a higher weighting between origin destination points that are in close proximity. Several different specifications were examined for fit with an inverse squared function found to fit the data for both indexes best.

Proximity to offshore market is measured as the average distance to main offshore markets measured in nautical miles using marine traffic. Different markets weighted by the size of the respective traffic to each market in 2016, as displayed in Figure 5-2, was measured using Eurostat data. Typically, distance in port choice applications would enter the utility function as the distance travelled varying in the context of each journey. We argue however, that decisions to run services are made on the capacity of a route to regularly maintain volume

in a manner that is profitable. As such, it is therefore not an attribute that varies contingent on the journey. This is in contrast to the shipper's perspective where the route chosen is typically the one that minimises transport costs to a destination that is determined by the origin/destination of import/export. This is not the case when considering the routing of a vessel from the carrier's perspective. Furthermore, it is argued that by allowing the distance to vary for each choice context, it would change the conditioning by which the probability of choosing a terminal is calculated. For example, if there are two services with one running to Rotterdam and one running to Antwerp, the conditioning of the choice probability becomes the probability of choosing a terminal conditional on the service running to Antwerp in one instance and Rotterdam in the other.

The proximity to hinterland market enters utility in the same manner as proximity to offshore markets as a fixed attribute. To measure hinterland access, road distances from each administrative district on the island of Ireland to each respective port were measured in average journey time. To account for different market sizes, distances were weighted using population in each district. While it would be preferable to use micro data on volume of imports and exports per region, this data was not available at the required regional unit of analysis.

#### *Variables not directly measured*

As per Table 5-2 and Martinez and Feo Valero (2016), there were a number of port attributes not explicitly measured in this study. It would have been desirable to measure additional effectiveness variables such as equipment/stevedore availability, incidence of cargo damage and customs clearance times but such measures were simply not available in a manner that allowed for comparison across terminals in a reliable fashion. Another variable omitted was a measure of port charges or monetary cost of using the terminal facilities. While vessel dues were publicly available for several ports, vessel dues, as leveraged by the port authority, are

typically a small proportion of total charges, with the bulk of port costs consisting of terminal handling charges. To explore further the potential for obtaining values for port charges, informal interviews were held with industry professionals. From these interviews it was ascertained that the contractual arrangements that determine these charges are often complex, incorporating bonuses for repeat business and discounts for stipulations that ensure minimum volumes of trade over a stated period (typically a year). Such arrangements are commercially sensitive and make creating objective measures of port charges, without resorting to survey methods, infeasible. Table 5-3 provides the summary values for all terminal attributes.

Table 5-3 Summary statistics of terminal attributes by port

Terminal	Congestion	Reliability (BTI)	Vessel Size Index	Distance to offshore markets index Score	Distance to hinterland markets index Score
Mean (Standard Deviation)					
Belfast	59% (32%)	0.53days (FA)	99% (FA)	21.6 (FA)	173.2 (FA)
Cork (Tivoli)	26% (29%)	0.25 days (FA)	90% (FA)	29.4 (FA)	144.2 (FA)
DFT (Dublin)	64% (40%)	0.40 days (FA)	99% (FA)	28.9 (FA)	237.1 (FA)
MTL (Dublin)	38% (35%)	0.67 days (FA)	100% (FA)	28.9 (FA)	237.1 (FA)
Portroe (Dublin)	23% (24%)	0.50 days (FA)	93% (FA)	28.9 (FA)	237.1 (FA)
Warrenpoint	10% (19%)	1.6 days (FA)	42% (FA)	24.9 (FA)	54 (FA)
Waterford	6% (16%)	0.35 days (FA)	65% (FA)	33.05 (FA)	27 (FA)
Overall Network	32% (36%)	0.59 days (.42)	84 % ( 20%)	27.6 (3.2)	158.1 (82.1)
<ul style="list-style-type: none"> <li>FA refers to a terminal specific fixed attribute that is invariant across choice situations</li> </ul>					

## 5.6 - Results

Three models were estimated as displayed in Table 5-3. First, the standard conditional logit (CL), second, a random parameters logit panel model (RPL), and third, an RPL model which includes interaction terms to examine observed heterogeneity around the mean parameters for several variables (Hensher et al., 2005). In specifying the two random parameter models all parameters were treated as random normally distributed variables. As per Hensher et al. (2005), owing to the non-linear transformation involved in the calculation of choice probabilities there

is no straight forward behavioural interpretation of the estimated parameter coefficient in logit results. The significance and sign however can provide some insight into how attributes on average are effecting choice probabilities (either positively or negatively). In addition, the properties of the RPL allow for the representation of heterogeneity around the mean of the coefficient scores, thus allowing for some inference on the degree of taste heterogeneity across the sample. Three further interaction terms are included in the final RPL model to examine the extent to which taste heterogeneity can be explained by observable carrier specific variables.

Table 5-4 Model Parameters

		CL	RPL	RPL with Interactions
Congestion	Mean of Coefficient	-.012 (.001) ***	-.020 (.002)***	-.010 (.004) ***
	Std. Deviation		.008 (.004) **	.039 (.009) ***
BTI	Mean of Coefficient	-.006 (.002)**	-.142 (.012)***	.142 (.073)*
	Std. Deviation		.226 (.013)***	.196 (.018)***
VSI	Mean of Coefficient	.019 (.006) ***	.264 (.030)***	-1.04 (.111) ***
	Std. Deviation		.283 (.015)***	.479 (.025) ***
Accessibility to Offshore markets	Mean of Coefficient	-.067 (.012)***	-.506 (.042)***	-.988 (.290)***
	Std. Deviation		.172 (.052)***	.793 (.048)***
Accessibility to Hinterland markets	Mean of Coefficient	.005 (.001)***	.110 (.004) ***	.043 (.004) ***
	Std, Deviation		.091 (.004)***	.057 (.003)***
Heterogeneity in mean parameters/interaction effects			Access Offshore: CMIX	.748 (.328) **
			Access Offshore: Dumhub	.355 (.080)***
			VSI: Draught	.128 (.014) ***
			BTI: Draught	-.027 (.011)
			BTI: Dumhub	-.067 (.016)
			***	
Log Likelihood		-3098	-1258	-1279
AIC		6206	2536	2588
Pseudo R <sup>2</sup>			.634	.627

\*\*\* indicates significant at the 1% level. \*\* indicates significant at the 5% level and \* indicates significant at the 10% level. Dumhub is a dummy variable measuring whether the call is to a hub port

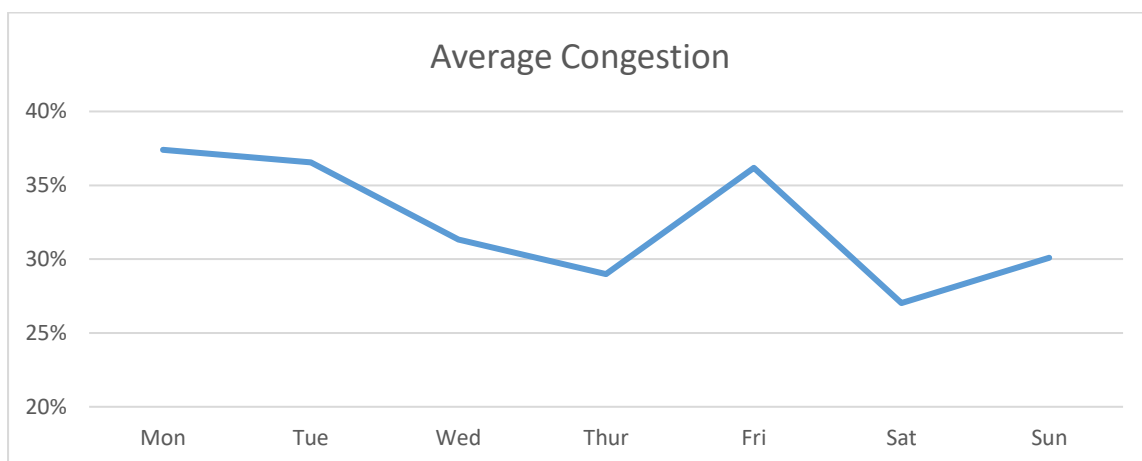
As shown in Table 5-3, the congestion measure is both significant and of the expected sign across the models. The significance of congestion has important implications for capacity development. Examining average congestion per day for the year across the network in Figure 5-2 provides insight into how congestion effects demand in the network. In particular, the distribution shows the effects of peak demand. Congestion is greatest at the start and finish of the working week. Speaking to industry professionals, this seems to be largely related to the need to accommodate the demands of importers and exporters particularly in regards to just in time production. It is interesting to contrast this result with capacity when calculated on an annual basis.

For example, in preparation of its masterplan (2012-2017), Dublin Port Company completed LoLo requirements analysis. Based on its high watermark of traffic in 2007, the port calculated that capacity was at 67%. In 2016, yearly capacity utilisation of container terminals has dropped to just over 60%. The results of the model however suggest that while the average traffic in a given year may be below total capacity, in a given week, terminals will intermittently reach full capacity. As such, congestion may occur resulting in suboptimal market clearance as shipping lines, who may wish to call into, for example, Dublin on a Monday, are unable to do so as the port is full. This may have effects for how the system deals with demand in the future. Either port terminals need to find a way to spread out traffic distributions across the week, or shipping lines need to use larger ships to accommodate increased demand.

Examining the remaining coefficients first for the CL and the basic RPL, VSI, BTI and hinterland accessibility are consistently significant and of the expected sign. Notably sea distance to foreland markets has a negative effect on probability in both models. This is counterintuitive as it would be expected that the sign would be positive as more proximity (a

higher score) would indicate better accessibility and as such, better capability to provide value to the logistics chain on average. Two possible explanations are proposed to explain this result. Firstly, when examining attribute scores across terminals offshore, accessibility for ports on the south coast have relatively better scores than terminals in Dublin, which, given Dublin’s market share, appears to affect the sign of the coefficient. In contrast, Dublin’s hinterland accessibility is far better (represented by a lower score) than any port in the country. Dublin has a favourable position as the nexus in the motorway system which following upgrading in early 2000s has further boosted its accessibility to other major population centres, relative to other ports (Vega and Reynolds-Feighan, 2016).

Figure 5-3 Arrival Patterns



Examining the breakdown of Irish trade, there is an imbalance between imports and exports with imports accounting for a higher percentage of total trade in volume terms, relative to exports. This is recognised by Intertrade Ireland (InterTradeIreland, 2008) who cite the combination of such factors as leading to increased centralisation of inventory amongst logistics service providers in the Greater Dublin Area (GDA) (Inter-trade Ireland, 2008). Thus it is likely that the benefits of distance to major sea markets are relative to the type of traffic that a port can attract. To test this, an interaction term (CMIX) is included in the final RPL

model. CMIX measures the ratio of imports over exports in a given port by month (which acts a proxy for the type of traffic the port can attract).

The second explanation relates to the manner in which the variable is measured. As shown in figure 5-2, traffic from Irish ports mainly serves hub ports in the Netherlands, Belgium and hub port in South East Great Britain. Weighting the index in terms of traffic calling to respective markets creates an index that largely reflects distance to hub ports as the majority of traffic serves these ports. There is however, a smaller but still significant amount of short sea traffic that calls from Irish terminals to ports in North East Great Britain, particularly from Northern Irish Ports. For carriers serving these markets therefore, access as measured would be unlikely to capture their preferences. To account for this potential source of systematic heterogeneity a dummy variable measuring whether the call is to a hub port (referred to as Dumhub) is interacted with the offshore access score.

Including interactions allows for the re-parameterisation of the mean to account for systematic sources of variance. It also affects how the marginal utility of a given attribute enters into the overall choice probability. Specifically, marginal utility for offshore accessibility becomes:

$$MU_{offshoreaccess} = -.988 + .748 * CMIX + .355 * Dumhub + .793 * N$$

where 0.04 is the standard deviation and N is the normal distribution. The effect of the interaction is therefore that as the ratio of imports over exports increases in a given port, the marginal utility from better access to offshore markets as indicated by a positive sign will increase. Similarly, as a carrier serves a hub market, her utility from closer proximity to offshore markets increases.

As outlined above, in interpreting the results of the RPL model, the mean coefficient must be interpreted in conjunction with the standard deviation coefficient. Focusing on the first RPL model there is significant heterogeneity across all parameters as evidenced by the significance of the standard deviation coefficients. The implication of this is that across the carriers sampled, there is variation in the relative level of utility gained or disutility tolerated from each port attribute. Examining the magnitude of the standard deviation relative to the mean coefficient allows for inference into the degree of unobserved heterogeneity present in the sample (Hynes et al., 2008). It can be seen that heterogeneity appears to be greatest surrounding preferences for the size of vessel capable of being handled index (VSI) and reliability.

Firstly, examining the VSI, the parameter is interacted with the draught of the vessel to examine how preferences change as the size of the vessel utilised increases. The mean of the coefficient switches sign, but becomes positive as vessel size increases as indicated by the sign of interaction term. A positive interaction variable is to be expected, as larger vessels naturally require larger depths. In this way as the vessel size utilised increases, the VSI score of the port should become more significant.

BTI is also interacted with draught and a dummy variable accounting for whether the carrier is serving a hub port as with the offshore access score core above. Similar to the VSI result, above the sign of the mean parameter switches (and loses significance) but becomes the expected sign when vessel size increases and carriers serve hub ports. Specifically, in the Irish context the former interaction coefficient indicates that carriers when serving hub ports place a higher value on reliability than vessels serving NW UK ports. An intuitive explanation for this result is that such carriers have an increased reliance on schedule integrity as carriers need reliability to maintain slots. For routes across the Irish Sea to NW UK ports a delay in port is

likely to be less costly, as a shorter crossing time allows for more flexibility in maintaining schedule integrity. Similarly, NW UK ports are likely to be less congested than major hub ports, making missing a slot less costly. Similarly, vessels running to hub ports tend to be larger, as the increase in journey time favours the use of larger vessels to achieve economies of scale. Larger vessels are more costly to run and it is more difficult to achieve capacity utilisation in a small market such as the Irish market. Reliability of performance is therefore more valued when schedules have to be kept in order to achieve value, particularly on loop calls that call to a number of feeder ports. Finally, while the inclusion of the interaction effects have served to explain some heterogeneity, it is notable that there is still significant taste variation evidenced by a still significant standard deviation coefficient for all variables. This indicates a failure to account for heterogeneity through introducing systematic variation with available carrier specific information.

Examining the model fit, there is a clear improvement in explanatory power from the CL to the basic RPL as seen by the log likelihood values, the pseudo  $R^2$  and the AIC statistic. The likelihood ratio test statistic of 3680 with five degrees of freedom, indicates that it is possible to reject the hypothesis that the basic RPL is not a statistical improvement on the CL at the 99% confidence level. Notably, there is no improvement from the basic RPL to the RPL model with interactions as indicated by the log likelihood value, the pseudo  $R^2$  and the AIC. This is despite the RPL model with interactions containing extra parameters. Thus, for the purposes of simulating scenario's in the next section, the basic RPL model is preferred as it the model that best fits the data.

### *Scenario Simulations*

Following Brownstown and Train (2000), substitution patterns between alternatives in the sample can be examined through simulating events using the outputs from the model

estimations. As set out in the Introduction, there are a number of scenarios that may result in potential disruption to the overall demand for traffic across the port network. Firstly congestion in Dublin terminals presents a potential risk factor given the ongoing rise in traffic through Dublin. As the significance of the measure of congestion illustrates, on average Dublin's terminals are not congested. However, when peak times are factored in, capacity during busy periods is starting to be tested. Speaking to industry professionals, this is particularly a concern for importers/exporters who rely on delivery of goods tied to the working week. In addition, there is scheduled to be significant construction within the port over the coming years, which is likely to have temporary effects on capacity over the period. Scenario one therefore simulates the effect of an increase in congestion (to the maximum amount) in Dublin's two largest terminals DFT and MTL on the number of vessels calling to the various terminals on the island.

A second major development is the movement from the Port of Cork to a new deep water terminal in Ringaskiddy. Scenario two simulates the likely effect of an increase in the VSI score of the port of Cork on the probability of port calls across the network. Scenario three updates scenario one to examine the joint effect of an increase in the size of vessels capable of being handled in the port of Cork given congestion in Dublin's two major terminals. Scenario four examines the likely effects of Brexit and the imposition of a hard border between Northern Ireland and the Republic of Ireland. To test this, the accessibility to hinterland market measure was adjusted for Northern Irish ports with a 27.1 minute delay added to all destinations in the south, with the opposite done for ports in the Republic. The time of 27.1 minutes was chosen, as it represents the maximum average wait time of three sampled crossings on the US and Canadian border as estimated by Gingerich and Maoh (2017), and as such, represents a good approximation to a worst case scenario.

Scenario simulations were completed using Nlogit’s Simulation function with results displayed in Table 5-4. In scenario one, where there is an increase in congestion in Dublin’s two largest terminals there are significant reductions in choice probability for the affected terminals. Portroe has the largest increase in choice probability while there were also a significant increase in the probability of choosing Belfast and a less significant gain in the probability of choosing Cork. Portroe, as the terminal in closest proximity, would be expected to increase the most as it is almost directly substitutable. In scenario two, an increase in VSI score improves the attractiveness of Cork. Interestingly, in scenario three, Cork now has the second highest probability of being chosen given congestion in DFT and MTL. Finally in the Brexit scenario there is limited change in choice probabilities. It is worth noting that the scenario simulations are conditional on the existing sample of vessel calls. As such, it only accounts for changes in port attributes. It cannot therefore factor in likely changes in carrier behaviour such as adaptation in ship size.

Table 5-5 Results of Scenario Simulations

Terminal	Base Case	Scenario 1 – Congestion in DFT and MTL*	Scenario 2- Development of Ringaskiddy Terminal	Scenario 3- Scenario 1 and 2 combined	Scenario 4 – Re-imposition of hard border
Probability of carrier choosing a given Terminal					
Belfast	18%	24%	16%	21%	18%
Cork	16%	19%	22%	27%	17%
DFT	26%	7%	23%	4%	26%
MTL	17%	7%	17%	7%	17%
Portroe	15%	35%	15%	34%	15%
Warrenpoint	4%	4%	4%	4%	3%
Waterford	4%	4%	4%	4%	4%

\*Dublin Ferry Terminals (DFT), Marine Terminals Limited (MTL)

Interpretation of the simulation results allow for insight into the structure of demand and substitutability across the network that can inform future capacity planning in the Irish context. The significance of the congestion variable indicates that congestion has an effect on the probability of a carrier choosing a terminal across the sample. Simulating the effects of an increase in congestion therefore, provides insight into substitutability across nodes given congestion. When examining the results of scenario one and three, two pertinent findings are evident. Firstly, for substitution purposes the VSI is a highly significant variable. In scenario one the terminals that provide equivalent VSI score (Belfast and Portroe) are those that are most likely to benefit from increased congestion in DFT and MTL. This is further evidenced by the relative choice probability between scenario one and three for the Port of Cork, highlighting the importance of the Ringaskiddy development for the future relative competitiveness of the port of Cork in comparison to Dublin in this sector.

Secondly, consistent across both scenario one and three, is the relative increase in Portroe in comparison to Belfast in scenario one and in comparison, to Belfast and Cork in scenario two. This is intuitive, as Portroe is the terminal in closest proximity to MTL and DFT. In addition while reliability and VSI score can be improved at other terminals, the relative hinterland access of terminals in Dublin port is determined by the ports geographic location and the structure of the motorway network. Barring a major shift in the distribution of population or structure of the road network the relative opportunities from routing a vessel through terminals based in Dublin will remain higher in terms of attracting cargo based on hinterland distance. This is consistent with the results of Chang et al. (2008) and Chou (2010) who both find that the size of the local economy are the most important factors influencing port selection along regional, feeder or shortsea operators.

Finally, under scenario four, the model predicts little change following the re-imposition of a hard border. This indicates that changes in travel times from one jurisdiction to another are unlikely to affect the nature of demand for port services in the respective terminals. The Dublin terminals, Belfast and Cork Tivoli, all serve relatively large immediate hinterlands, as they are located in the three largest metropolitan areas. The majority of their hinterland accessibility scores are therefore generated by each relevant population base. A changing access to relatively distant markets does not majorly affect their scores as measured. Work done by Dublin Port Company and the Port of Cork as part of their respective master planning, would support this. Dublin Port Company found that 60% percent of their total traffic comes from within 80km of the port. While the Port of Cork found that 94% of all trips from Tivoli container terminal stay within the Munster region where the port of Cork is located (Port of Cork, 2010).

## 5.7 - Discussion and Conclusions

This study presents a novel application of port demand modelling using AIS data to examine behavioural patterns affecting demand for port services. It is also the first application of a discrete choice modelling approach to the LoLo sector in Ireland, adding to prior studies on the RoRo sector (Mangan et al., 2002; Breen et al., 2016; Vega and Valero, 2018). In addition, through focusing on a feeder and short sea network, the study represents an application to a type of port network that has been relatively underexamined in the wider literature.

The results have several implications for policy. In particular, they demonstrate the importance of factoring in peak demand in examining the effect of congestion on port choice across the network. The simulations also indicate the importance of hinterland accessibility in determining port choice. Interestingly from a policy perspective the results suggest that an increase in the VSI score can increase the substitutability of a given terminal. There is no reason

to suggest that if a sufficient gap exists between dominant and less dominant nodes in terms of reliability that substitutability would similarly be improved. It is worth noting however, that substitutability is likely to be a function of having the right mix attributes, with the relative benefit of increasing a particular dimension in isolation unlikely to significantly improve substitutability (so for example improved reliability with a poor VSI score).

The major contribution of the chapter is in demonstrating the potential of port choice modelling using AIS data. The data is particularly useful as it allows for a full set of terminals to be surveyed relatively easily. The data also provides a means to create measures for all terminals including the congestion and BTI scores in a consistent manner using a single source of data. In this way, the approach has the potential to create a means to model demand that is highly replicable across jurisdictions. In addition, the relative improvement of fit from the conditional logit to random parameter logit show the importance of relaxing the IIA assumptions and allowing for full substitution and taste heterogeneity both across alternatives and over time.

Despite this however, the chapter has a number of limitations mainly caused by restrictions due to data availability. Most prominently, it was not possible to identify unique services. Therefore, assumptions were made to model choice probability at the vessel rather than service level. Identification on services would allow the researcher to capture unobserved heterogeneity associated with individual decision makers, thus improving the predictive power of the model. In addition, the data only included information on port calls to Irish ports. With further data on onward calls it may be possible to identify the full network. This would potentially mean one could model route rather terminal choice, which again would perhaps be a better approximation to the actual decision making process. Furthermore, as discussed in

Section 3, the study is limited by the attributes that could be included in the model, which is indicative of the use of purely RP data.

A common approach toward alleviating these issues is the ‘data-enrichment paradigm’, where SP data is collected and used in parallel to RP data to facilitate improved attribute trade-offs between alternatives (Hensher Rose and Green, 2015). Joint RP/SP approaches are common in the wider literature on demand forecasting and present an interesting avenue for further research in the port context. Additionally, while we introduce several new measures of constructs such as congestion and reliability, it is important to note that such measures may be improved in the future particularly as the use of AIS data becomes more prevalent.

A final issue evident from the results is the degree of preference heterogeneity. In the RPL model with interactions several vessel specific variables were interacted with the attributes, however they do not necessarily explain all the heterogeneity observed across the sample. Further vessel specific information, in particular the type goods regularly served on routes may go some way to alleviating this issue. This data was unavailable at the time of this study. It may however, become available at a later point. The use of richer vessel level information in combination with experimentation with alternative model specifications such as the latent class model could potentially shed further light on the nature of heterogeneity across the sample. These issues, while limitations, also indicate avenues for future research. The study demonstrates the potential of the role of discrete choice analysis on AIS data and provides a template to follow where new sources of data are available to enrich the policy debate regarding future port capacity planning.

# Chapter 6 - Factors Influencing Strategic Decision-making in Port Capacity Planning: A Case study of the Irish Port Sector

## 6.1 – Introduction

Given the prominence of seaborne trade, the development of port capacity to serve cargo trade is widely recognised as a critical determinant of the capability of regions to trade internationally.<sup>26</sup> It is of national strategic importance that capacity is developed in a timely and appropriate fashion to avoid excessive under (leading to congestion), or over (leading to waste of resources), capacity (Meersman and van de Voorde, 2014).<sup>27</sup> The provision of port capacity depends on timely and appropriate port development, which in turn relies on the appropriate management of port infrastructure. PAs are most often the bodies responsible for strategic planning of port infrastructure (Vonck and Notteboom, 2016). In planning capacity therefore, the Port Authority (PA) must choose a course of investments to ensure that the port has sufficient capability to match supply with demand in a manner which is sustainable (Dekker and Verhaeghe, 2006; Bichou, 2014).

Within the literature on port capacity planning the rate of capacity growth is most frequently evaluated as a function of matching physical capacity to future demand. Examining capacity development frequently entails optimisation of an objective function to find optimal investment or expansion levels with specified parameters, often incorporating factors such as uncertainty and social welfare requirements (see Chang et al. (2012) and Zheng and Negenborn, (2014) for recent reviews of this literature). Alternatively, systems and simulation

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<sup>26</sup> The effective throughput capacity of a port system is the maximum amount of any given input that can pass through the system over a given period of time (eg. a year or a week etc.), whilst maintaining a minimum level of service (Bassan, 2007; Taneja, 2013).

<sup>27</sup> The natural cycle of port development with additions in capacity necessarily occurring in a lumpy rather than continuous fashion, prevents port systems from ever truly attaining efficiency with supply perfectly matching demand. Instead port systems will inevitably exist in a flux between under and over capacity (Sánchez and Wilmsmeier, 2010).

approaches have sought to replicate conditions in port systems to investigate current and theoretical capacity levels, often testing for the presence of performance attributes such as congestion (for a recent review of this literature see Dragović et al (2017) .

Such treatments of port capacity provide important adjuncts to decision making and are in keeping with the classic treatment of capacity expansion problems for production facilities within the wider operations literature (Luss, 1982; Dekker and Verhaeghe, 2008). Regarding port capacity expansion however, empirical examinations, most notably Dooms et al. (2013), show that in planning future infrastructure, PAs must also take into account complex stakeholder relationships in delivering long term value from port infrastructure. Ports are generally comprised of many physical elements but also many different and often conflicting agents (e.g. terminal operators and local community groups), with ports characterised as complex socio-technological systems (Bekebrede and Mayer, 2006).

PAs must rely on coordinated action from multiple private and public stakeholders which are often in conflict (de Langen, 2006; Francesco Parola and Maugeri, 2013). Decisions on developing port infrastructure must therefore factor in more than just the development of physical infrastructure but also the relationship between the range of stakeholders who combine to make a port function, encapsulated in the port ecosystem concept. In the long term, therefore, port capacity is not only likely to be determined by how well the Port Authority manages the growth of physical infrastructure but also the growth of the functioning of the wider port ecosystem.

In addition, ports as nodes embedded in the wider transport and economic system are typically subject to dynamic environments which makes predicting the future economic value of an investment uncertain over an extended period of time (Bekebrede and Mayer (2006) state

anywhere over five years).<sup>28</sup> Taneja (2013), illustrates several examples where changing market structure and demand forced ports to incur high adaptation costs following large scale infrastructure investment.

In planning infrastructure, PAs must therefore allow for the potential for the economic value of an investment to change and accommodate the risk of a chosen investment not achieving intended results (Martins et al., 2017). Notteboom (2016) argues that to maintain competitiveness, ports in a dynamic setting must develop adaptive capacities to respond to external shocks and hazards as well as take advantage of opportunities as they arise. Notteboom (2016) proposes, that ‘Antwerp and Hamburg have been able to remain competitive vis-à-vis rival ports (despite the significant nautical access challenges both ports are exposed to) by developing strong adaptive capacities combining technological, financial and human resources and a strong political and institutional setting’. Parola et al. (2016), similarly argues that a port’s sustained competitiveness in a dynamic environment is a function of the port community’s ability to grow resources and capabilities over time.

Building from such observations, it is proposed presently that in achieving an appropriate match between the demands of the freight market and the supply of port services, PAs in practice must not only consider tangible resources related to physical capacity such as quay walls and cranes, but also intangible resources such organisational capabilities and stakeholder buy-in. Therefore, when considering future capacity provision, performance (i.e, maintaining appropriate balance between over and under supply), and the creation of sustained value is a function of the capability of PAs to successfully develop a wide variety of resources and capabilities.

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<sup>28</sup> This presents a major challenge as port infrastructure by its nature (high cost and long lead time), favours investment at scale for the purposes of cost efficiency (Dekker and Verhaeghe, 2006). In a dynamic environment however, investing at scale carries increased risk.

The objective of this chapter is to explore this proposition through examining what PAs consider from a strategic perspective when they look at the long term supply of capacity to freight markets. To achieve this, an exploratory case study is carried out in the Irish state owned port sector, where the decision to develop capacity is examined with senior executives in Irish PAs. To facilitate this enquiry, key concepts from the strategic management literature are evoked to reconceptualise the capacity planning process as a capabilities search problem. The purpose of this conceptualisation is to provide a strategic framework to analyse decision making regarding capacity planning across organisations. Using the concepts introduced, assertions of senior executives are examined to identify the key capabilities required to supply capacity sustainably in the Irish context. Existing decisions on capacity development are then examined as a function of developing identified capabilities, to explore how Irish PAs make strategic decisions on investment measures to supply capacity in the long term.

The findings from the Irish case show that in supplying capacity, PAs must respond to a wide variety of challenges associated with both the freight market they are serving and restrictions on future supply, accruing to the ports institutional and operating environment. The findings as such, have practical implications for how matching capacity in port strategic planning is viewed. Namely, in considering long term capacity, all required resources and capabilities must be considered. Future capacity development for any given market is largely influenced by the criticality of particular capabilities in a given context, as determined by the opportunities and challenges in developing such capabilities, in supplying future capacity. What determines the rate of capacity development in individual ports systems therefore, is largely context contingent.

## 6.2 - Case description: the Irish State-owned ports sector

Republic of Ireland state owned ports were commercialised under the Harbours Act 1996.<sup>29</sup> The objective of the Act was to remove some of restrictive barriers inhibiting the harbour companies and to encourage competition by allowing the newly formed port companies to operate in a commercial manner (Mangan and Furlong, 1998). Since the passing of the Act the governance style of the state had been largely 'laissez faire' in approach until the introduction of National Ports Policy (2013). This set out a long term policy for ownership, governance and future development of state owned Irish ports. National Ports Policy (2013), outlined a strategy to tier state owned ports, based on a combination of their throughput, market share and capability to provide capacity for future growth to serve the national interest. Tier 1 and 2 ports were classed as ports of national significance and are to be retained under full state ownership, while Tier 3 ports of regional significance are to be transferred to local authorities.<sup>30</sup> Through tiering the ports, policy makers are recognising variance in requirements across the ports in terms of governance. The logic underlying the policy is that primary trade flows serving national needs will occur in Tier 1 and 2 ports with sufficient scale achieved to generate efficiencies.

The chosen embedded units of the case study were Tier 1 (Dublin Port, Port of Cork, and Shannon Foynes Port Company) and Tier 2 (Port of Waterford and Rosslare Europort) ports, as all share a common institutional framework in terms of capacity development. As per National Ports Policy (2013), it is specifically stated that Tier 1 are mandated to 'lead the response of the State commercial ports sector to future national port capacity requirements'

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<sup>29</sup> An exception to this is Rosslare Europort which as a result of an historical agreement between the port and the port of Fishguard, operates as a subsidiary of Iarnród Éireann, the state Rail board. It is however, still state owned.

<sup>30</sup> As of time of writing, all remaining PAs have been transferred to local authorities bar the port of Galway which is delayed pending review of the ports development plans.

with Tier 2 also recognised as having a responsibility to develop additional capacity. All future state support for major infrastructure developments will respect this, a position which has been reiterated in the National Development Plan 2040. In addition, the other major policy stance in relation to capacity development, is the maintenance of the prior position of no further Exchequer funding for infrastructure development with National Ports Policy (2013) outlining the view that projects should be funded on a commercial basis.

The objective therefore, is through examining the respective agency of the embedded units in alternative port settings to draw inference as to how contextual factors are affecting the completion of a common mandate to deliver capacity. The respective cargo profiles, market share and shift share since 2000 are represented in Table 6-1. As identified, the scope and scale of operations across the ports is quite varied. In addition, each port across the system is embedded in variant economic, social and physical systems and thus PAs face very different opportunities and challenges in developing capacity (Sánchez and Wilmsmeier, 2010). This is despite a common mandate and system of governance.

Table 6-1 Port Throughput Growth <sup>31</sup>

Port		RoRo	LoLo	Liquid Bulk	Dry Bulk	BreakBulk
Dublin	Tonnage 2016 (000's)	12667	5062	4017	2053	2053
	Market Share	48%	55%	15%	13%	13%
	Shift-share 2000-16	+3540	+106	+1321	+303	-169
Cork	Tonnage 2016 (000's)	84	1889	5430	1435	139
	Market Share	0.32%	21%	21%	9%	10%
	Shift-share 2000-16	-182	+740	+296	-279	-430
Shannon Foynes	Tonnage 2016 (000's)	N/A	N/A	1050	9714	184
	Market Share	N/A	N/A	4%	61%	13%
	Shift-share 2000-16	N/A	N/A	-485	+647	+53
Waterford	Tonnage 2016 (000's)	N/A	279	0	970	76
	Market Share	N/A	3%	0%	6%	5%
	Shift-share 2000-16	N/A	-924	-198	421	-25
Rosslare	Tonnage 2016 (000's)	2133	N/A	N/A	N/A	46
	Market Share	8%	N/A	N/A	N/A	3%
	Shift-share 2000-16	-538	N/A	N/A	N/A	+46

### 6.3 - Theory and Conceptual Framework

#### 6.3.1 - The Capability Search Problem

A capability search problem is a task best associated with the asset/resource orchestration function of management. Asset/resource orchestration theory building from dynamic capability theory, refers to the specific task or function of the manager in the search, selection, and configuration of resources and capabilities to achieve optimal value from firm's assets (Helfat et al., 2009, Barney et al., 2011). Asset orchestration is about putting the firm in a position to implement its competitive strategy by developing necessary capabilities to achieve sustainable value creation. Pisano (2017), specifically deals with the strategic choice set available to decision makers in a capability search problem.

<sup>31</sup> Unitised trades (RoRo and LoLo) market shares are calculated on an all-island basis while bulk is ROI only. Shift shares were calculated using the method of Notteboom (1997).

Pisano notes that strategy makers have a direct role in shaping the accumulation of firm's capabilities by choosing among investments in different types of capabilities. Pisano relates this to product market strategy and in particular to Porter (1985) and the five forces. Pisano argues that competition occurs at two levels, highly visible product market strategy (market entry and market positioning) and less visibly competition to develop capabilities. The two therefore, are intrinsically linked as firms need to develop capabilities to enable them to achieve competitive advantage through employing appropriate product market strategy. In line with Teece and Pisano (1994), Pisano (2017) posits that capabilities arise from a series of coordinated investments over time and as such require a commitment to a path for capability creation.

In recognising the role of path dependency, firms do not have complete freedom to adjust by changing the firm's capability set (Pisano, 2017). Adaption has a cost and the firm is constrained by its current resource position. Pisano however, rejects the idea that capability investment paths are entirely deterministic, i.e. decision making is entirely constrained by past decisions. Pisano (2017), argues that managerial discretion is greatest in the choice of path, ensuring that firms choose to pursue a series of capacity to ensure the long term capability of the firm to generate value. A capabilities search problem is one of deciding how and when to develop capabilities to ensure competitiveness in the long term. In doing so, strategy makers must consider future opportunities and challenges as well as the firms existing capabilities in adopting an optimal strategy.

### *6.3.2 - Conceptual Framework - Reconceptualising Port Capacity planning as a Capabilities Search Problem*

In port capacity planning, the task is to put the port in a position to handle identified traffic requirements, through developing the capabilities required to supply capacity to the market on

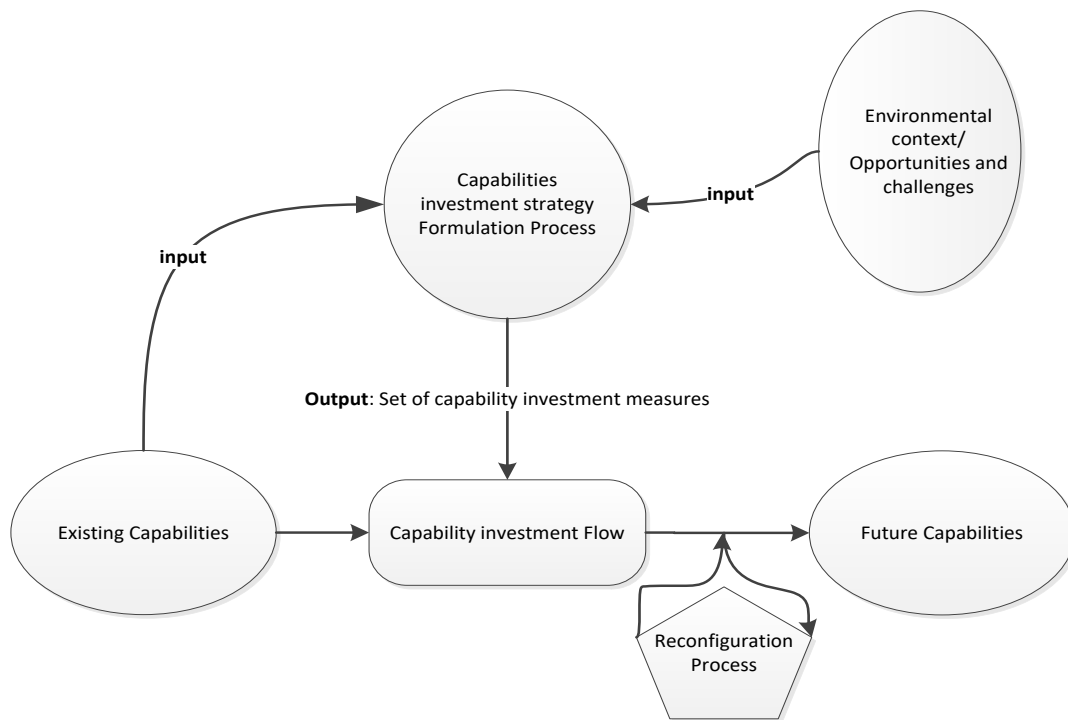
a repeatable basis. The capability of PAs to plan and manage capacity is itself a dynamic capability, easily likened to an asset/resource orchestration function. The strategy to develop specific handling capabilities, it is argued, is equivalent to the search/selection process as detailed by Helfat et al. (2009) and more explicitly (Pisano, 2015; Pisano, 2017). Achieving a match between supply and demand involves ensuring that within the port system the identified capabilities are present to meet future capacity requirements.

The objective of the capacity planner is therefore to position the port to realise value from the port asset through the supply of capacity in the long run. As above, the PA does not have complete flexibility to alter capabilities and must commit to a path for capacity/capabilities development. This is easy to demonstrate given the expense and long lead times associated with port development. A change in direction or adaptation is typically associated with very high costs in both time and money (Taneja 2013). The task of capacity planning, as conceptualised, therefore involves committing to a path for capability development to expand existing handling capabilities where needed to achieve this competitive positioning. This process, as represented in Figure 5-1, involves examining the existing capabilities of the port system in the context of future requirements to choose a course of investments that ensures the port has the capability to meet future demand. This conceptualisation is also consistent with Notteboom (2016)'s framework for adaptive capacity building, where a key component of decision making is the matching of future ambition to current abilities to identify gaps. The unit of analysis in this study is the process by which PA's make strategic decisions to commit to sets of capability investment measures (represented in Figure 5-1 as the output). Investment measures, maybe highly capital intensive such as the expansion of a facility, or less so, such as an organisational restructuring (see Dekker and

Verhaeghe (2006) for review). Therefore, capacity planning is a task of updating or reconfiguring existing capabilities through investment in the stock of capabilities.

To operationalise the framework for application in the case study, it is first necessary to identify what capabilities are critical for PAs to achieve performance in matching supply between supply and capacity for freight markets. As in Pisano (2017), Winter's (2003) definition of a capability as a collection of routines that enable an organization to perform some activity on a consistent or repetitive basis is followed. As such, capabilities identified are akin to ordinary capabilities, defined by Teece et al (2016, p. 19) as those capabilities that 'enable the production and sale of a defined (and hence static) set of products and services'. Essentially, this implies the processes that enable PAs to competitively supply capacity to the market through the leveraging of resources. Pfeffer and Salanick's (1978) determination of criticality is employed whereby the degree of criticality is determined by the capability of the organisation to continue functioning in the absence of the resource or in the absence of the market for its output. As per Pfeffer and Salanick (1978), criticality is also influenced by the availability of the resource, with scarcity or difficulty in obtaining the resource increasing the resources criticality. The first research objective is to identify the type of critical capabilities PAs require in order to position the port to match capacity supply with demand for port services in any given port market.

Figure 6-1 Process of strategic decision making in capacity planning as a capabilities search problem



**RO1: Identify the Critical Capabilities PAs require to consistently achieve performance in the matching of demand with the supply of port services for freight cargo in the long run.**

**RO2: Explore across port contexts how PAs in strategic decision making are responding to respective challenges and opportunities to develop capabilities to serve freight markets.**

Identifying the generic critical capabilities that underpin overall capability to supply capacity for freight markets in the Irish context enables the examination of capacity development across port systems as a function of ensuring that the port has the required capabilities to match demand. This allows for the comparison of the process across port contexts by examining how

port managers are ensuring the port has the required capabilities through strategic choice on capability investment path.

As conceptualised in Figure 6-1, a key aspect of the decision to develop capabilities is how the PA accounts for the relationship between its existing capabilities and the opportunities and challenges facing the port in the future. It is clear from the description of the case in section 2 that ports across the system face different challenges and are responding from different capabilities bases. This leads to the second research objective which is to explore across port contexts, how PAs are responding to respective challenges and opportunities to develop capability bases.

The embedded nature of the port would suggest that this process is particularly important, as consistent with existing evidence and normative theory, port performance is contextual. In particular, Brooks and Balthazar's (2001, 2006) matching framework argues that port performance is a fit between strategy, structure and environmental context. Similarly, evidence on the effect of reform on port performance points to the importance of the contextual environment in affecting the post reform performance (Brooks and Cullinane, 2006; Brooks et al., 2017; Parola et al., 2017). Through addressing the second research objective, the study aims to provide insight into what influences strategic decision making in regards achieving performance in matching supply with demand for port services in freight markets.

#### 6.4 - Methodology

To meet the research objectives a case study approach was chosen as the research approach. George and Bennet (2005) distinguish case study analysis as trying to determine underlying casual mechanisms, while Yin (2013) describes this as the 'How' and 'Why' questions. Case studies involve in-depth analysis of a limited number of cases that enables the examination of more variables than large sample studies. A single case study design with embedded units was

chosen, with the Irish Port sector chosen as the case and state owned ports as the embedded units. Case design and selection is justified primarily on the basis of unusually high access to PAs and policy makers within the Irish State owned Port System, by virtue of the author's position within a government agency. Thus, akin to Dutton and Dukerich (1991)'s famous case study of the New York Port authority, the selection of the case is justified on the basis that it presents an opportunity to reveal insights that are unusual in nature (Eisenhardt and Graebner, 2007; Yin, 2013).

A secondary advantage to the current design is that all ports in the sample have comparative governance and ownership structures. This better enables comparison of strategic decision making as it is done at the same level in each of the PAs. In situations where the governance arrangements and organisational structure of the PA are substantially different, the casual mechanisms that result in development of strategy are inevitably going to be different (for example if capacity expansion was planned centrally with stronger shareholder control). The examination of strategic decision making under common governance arrangements allows for some degree of control of this intervening factor.

#### *6.4.2 - Data Collection and Analysis*

Data collection was completed in a two stage process as follows:

**Stage 1- Identifying the Critical Capabilities PA's require to consistently achieve performance in the matching of demand with the supply of port services for freight cargo in the long run.**

## **Data Collection**

Semi-structured interviews with senior executives of PAs tasked with responsibility for the development of port capacity were chosen as the primary data collection technique for step 1. The level of analysis is organisational decision-making rather than individual, despite the fact that data is elicited primarily from individuals. The inferring of organisational level knowledge is partly justified through the assumption that the top management team of an organisation must form an epistemic community of strength in order to create a viable economic unit. Huff and Huff (2001) describe this as a shared schematic framework that provides ‘the basis for coordinated activity’. Interviews were therefore restricted to senior executives with oversight of the port planning process.

In preparation for the interview, interviewees were provided with an interview guide, forwarded directly in advance of the interview. In developing the guide, several pilot tests were conducted at an international industry event for PAs and separate meetings with potential interviewees. Initially, the guide focused on identifying ‘factors critical to successfully planning capacity’. It was found, however, that the term factors led to ambiguity, as interviewees were uncertain as to whether they were being asked about factors relating to the process of planning (choosing between development options) or actually executing plans. It was also found that the use of the word ‘criteria’ provided better focus to the actual process of planning or choosing between different options in planning capacity. Therefore, consistent with the literature on transport planning and infrastructure design, the guide was framed as a multi-criteria decision on choosing between different development options (Macharis and Bernardini, 2015). This involved asking interviewees to consider how ports identify development requirements and discuss what criteria were critical when choosing between different

developments options. Finally, interviewees were asked how they evaluate the current state of the port system in respect to future capacity requirements.<sup>32</sup>

To choose an appropriate time period for the ports to consider Dooms and Verbeke, (2006)'s categorisation of port planning horizons was followed with the planning horizon fixed to 12 -15 years. This timeframe was most consistent with the views of pilot interviewees. As per Evers (2011, p. 501), interviews were semi-structured and open ended so the interviewee could reply 'freely in his/her own words in stream of thought without any limitation being forced on them'. In total, interviews were held with eight senior executives across four of the five Tier 1 and Tier 2 ports. Each interview lasted approximately fifty minutes in duration, was recorded with prior permission and subsequently transcribed. Finally, to help improve the face validity of the findings, follow-up interviews were completed with all five ports post-analysis. The capabilities as identified through the analysis of transcripts were discussed and their applicability assessed by the interviewees.

### **Data Analysis –Casual mapping**

To identify critical capabilities, the study focused on the causal assertions of decision makers using causal mapping techniques. Causal mapping is a family of techniques that emerged from Axelrod (1976), designed to elicit and represent systematically actors' causal beliefs concerning a particular issue or event (Hodgkinson et al., 2004). Causal maps are representations of causal assertions that generally consist of nodes (which depict concepts) that are linked by arrows (that depict causal relationships) and come together to form a directed graph (Eden, 2004). The assertions of causality of interviewees are focused on because

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<sup>32</sup> A sample of the interview guide used in the study is included in Appendix B.

causality, and in particular, causal associations between concepts, are the primary way in which understanding about the world is organised (1990). In addition, choice amongst alternative actions involve causal evaluation. In this way examining causal explanations allow for the positioning of the content of decisions and actions in the context of the variables that affect port development. Ackermann and Eden, (2004, p. 128) describe context as the ‘consequences and explanations that are linked to each statement’.

To construct the maps the technique outlined by Wrightson (1976) as modified by Huff et al. (1990) was followed. This technique was originally designed for documentary coding, but adapted here to analyse interview transcripts. It involves examining every statement made by the interviewee and isolating cause and effect concepts. Concepts were coded using the QADCAS software NVIVO, and linked to one another according to pre-defined standard ‘relationships’ as produced by Huff et al. (1990, p. 315). Using NVIVO, it was then possible to use the resulting relationships to generate causal maps.

The output was a series of directed graphs mapping each interview as an association of concepts through causal assertions<sup>33</sup>. The maps were then used to identify and classify the key capabilities required to develop capacity. To achieve this each map was segmented by clustering concepts and causal assertions that had a common subject matter. Once the maps were segmented it was possible to easily compare across different maps and identify commonalities in the composition of map segments. This resulted in a set of groupings of concepts and causal assertions. Using the conceptual framework outlined in section 6.4, the groupings were then classified in into key capabilities. The resulting key capabilities are presented in section 6.5.1.

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<sup>33</sup> A sample from a generated causal map is included in Appendix C for illustrative purposes. Due to confidentiality agreements, it is not possible to furnish full causal maps, as doing so would identify individual port companies and/or interviewees.

The use of casual mapping in this way was a means to facilitate the identification and classification of critical capabilities consistent with RO1. The maps create a representation of the data generated through semi-structured interviews that allows ease in comparison across interviews. Further advantages of the method are that the use of the coding approach and representation of a full transcript in a single directed graph assists in the systematic examination of the entire data set. Also, the use of QADCAS in the generation of the maps enables the circulation between raw data and transformed data enabling ease in review of classifications and process.

It is worth noting that the use of causal mapping in the current study is largely limited to a transformation of the raw data. The approach taken is similar in scope to the original application of Wrightson (1976). There have however been significant advances in the methodology in subsequent years. Much of these advances have extended the use of causal mapping through closer linkage of data analysis with elicitation through increased subject participation (Huff and Jenkins, 2002; Ackermann and Eden, 2004; Bryson et al., 2016). In addition while Axelrod (1976) combined analysis of qualitative data with quantitative methods, significant advances in this direction have also occurred (a prominent example is the use of fuzzy set theory in fuzzy cognitive mapping (Kosko, 1986; Osoba and Kosko, 2019)). The degree of participant involvement required from interviewees limited application of such methods in current studies.

**Stage 2- Explore across port contexts how PA's in strategic decision making are responding to respective challenges and opportunities to develop capabilities to serve freight markets.**

## **Data Collection**

The second stage analysis primarily draws on the interview data and field notes from several consultations and meetings conducted with senior executives from all five ports collected during the course of one of the author's activities in the Irish Maritime Development Office. In addition, existing available corporate documents were also included in the data set. Corporate documents included both annual reports, planning documents (including submissions to regulatory bodies and master planning documents) and finally, other port company policy documents (a list of documents utilised are referenced in Appendix D).

### **Data Analysis – Thematic Analysis**

Once critical capabilities were identified the second stage analysis involved returning to the data to conduct a thematic analysis of transcripts, field notes and publicly available corporate documents. This was done by using the critical capabilities identified in the first stage analysis as themes and examining how PAs are developing these capabilities in a given port context. By examining strategic choices on capability investment programmes surrounding generic capability groups, it was possible to compare choices across different decision contexts to identify factors resulting in variance in how managers are responding to common challenges (i.e. how to ensure that the port had sufficient capabilities to achieve the supply of capacity). The results of this analysis are presented in section 6.2.

## **6.5 – Findings**

**This section presents findings in line each of the research objectives.**<sup>34</sup>

6.5.1 - RO1: The Critical Capabilities PAs require to consistently achieve performance in the matching of demand with the supply of port services for freight cargo in the long run.

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<sup>34</sup> Note: To respect requests for confidentiality no individual ports are discussed explicitly and findings reported in a manner that respects anonymity.

From the findings five capabilities emerged as critical to the task of port capacity planning in the Irish state owned port sector. In the following section the critical capabilities are described with a sample of underlying data providing illustration from the case study findings.

**i. Capability to leverage throughput**

Throughput is the primary resource a cargo port needs to function, described as the currency of the port. Capacity planning was described as starting with throughput. Across the ports sampled there is a heavy emphasis on being able to identify future traffic or throughput requirements, and once identified secure throughput through attracting business.

Table 6-2 Sample of underlying data 1

<p><i>‘Throughput is the currency of our port, so when we are planning capacity, what you need to be able to do is identify and plan for future growth in throughput, i.e. tonnage. That is I suppose the key metric in terms of how we define what we need in the future or what we don’t need, and all that. so it starts with tonnage.’ Port A</i></p> <p><i>‘Well I suppose its management job really, which is basically myself and the harbour master. To look at what the needs of the business are, and to identify what those needs are. And that’s kind of a first issue is management identify what the needs are and then we will then look at what work needs to be done to kind of develop that.’ Port D</i></p> <p><i>‘So really it’s a long term view that we take of where it’s going. X’s strategy that is sitting in front of you that is a strategy for X, that looks at where the port needs to be in the next 10 or 15 years if you want to be in the game, there is an obvious trend that the X sector is increasing, its increasing in all Irish ports. There is an obvious issue that port infrastructure is currently not in a place to meet the demand of growth levels. That is driving the focus of the port companies to plan for capacity development. It is a perfect example of how the port plans for capacity development.’ Port B</i></p>
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**ii. Capability to leverage Physical Infrastructure**

For the operation of the infrastructure system, PAs rely on the capability to leverage physical infrastructure. In supplying capacity for a given market, five primary components of physical infrastructure were identified.

Nautical Access: The level of nautical access determines the size and frequency of vessels that can enter a port in any period of time.

Quay Space: the length of available quay space as well as depth of water alongside limits the level of berthage available for handling vessels in any given port system.

Land Space: Once a vessel discharges at the berth, the port needs sufficient land space alongside to receive cargo and space for the transit and/or storage of cargo.

Intermodal Connections: Ports rely on supporting transport infrastructure to connect the port to onward destinations.

Equipment and Superstructure: In order to operate the infrastructure, the port needs to be equipped with appropriate equipment (including ICT infrastructure) and superstructure.

It was stressed that in leveraging physical infrastructure, PAs must make assumptions about the capability of the port to leverage all five components simultaneously. In addition, factors such as seasonality and peak trends were highlighted as key to calculating available capacity in physical infrastructure. (This was cited as a failing of regulators who tend to purely on the dimensions of the quays).

Table 6-3 Sample of underlying data 2

*'for a port of scale you need deep water, so water above a certain draft level, You need the quay space then for the ships, to pull up alongside, so big ships need deep water but they also need quay space, And then when you discharge ships you need a big land bank beside, so its your water quays and land... obviously, the port is part of a supply chain, so therefore there is the need to connect the infrastructure to the port.... If you have a shortage in any of those primary infrastructures you are in trouble' Port A*

*'The port interface in getting this, be it containers RORO, LOLO, bulks, oils whatever getting them onto a ship and off of a ship. Its absolutely vital that the ports are equipped with the proper equipment. That's the first thing the connectivity and the equipment and the port infrastructure. That infrastructure can be anything from access, depth of water quay space, sufficient quay space sufficient dock, sufficient land banks behind it.' Port B*

*'So it means we can table a five year plan with the growth predictions in that and we can live that we have the capacity to do that. We don't have to lay block to do that, so therefore we don't have issues with permissions we don't have issues with quay lengths we don't have issues with infrastructure, with equipment etc etc.' Port C*

### **iii. Capability to Port Service Chain**

To leverage physical infrastructure, the port relies on a network of service providers, described by Talley (2014) as a port service chain (PSC). The PSC is a useful conceptualisation that allows us to consider the network of mostly independent actors who utilise port infrastructure in the provision of port services as a single resource. Depending on the degree of private sector involvement the PA may only have direct responsibility for some port services. It is responsible however, for ensuring that appropriate internal governance structures are in place to ensure coordinated action along the PSC.

In considering the PSC, PAs also must factor in the requirements of the wider logistics chain, including the efficiency of customers. A good example of this from the case study was operating hours. It was stressed that a port can move to 24/7 and if customers are not willing to receive the cargo in that time period there is little benefit accrued. Gains in efficiency through operational measures were found to be proportional to measures to improve demand management. In relation to demand management, while port service providers could be coerced, the power of customers meant that there is little the port can do in such situations. One potential measure identified was that of better community management through the use of ICT infrastructure to promote efficiencies through increased communication along the logistics chain.

Table 6-4 Sample of underlying data 3

*'Consequently, the Port has focused on regaining land from tenants and franchise holders and endeavours to ensure that the remaining land held under lease or licence is used effectively and efficiently.'* Port E

*'Okay so what is your efficiency on the lolo terminal today from the point of view of turnaround truck times,... turnaround ship times,... what's your effectiveness in the engineering department from the point of view of answering calls and jobs that sort of things. how do you measure your level of environmental compliance. Is that through complaints, that you get less complaints from a year to year basis, or that you have less breaches of regulatory compliance on a year to year basis.'* Port B

*'For us some of that is very passive in so far as we dont stevedore, we dont store goods. We are a port authority as regard bulk, we really dont have a direct hand in influencing what happens. In the container side of it we are the stevedore, we are the container handler so we are more direct in that so we are more like a business and less like an authority. So its trying to measure all those things'* Port C

#### **iv. Capability to Leverage Capital**

Underpinning port development plans are assumptions about the ability of port infrastructure managers to sufficiently fund port development. In terms of leveraging capital, four sources of finance were identified from the interviews. Ports can draw on their own cash reserves, they can leverage credit from financial institutions, they can enter into joint ventures in public private partnerships with private companies, and finally there is a limited amount of grant aid available from EU sources. Notably ports receive no support from the state for port development projects; however the port is reliant on the state to provide connecting infrastructure and also utility infrastructure such as power, water and broadband. A key consideration in leveraging capital is the underlying commerciality of port service provision as ports have to ensure that funding capital can be leveraged in a manner that enables the port to grow and remain sustainable. The management of profitability is an important component of sustainable port development. In particular, cash flow management and ensuring that sufficient cash flows exist to support future expansion and additions to the stock of assets. In the context of infrastructure management, cash was described in one setting as being king.

Table 6-5 Sample of underlying data 4

*'Lastly its funding, it's certainly in the first thought that comes into everyone's mind (certainly the financial controller of the company) is how are we going to afford it. Funding mechanisms in order to weight the criteria for the port are vitally important. The deeper we get in to developing capacity ourselves be it new or existing facilities then the harder it is to move forward into other areas because the more constraint the funding covenant becomes on any loans rating we get.'* Port B

*'When you are planning you are doing your capital investment programme and obviously cash flow planning, is a big aspect to that. So that we can actually afford what we want to in the capacity and it is sustainable.'* Port A

*'the engineering options in the Masterplan are advanced with an eye to the Company's ability to finance them. X envisages the Port developing through a series of "bite-sized" project investments which keep the company within the bounds of reasonable and acceptable levels of financial risk associated with taking on project debt.'* Port E

#### **v. Capability to Social License to Operate**

PAs must leverage support from a variety of stakeholders whose interest in port development is not directly commercial. Support from non-commercial stakeholders has been linked to sustainability objectives of PAs and frequently referred to as the ports license to operate or grow (Verhoeven, 2010). Similar to the PSC concept above the Social License to Operate (SLTO) concept allows us to consider the various support mechanisms the port company relies upon as a single resource. In the Irish context, two particular instances were identified where obtaining the SLTO are critical for port development. Firstly, in relation to development of port infrastructure, the port relies on the support of its shareholder and various government departments for the appropriate development of supporting infrastructure as well as the appropriate zoning of land for future developments. Secondly, the port relies on obtaining its license to operate in the context of obtaining the relevant regulatory licenses and planning permissions to grow and develop.

Table 6-6 Sample of underlying data 5

*'its aimed first and foremost for the people who use us, so importers and exporters. It's the economy who are the main drivers, and then it's the Irish tax payers and Irish public and what's required in Ireland inc, and that's represented by the local authorities and by the national authorities and development agencies. Then it's about all your local communities too. I think the stakeholder base is very very wide. But again we are economic and it's an economic fulfilment, facilitation role is what we have. sometimes its quite hard ot see who your customer is, because your customer is covered by several layers of stuff that you don't actually get to them directly all that often.'* Port C

*'They are not major issues, we have made submissions to X county council, the X county development plan is very much in line with the development needs of the port. So you know the county development plan is lined up, the council is supportive in principal of the needs to develop the port. We don't have environmental protection areas in any of the port area, we do have some miles away to the north of us and to the south of us and the east of us and the west of us, but not in the actual port area. From that perspective we are actually quite lucky.'* Port D

*'It does for example because if we are looking at going to An Bord Pleanala , which we are doing extending our jetty out there, they will be looking for traffic projections, tonnage growth, so we say there is going to be an extra say 20% per annum HGV's coming in and out of the ports we are not satisfied that the existing roads are capable of that,. They may say well they could make conditional planning until the road, the new road is built, you can't go ahead with it. so that is something i think they can do.'* Port A

#### *6.5.2 - RO2: How PAs in strategic decision making are responding to respective challenges and opportunities to develop capabilities to serve freight markets.*

In examining how PAs make choices in the capacity planning process, two emergent themes were prominent across the sample. Firstly, common to all settings was the impact of long lead times, high costs, complexity and subsequent uncertainty inherent in the process of infrastructure development and the impact on the criticality of forward planning and anticipating market demands. This factor had clear effects on how PAs choose to act to ensure capability to respond to market demands in the supply of capacity. Secondly, in examining choices on investment path, there was divergence in the manner which managers across the sample were investing in developing capabilities. By examining causal assertions surrounding these choices, it is possible to relate this divergence to variance in the existing capability position of the port and subsequent challenges and opportunities in the development of respective capability positions. The effects of these two factors are explored in detail below.

### **A. Criticality of forward planning and effect on developing capabilities**

The criticality of forward planning in anticipating market demands was a major emergent theme common across all settings. To develop capability to expand or develop new trade, the port typically needs to have assets that are general in nature such as basic physical infrastructure as well as market specific assets such as specific handling equipment and organisational expertise. Acquiring both takes considerable time and involves a high degree of complexity and subsequent supply side uncertainty. In particular, in relation to developing physical infrastructure, it was noted that there is a high degree of uncertainty associated with obtaining regulatory permissions, with estimates of the lead time for any piece of capital infrastructure in Ireland ranging from between five to twenty years. The potential for challenges to port development due to environmental sensitivity of port development and inefficiency of planning authorities were cited as major contributory factors.

The number of state agencies required to deal with, as well as the lack of coordination between these agencies, was seen as the constraining factor. In one instance, it was noted that the obtaining of planning permission is the most risky aspect, describing the actual building process as relatively straightforward. In addition to obtaining the SLTO, difficulty in obtaining capital support, particularly from commercial lenders, was another factor cited as a limitation in the ports capability to respond. Both the difficulty in obtaining finance but also the expense of such finance once obtained, were cited as constraining future port development (port infrastructural projects owing to their long gestation periods and low yields are typically difficult to finance, and attract high costs of borrowing). In addition to difficulty in expanding capabilities, port assets typically have long life spans, forcing PAs to plan ahead and anticipate port requirements up to thirty or sometimes even fifty years into the future. The key to success in capacity provision therefore, was described as forward planning and by a significant

timescale, and then ongoing management review to make sure that plans remain relevant and stay on track, thus avoiding the threat of mismatch between supply and demand, leading to capacity and service issues and failure to deliver on time.

The major observed effect of the difficulty and length of time it takes to expand capabilities was on the capability of the port to react to changing dynamics to avail of new opportunities for expansion as they arise. Directly related to the window of time in which an opportunity is available, the degree of capability expansion required limits the capability of the port to respond. Assertions about capability to increase capacity were more positive in situations where capacity could be improved through management measures to increase utilisation of existing physical infrastructure or the addition of equipment and superstructure rather than additions in capital stock, which required planning permission. Three types of measures were identified from the interviews as particularly problematic.

- The difference between requiring capital as opposed to maintenance dredging was highlighted, with capital dredging particularly challenging. This is due to environmental sensitivities and objections that arise in obtaining licensing.
- The obtaining of appropriate zoning, acquisition and development of land adjacent to water resources can be problematic. This is due to planning difficulties but also the high cost of purchasing land off third parties.
- Finally, problems frequently arise in relation to measures that require the expansion of hinterland connectivity. In this situation the port is wholly reliant on government bodies, namely Transport infrastructure Ireland and the National Roads Authority.

The ports existing capability position serves to limit the availability of opportunities to ports and restrict the set of strategic responses available to PAs and potential development options.

## **B. Effect of capability positions and future challenges on choice in capacity development path.**

While there was commonality in the process by which PAs approach the planning of capacity, in examining the resulting choices there was clear divergence in how ports across the sample are developing capabilities in the supply of capacity. Using the generic capabilities to identify equivalent choice situations and by examining the casual assertions surrounding these choices, it was possible to identify the underlying factors that influence this divergence. In particular, given the specific spatial characteristics of the port, PAs are forced to adapt to alternate opportunities and challenges as determined by respective operating environments. Spatial factors relate to the location of the port and its relations with organisations within its environment as influenced by its scale and the nature of its operations. Temporal characteristics relate to patterns of changes or dynamics occurring in the ports own lifecycle, the wider industry and macro environment dynamics. To illustrate this, six examples of divergent adaptation to varying capacity challenges are presented below.

### **i. Capability to identify throughput and degree of market specificity in investment.**

Across the ports sampled, there is a heavy emphasis on the importance of being able to identify future traffic or throughput requirements. There were differences however in assertions about the ports capability to plan with pre-identified throughput requirements, ranging from identified throughput being an absolute prerequisite to any port plan, to any long term forecast being a high risk game. This has effects on how the port plans infrastructure. In situations where throughput requirements were identified, the task of capacity planning involved investing in measures to best serve that need, through the development of infrastructure and specified capabilities. Phasing port development by using stages of development in such

situations was identified as providing some degree of buffering, should conditions change. Where future market positions were less secure, capacity planning was more about putting the port in a position to capitalise when the port has more information and thus lower uncertainty, described in two interviews of investing to be shovel ready for when the business case arises. This manifested itself in the addition of strategic assets and the investment of knowledge resources prior to the formalisation of investment plans.

## **ii. Ports Location and capability to secure throughput**

The location of the port was found to play a large part in the type of the business the port can attract. The position of the port as a node in a logistics chain was referenced, and in particular the capability of the port to provide value to the logistic chain relative to competitor ports is largely affected by geography and relative accessibility to key hinterland and foreland markets. Ports therefore, by virtue of their geographic location, relative to competitors, are suited to developing capacity in certain markets. From the supply perspective, similarly the physical resources, most notably depth of water, inhibit some ports from entering markets. From the sample, this included the potentially emerging biomass trade which requires large vessels and certain classes of large RoRo vessels which call to Irish Ports. Once a port is engaged in serving a market the geographic position of the port was further found to affect how the port develops capabilities are competitive in the respective markets. This was contingent on the market sector with strong differences between the unitised and bulk sectors.

**Unitised sector:** In the RoRo sector proximity to foreland destination and capability to provide frequency and speed of crossings was found to be important to attracting business. In attracting container traffic, the nature of the ports direct hinterland was found to be a key factor in particular the balance in traffic generated in both imports and exports. In relation to overcoming an imbalance in hinterland traffic, two strategies emerged from interviews. One alternative was

trying to promote the development of accessibility to areas not well served by existing ports and as such generating balanced volume in this way. Secondly, the promotion of port centric logistics and in particular, the benefits of utilising cross docking facilities over transport by road, was highlighted. Consequently, ports in the periphery are actively attempting to develop capabilities to allow them to differentiate their offering in a positive manner from ports in more advantageous positions.

**Bulk Sector:** In the bulk sector, the lower value of goods resulted in transport costs accounting for a higher proportion of costs. Furthermore, bulk products need to be stored or warehoused typically for a longer period of time in contrast to unitised cargo which is typically transit cargo. It is generally in the interest of bulk shippers to set up facilities for storing or bagging goods on or near the port location. This will typically require a form of capital investment, which has the effect of tying a particular customer to a port. In this instance, competition comes in the form of requiring customers to invest in the port rather than attracting transitional traffic. The small size of the Irish hinterland was cited as a limiting factor in growth in bulk trades. One strategy to overcome this was to attract large scale industrial production from international markets, such as the processing of energy related products.

**iii. Slack in availability of resources and capability to leverage the PSC and capital**

The level of slack in availability of resources was the main factor identified as resulting in variability in capability to leverage physical infrastructure across ports. The location of the port was prominent in this, especially as ports in close proximity to urban centres faced both increased competition for land as well difficulty expanding near restricted locations. Another form of slack identified rose from the level of nautical access, given different types of port location (river, coastal etc). Due to the presence or proximity to zones of environmental designation, such as Natura 2000 sites, capital dredging can be restricted. In areas with

particularly challenging hydrodynamic conditions, achieving consistency in depth through maintenance dredging can be difficult and very costly. The latter appears to be more of a problem when scale of operations is smaller, as cost efficiency of maintaining depths relative to revenue is more challenging due to a higher per unit dredging cost. The effect of slack in resource availability, is that ports have to invest relatively more in measures to protect the port system. Conversely, in situations where ports have, or are able to acquire, surplus resources, the challenge was not to develop capabilities to buffer the port but to best utilise a strategic asset/opportunity.

A similar effect can be seen in relation to the amount of excess capacity and assertions of urgency surrounding the need for efficiency improvements. In settings where the bounds of existing fixed capacity are starting to be tested, there is a much greater emphasis on optimising land use. In one context, where in a particular trade, the port currently has excess capacity, increasing efficiency was described as not '*mission critical*', however this was likely to change as capacity is utilised. This has a knock-on effect on competitive strategy, whereby excess capacity can allow PAs to offer greater flexibility to customers. Conversely, where there are constraints, PAs have to impose tighter demand management measures. A noted example of this in the unitised sector is the management of dwell time for containers; where there is less pressure more lenient demurrage policy can provide a competitive advantage. The degree of importance attributed to the drive for efficiency was found to be contingent on the trade. In bulk trades the margins are typically lower than in unitised trade, therefore the marginal costs of increasing efficiency are typically higher in proportion to marginal revenue gained by measures to increase efficiency.

**iv. Scale and nature of operations and capability to leverage the PSC and Capital.**

Scale of operations is an important contingency factor in leveraging private sector participation. Where there is sufficient scale to support multiple operators, the PA can rely on a market mechanism to a greater degree to ensure private sector compliance, thus reducing the burden on PA governance. This was found to be more of an issue in the unitised sector where port services are typically provided in single operated terminals as opposed to common user terminals. In particular, it was argued that when scale is not sufficient for two terminals to be operated, there is a risk factor in handing responsibility for the operation of port services over to a single private operator, thus creating a private monopoly. In the absence of a competitive market mechanism to control monopoly behaviour, the danger arises that the cost of port services will artificially increase with the costs passed on to the consumers of port services. In contrast, bulk trades tend to involve fewer intermediaries than unitised trades and tend to serve single end shippers rather than the thousands of shippers that may be served by a unitised call. As such, the risk of monopoly pricing on the part of service providers is reduced in a market that very often tends toward monopsony.

The degree of private sector participation has significant effects on the type of capabilities PAs need to develop. Private sector partnerships were found to afford the PA significant opportunities in leveraging capital for port development as well as potential enhanced efficiencies in port service delivery, while releasing the PA from the burden of operating port infrastructure. However, a number of additional challenges were identified. In instances where responsibility for marketing of port services is primarily devolved to a private sector, the PA effectively relies on the private sector partner to drive the business. This can be problematic when the private sector is underperforming and can lead to underutilisation of port assets. In such instances, it was stressed that the PAs must ensure that there are sufficient

governance mechanisms built into usage agreements to protect against such occurrences. Furthermore, long term leases or concessions can create difficulties when it comes to port development. In particular, where land is scarce, changes in land usage can cause difficulty where there is conflict with the interests of port concessionaires.

Scale of operations was found to have an effect on the capability of ports to leverage capital. It was found that ports of lesser scale had difficulty attracting commercial lending. In such instances, an attractive option to grow the port is to invite public private partnerships or joint ventures. In situations where cash flows are not sufficient to fund development, attracting a private sector operator can provide a solution. However, in situations where governance of private service provision is challenged, there may be a trade-off between the improved capabilities to leveraging financial capital versus social capital. This was described as the need for private investors to obtain sufficiently competitive return on investments which may result in an increase in prices to customers and negative impact of the competitiveness of the local region to trade internationally.

**v. Location and recognition of port activity and capability to leverage the SLTO**

Ports located in close proximity to large urban areas face more complexity in the obtaining of the SLTO given the wide range of stakeholders they have to deal with. In the Irish context this relates to pressure from other sectors of the economy for prime urban real estate for residential housing, other commercial developments and leisure uses. Complaints also arise from residential groups in relation to traffic and the effects on recreational amenities and aesthetics. Again this is contingent on the market sector with bulk goods typically perceived as ‘dirtier’ than unitised cargo. Similarly, in relation to obtaining regulatory permissions, proximity to a Natura 2000 or environmentally restricted zones will ensure added constraints and complexity in obtaining planning and regulatory permissions. This is more pronounced

for certain classes of bulk trades. Recognition of the role of the port in facilitating economic growth, both nationally and internationally was found to play an important part in the ports capability to leverage SLTO. In the Irish context, classification as a port of national significance and at a European level, TenT classification plays an important role in port recognition in regional and national development plans

In situations where obtaining the SLTO is challenged, a number of strategies emerged to leverage the support of salient stakeholder groups. To gain support from regional and national bodies, strategies to leverage support include various forms of lobbying to highlight the port as an economic facilitator including the commissioning of economic impact studies. Similarly, local community groups are a powerful stakeholder group. Strategies identified to leverage support here included awareness campaigns and the completion of infrastructure projects that do not necessarily generate a commercial return to port but benefit local communities. Included in this category is the creation of recreational amenities such as marinas, but also the promotion of cruise activity, which, although quite valuable to city commerce is relatively less profitable than cargo activity for a port and can absorb valuable port resources. There was also a noted reticence about the increasing importance of environmental issues in shaping port activity and development. In one instance, this has manifested itself in an active project to monitor the impact of the port on the local marine ecosystem through the deployment of technology.

**vi. Macro environmental factors and capability to identify tonnage, leverage SLTO and Capital**

A number of examples of how changing economic, social and institutional structures have shifted the requirements of the port, forcing managers to adapt, were identified. Firstly, in relation to identifying future requirements, it was stressed that what is critical in one period of

time will change over the course of a port's lifecycle. This was highlighted in one instance through describing the decline of the oil importation industry in one port, resulting in a shift to containerisation. Another PA described the effects of the drive toward renewable energy as drastically changing the importance of the once critical fossil fuel market. It was stressed in both instances that port management must constantly be on the lookout for new trends, which is particularly important given the length of time it takes to plan and deliver new port infrastructure. Additionally, shifts in how logistic chains operate and trends in the patterns of movement of goods can alter the requirements for ports to be competitive in specific trades. The rise in ship size was recognised as an important development. Increasing in ship size was found to be important in bulk trades and a potential vulnerability given difficulty in expanding depth of water to accommodate a larger vessel. Interestingly, in the container trade, the relatively small scale of the Irish market was found to be an inhibiting factor, placing an upper limit on the size of vessel that can operate out of Ireland.

Similar effects can be seen in how PAs adapt to changing factors in leveraging financial and social capital. The availability of capital has changed in recent years. In relation to EU funding, it was commonly held that the availability of grant aid has diminished significantly. In addition, EU funding calls have been typically oversubscribed. EU funding was seen across the sample as an unreliable option. In the absence of exchequer funding, ports are reliant on debt financing, their own resources or public/ private partnerships. Directly linked to the availability of capital is the cost of capital. As port projects typically have longer gestation periods than most commercial projects, obtaining funding at rates that can lead to sustainable development was found to be difficult. While there are alternative debt options, that are potentially cheaper, such as the European Investment Bank, debt financing was found to be restrictive in a number of cases. In leveraging the SLTO, factors affecting wider societal

pressures impact the port in various ways. The two prominent examples were the current housing crisis and renewed pressure to realise value from port lands situated in areas that could be used for urban housing, and changing societal preferences and the increased need for proof of environmental sustainability.

Table 6-7 Sample of Underlying Data 6

<p><b>Criticality of forward planning and effect on developing capabilities</b></p> <p><i>‘So a company may come into us and have requirements and a timescale of say 12 months. If we have to plan for that forget about it. It could take 10, 20 years to plan for it. We have to have the facilities; we have the foresight, and the facilities to handle reactionary cargoes when and if they arise.’</i></p> <p><i>‘The master planning process of the consultation phase is very important, consultation is very important, when you’re talking to customers you almost need to know what you are doing, where you think your sector is going, where your business is going. So the long term view is very important. So we are putting in assets that have 50 year lifespan that take 7 years to do. So that’s how the long term planning is critically important.’</i></p>
<p><b>Capability to identify throughput and degree of market specificity in investment.</b></p> <p><i>‘No infrastructure is going to be planned at any sort of a large scale unless it has a certain amount of tonnage that will commercially wash its face. Or unless it will be delayed on such a time that something comes across will justify it.’</i></p> <p><i>‘Measuring demand is probably the biggest issue, when you get back from all of that fellas love an engineering and building quays and cranes and stuff and waters and depths, and at the end of the day demand is really the difficult thing to manage .... measuring where that demand is going to go, that’s a high risk enough game’</i></p> <p><i>‘.... the plan must be sufficiently flexible to be able to be adapted to unforeseen changes which will inevitably occur. Such changes could be related to various aspects of the ports business including economic circumstances, marketplace and customer requirements, port operating practices, advancements in technologies, statutory requirements and the policy environment. The choice of preferred site(s) for development will therefore be influenced by how flexible the site might be in terms of how it may be developed for a variety of different trades, vessel sizes and associated requirements.’</i></p>
<p><b>Effect of the ports location and capability to secure throughput</b></p> <p><i>‘... the port’s location at the major centre of population on the island and at the hub of transport networks suggest that, if operated efficiently and cost effectively, X’s market share is more likely to increase over time than decline.’</i></p> <p><i>‘Rather than the chance of them going to another port because of the transport cost, if you have something that is bound for the (...x) area to go to (y.....) area it doesn’t really make sense transport will eat out the benefits or difference.’</i></p>
<p><b>Slack in availability of resources and capability to leverage the PSC and capital</b></p> <p><i>‘If you don’t do that in a cohesive structured manner, you find that when you go looking for the landbank, or you go looking for the sea shore related area into the future its not there, and you are buying it off 3rd party development.’</i></p>

*'Water depths in development in the short to medium term are fairly fixed for most ports, unless you go into significant capital dredging which is environmentally sensitive and extremely expensive.'*

*'It's (efficiency)... not mission critical so we are not that heavy at it and it's not a constraining factor so we are kind of keep it coming keep the fettle to the mettle, keep bringing it in. When it gets tighter we will manage it differently'*

**Scale and nature of operations and capability to leverage the PSC and Capital.**

*'What you start to create, when you look at the Lolo sector you have one terminal so you end up creating a monopoly, you also end up handing that particular sector to one investor and the cost to the customer of the port thereafter, and the cost to the local region will no doubt increase because these guys will have to make their margin back as well'*

*'The key question is how does a port develop when their balance sheet is not big enough to generate funding?'*

**Location and recognition of port activity and capability to leverage the SLTO**

*'X Port Company will address specific requirements arising under the Birds and Habitats directives in the context of any developments which have a potential impact on natura 2000 sites. this would include establishing the justification for such developments and identifying any mitigation or compensatory measures that may be required.'*

*'So it's critically important that there is an ongoing job of this lobbying, ensuring that the local authority is up to speed on your plans. All of that constant meetings with people, trying to ensure the port requirements remain front and centre.'*

**Macro environmental factors and capability to identify tonnage, leverage SLTO and Capital**

*'So as the social housing started to gain momentum and more pressure is being put onto the local authority more pressure is being put onto the port. As the social housing crisis started to gain momentum and more pressure is started to be put on the local authority, the more pressure is being put onto the port authority in order to prioritise and influence the move out of the city'*

*'Unfortunately by the time we had that proposal developed, the recession had come and cash was tight and so forth'*

## 6.6 - Discussion

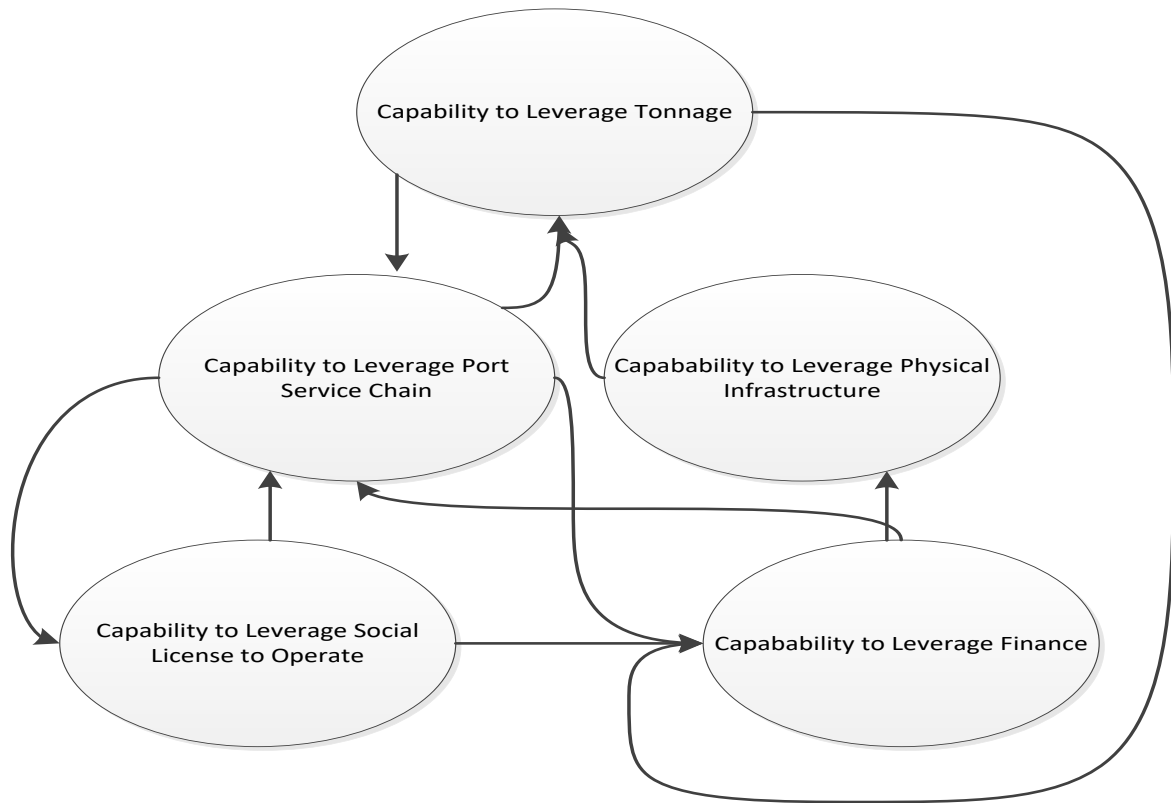
Addressing RO1, five critical capabilities were identified in the Irish context as critical in the supply of capacity to freight markets. The presentation of the critical capabilities was in thematic form, however this division is artificial as all capabilities are interlinked with each category interdependent of each other. Regardless of the nature of a port's business, to fulfil its function as a node in a logistics chain, a port primarily needs to be able to identify and secure throughput. To secure throughput, the port needs to be able to utilise port infrastructure which relies on there being both sufficient fixed capacity within the physical infrastructure and a

functioning port service chain to operate it at sufficient levels of efficiency and effectiveness. The leveraging of port infrastructure further relies on the repeated leveraging of both financial and social capital to sustain its operation. The sustained leveraging of financial and social capital subsequently depends on the ports output both in terms of economic (as determined by profitability and commerciality) and social (as determined by wider stakeholder buy in) factors. Such factors in turn relate to its capability to secure throughput and how it leverages infrastructure and the port service chain. Underpinning choices on path of development of future capacity for freight markets in the Irish context therefore are assumptions about the capability of the PA to co-specialise these resources sustainably. As per the definition of criticality failure to achieve sufficient capability in any of the categories will result in a failure to achieve sustained capacity development. In examining future capacity therefore, the PA cannot view any particular resource in isolation from each other.

In deciding to deliver capacity for a given market, PAs strategically balance their own objectives with the current and future preferences of all the organisations in its environmental set. From the case study, this includes competitors and customers, port service chain partners and suppliers of physical resources and capital, shareholders and regulators, and finally local community groups and stakeholders with wider environmental and socioeconomic interests in the development of the port. The degree of effort extended in the Irish context to coordinate action amongst stakeholders, would indicate that in many instances matching capacity is a stakeholder management problem as much as it is an engineering problem. Port managers, in order to identify future capacity requirements, are investing in lengthy and extensive master-planning programmes, which require lengthy stakeholder consultations. Consequently, delivering on plans involves negotiating a complex planning and socio-political landscape. In investing in capacity expansion, the success or failure of the port in delivering capacity is as

much reliant on the capability of the port to leverage tonnage, capital and social capital as it is to develop physical and operational capabilities.

Figure 6-2 Identified Critical Capabilities



### 6.6.1 - Implications of capabilities approach to Capacity development in the port sector

In the introduction to this chapter, it was stressed that understanding how decisions in capacity planning are made is critically important to both PAs and national policy makers. Understanding how decisions are made assists in the evaluation of the appropriateness of a particular choice. The capabilities framework introduced allows for a level of understanding of choices through linking decisions to capability challenges. The outcome of this approach and its application in the Irish context leads to a number of insights into how performance regarding capacity development can be approached, as follows:

**i. Need to consider all resources and capabilities in considering long term capacity to supply freight markets**

In the Irish context, it was clear that in practice, in the consideration of matching supply with demand in the future, the PA must factor in more than when to add physical capacity to the port system. As well described in Der Lugt et al. (2013), the process involves careful consideration of the future resources and capabilities the port will require together with the capability of the port to acquire same. This is best illustrated by the following three quotes from across different port contexts, when discussing the biggest challenges to developing capacity:

*'You can't plan and forshore concurrently, you have to get planning, now there's changes but they are not implemented, then you have to go through your details and procurement. So then obviously, the construction of everything you are building and that is normally the shortest and easiest part from a management point of view, because the uncertainty or risk is all to do with the environmental requirements. your seven years, is with the best will in the world.'*

*'(three biggest choke points to capacity development)... Funding, the whole enviornmental thing and the other choke point is our ability to respond to changing cargo requiriements.'*

*'Measuring demand is probably the biggest issue, when you get back from all of that. Fellows love engineering and building quays and cranes and stuff and waters and depths, and at the end of the day demand is really the difficult thing to manage.'*

**i. Performance in capacity development is context Specific**

If the capabilities view of performance in relation to capacity development is accepted, the major implication for how performance in relation to capacity development is viewed, is that performance is context contingent. Namely, performance is a function of how well PAs develop resources and capabilities to overcome and exploit opportunities and challenges in capacity

development as the port evolves. Performance itself must be relative to these challenges and opportunities, which, as the case study demonstrates, are context specific, and contingent on the spatial and temporal characteristics of the port system.

**ii. Potential for identifying common challenges and scenarios through using capabilities framework:**

Variance in environmental complexity, dynamism and also slack, will make the overall task of capacity development specific to each context. The findings of the case study, however, indicate that breaking the task into a function of leveraging several generic capabilities does allow for the identification of commonalities. For example, every port in Ireland is challenged in leveraging capital; however the challenge is more equitable for ports of similar scale. Similarly, in leveraging throughput, there are obvious similarities in more peripheral ports than with ports which are more central to logistic chain activity. Corresponding capacity challenges can be identified through the various generic capability types. In many ways this is what Notteboom (2016) does in examining adaptive capacity building in his case study of Antwerp and Hamburg. Here the author focuses on a particular capability challenge, namely the difficulty in leveraging access to deep water and subsequent challenges with nautical accessibility, relative to competitors. In both instances, Notteboom (2016) identifies factors that have contributed to successful adaptive capacity building. This analysis may be expanded upon to identify and categorise varying capability challenges, in this way allowing for the potential to move towards normative best practice recommendations for different scenarios. This would promote best case solutions to specific capabilities related dilemmas.

## 6.7 – Conclusion

This study develops a novel characterisation of choice in capacity planning as a function of choosing between different capability development options. As conceptualised, in order to supply capacity, a port must have the necessary capabilities in place. In capacity planning therefore, PAs are choosing to invest in a set of measures that the PA feels will develop the necessary capabilities for the port to create sustainable value through capacity supply. As set out in the introduction, the purpose of this conceptualisation was to examine what resources and capabilities PAs need to develop and explore how they make strategic decisions to develop them. The framework applied creates a means for describing the process of choosing between different capacity development options in a manner that allows for comparison of the process across contexts. The results of the application in the Irish context demonstrate the importance of considering all tangible and intangible resources required in the supply of capacity.

It has been shown that underlying strategic decisions to commit to a path of developing capacity were assumptions surrounding the capability within the port system to leverage multiple resources simultaneously. Moreover, it is clear that across contexts, the strategic importance of various capabilities will change, depending on the context. Any evaluation of future capacity development within a given port, for a given port system therefore, must be cognisant of all capabilities required to develop capacity and the strategic importance of given capabilities remaining contingent on the context in which capacity is being developed.

### *6.7.1 Limitations of Research and Future Research Agenda*

The idea of a contingency approach towards examining the role of the manager in achieving performance in the port context is not new. The findings and arguments outlined above, are in many ways very similar to ideas of Brooks and Balthazar (2001), and the resulting matching

framework. It is argued however, that through identifying specific capability challenges further insight is provided into how environmental forces affect strategic decision-making in the crucial sphere of capacity provision. In addition, when considering the task of capacity planning, the five capabilities framework deals more directly with the appropriate level of strategy, i.e. capability search vs product market (Pisano 2015;Pisano2017).

While there are many limitations associated with the case study method (well documented by Eisenhardt (1989) and Yin (2013)), it is argued that the major limitation in this context is the power of extrapolation to the wider port industry. For example, all the ports sampled are gateway ports and are moreover, peripheral in relation to the global port network. The inability to generalise is as such, a noted limitation of the case study research; as per Welch et al. (2011), the best that can be hoped for is contingent causality. Generalising to a larger population of cases however, was not the primary goal of this research; if it were, then a different research strategy would have been undertaken. The objective of the research was to explore the process of strategic decision to examine in practice what influences the choices of decisions makers, when matching supply with demand for freight services. To achieve this objective, a means for exploring how PAs achieve performance in this regard was created, through the application of established frameworks from the wider strategic management literature.

As outlined in section 6.4, the use of causal mapping in the study is limited to use as a technique for the coding and visual representation of transcript data. A limitation of this approach, when compared to newer causal mapping techniques such as Ackermann and Eden (2004), is the limited participation of interviewees in the construction of causal maps. The participation of interviewees in map construction would likely improve both the content and face validity of the findings. A further limitation is that the relationships between concepts as

constructed, only provide insight into the direction of causality between concepts, not the magnitude. Thus, through the examination of causal maps as constructed, it is difficult to infer, as to the relative importance of alternative identified causal relationships. This can be particularly problematic as a causal map generated using coding of interview data is likely to contain a large number of causal relationships. Newer techniques, in particular fuzzy cognitive mapping techniques, allow for the elicitation of magnitudes of relationship through the use of verbal scales. In the current context the level of access to interviewees did not enable the use of such methods. In future studies it is likely that the use of newer mapping techniques would allow further insights to be drawn from the analysis of strategic decision making in the port context.

It is hoped that the framework and constructs introduced will lead to future work in this area to test such constructs, both in different contexts and more robust manners. It is proposed that the future research agenda for this area, should focus on using frameworks such as the one introduced, to address normative questions as to what type of strategy leads to sustained capacity delivery in various contextual settings. Another important topic for further enquiry is an examination of which institutional arrangements operate best in facilitating performance in capacity development across contexts.

## Chapter 7 - Conclusions

This chapter discusses the key findings of the thesis and outlines the contribution of each research chapter. . Section 7.1 reiterates the major contributions of each chapter, relating the findings to the research objectives outlined in Section 1.4. Section 7.2 outlines the limitations of each chapter (the purpose of this section is to allow for thorough interpretation of the results). Section 7.3 outlines the implications of the research findings for future research in the area of port performance measurement in support of policy design. Finally Section 7.4 outlines the implications of the research for the practice of port policy design.

### 7.1 - Key Findings

In Chapter 2, a systematic review of the literature was conducted in order to examine the dimensionality of port performance and the manner in which performance was measured across identified dimensions. The literature review required a categorisation of the existing literature into principal dimensions. Using the resulting characterisation, a construct of performance applicable to policymakers was formed. Specifically, port performance is characterised as a formative construct. The remainder of the study discusses the implications of a formative construct of performance for use in the design of performance measurement systems to address policy concerns when performance is multidimensional. Objective one was to examine how policy makers can decide what to measure to achieve policy objectives. It is argued that the findings of chapter 2, and specifically the implications of a formative construct of performance imply that there is an emphasis on policy makers to be able to define what performance is in each policy context.

Chapter 3 proceeded to examine performance change across the four largest state-owned Irish ports using a mixed methods approach. The findings of this chapter contribute to

the literature on port performance in Ireland through providing the first performance evaluation of Irish port companies since Mangan and Cunningham (2000). The results show that performance overall has largely mirrored that of the Irish economy. Across the ports, however, there was a notable divergence in performance post-recession. Identified factors affecting performance change across the period, include demand-side structural change, labour rationalisation, business model choice, and cargo mix choices.

The chapter further contributes to the wider literature through introducing a means to examine productivity change with a restricted sample through the use of a mixed methods approach. Here, rather than focusing on the measurement of the relative efficiency across ports, the chapter uses an index number approach to examine productivity change in individual ports from 2000 -2016 (productivity is measured relative to the year 2000 as the base). Explanatory accounts of performance available from extant qualitative sources are then employed to provide context to observed changes in productivity (measured as the rate of input consumption to output production). Using this approach, it is possible to identify key factors which affected productivity levels. The capability to identify explanatory factors is a key advantage of the method. In contrast, in larger sample statistical approaches, the exploratory potential is restricted by the requirement to identify explanatory variables in advance.

Chapter 4 reviewed an issue especially pertinent to policy design in peripheral port markets. Peripheral markets are characterised by limited volume. In such a market it is questionable whether there is enough volume of traffic to support multiple competitive PAs. From a policy perspective, there is a strong argument that in order to improve the competitiveness of PAs , resources need to be concentrated and larger PAs need to be established. To examine this issue, the chapter purposively samples Spanish North Atlantic and Irish PAs to examine whether there is a predictive relationship between the scale of operations

and technical efficiency in peripheral port markets. Using a Simar-Wilson double bootstrap approach the chapter finds a positive relationship between scale of operations and technical efficiency. In addition as the market contracts, it was found that the relationship intensified. The implications of this result for public policy design in the port sector is further discussed in section 7.4.

Objective two was to examine how policy makers can evaluate port performance change over time respective of the key internal and external drivers that influence port performance. The key difficulty in evaluating performance in this context is that with performance being multi-dimensional, there is in most likely to be multiple performance effects to evaluate. Furthermore, as port infrastructure systems are complex there is likely to be multiple potential drivers of performance change in any given performance context. The combination of the exploratory methods employed in Chapter 3 and deductive methods used in Chapter 4 provide a means to deal with this challenge. Exploratory methods allow for the identification of potential drivers of performance, while the deductive approach allows for the testing of the strength of the relationship between a driver and performance effect. In the current context, in Chapter 3, the relationship between size and efficiency in driving performance given market limitations was identified as key driver of differential performance between Irish ports over the period. In Chapter 4 this relationship was tested through the expansion of the sample and the use of regression methods.

Chapter 5 measures performance from a network demand perspective. Understanding what influences demand flows for and across ports as network nodes is essential to capacity planning at the national level. Data restrictions present a key challenge for policymakers in reliably modelling demand, particularly in small markets such as the Irish LoLo market. Traditional, survey methods and stated preference experiments were the preferred method for

generating data in the literature examined. However, limited population size and the complexity of the choice context, can make obtaining the relevant sample size a timely and costly process. As digitalisation increases, the emergence of new sources of data is providing new opportunities for disaggregate demand modelling. This chapter utilised one of the most common forms of such data (AIS data), to perform demand analysis within the Irish LoLo terminal network. In the process, the chapter introduces new metrics for reliability and congestion that are improvements on what is already present in the revealed preference literature.

The chapter, applying a Random Utility Maximisation Framework, models LoLo terminal choice conditional on a carrier choosing to run a service. Common Logit models are applied to estimate this probability; namely a Conditional Logit, Random Parameters Logit (RPL) and an RPL with interaction terms to examine for heterogeneity around the mean attributable to observable factors. The advantage of the RPL model is that it allows for random taste heterogeneity, flexible substitution patterns and correlation over time (enabling panel data estimation). The improvement of model fit from the conditional logit to the RPL demonstrates its suitability for this type of modeling. To demonstrate its utility further, several real policy scenarios are simulated, the results of which have direct consequences for future capacity planning across the network.

The major contribution of the chapter is demonstrating the potential of port choice modeling using AIS data. The data is particularly useful as it allows for a full set of terminals to be surveyed relatively easily. Objective 3 was to examine how policy makers can evaluate the performance of a port as a node in providing access to the maritime network relative to other ports in a port network. Chapter 5 provides to a means to do this that is highly replicable allowing for relative ease in repetition across time. The method also allows for thorough examination of

substitution patterns and taste heterogeneity, which provides significant advantages in the examination of network demand. Finally, as discussed below, we additionally identify several future research avenues for this type of approach to demand modeling.

Objective 4 was to examine how policy makers can understand how port managers achieve performance in matching supply and demand for port services. To achieve this Chapter 6 investigated the capacity expansion problem across Irish ports from a strategic perspective. A key performance function of a PA as the responsible body, is the development of capacity to meet future demand for port services. At a policy level, given devolution of power to PAs, it is important that policy makers have recourse to determine if capacity is being developed appropriately. In a less complex production system, the rate of appropriate capacity development is easily approximated by examining the relationship between forecast capacity and demand. However, in the port setting, forecasting future demand is beset with problems of uncertainty, particularly given the long planning horizons typically involved in port capacity planning.<sup>35</sup> Similarly, adding capacity is a complex task involving multiple actors, adding considerable uncertainty into ascertaining the rate at which capacity can be added. It is argued, based on the empirical literature, that in achieving an appropriate match between the demands of the freight market and the supply of port services, PAs in practice must consider both tangible resources related to physical capacities such as quay walls and cranes but also intangible resources such organisational capabilities and stakeholder buy-in. These important considerations imply that from a policy perspective, that ascertaining the rate of appropriate capacity development extends beyond examining the match between physical infrastructure and prospective demand.

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<sup>35</sup> Uncertainty here refers to both the volume of demand and the future requirements for competitiveness. The latter factor is a particular concern given vessel and supply chain technology and customer preferences.

This chapter creates a framework for examining capacity development in a given port context respective of strategic considerations that influence the choice of port capacity development path. To achieve this, a conceptual framework is introduced whereby capacity development is conceptualised as a capabilities search problem. Under the framework, capacity planning becomes a task of choosing a path of investment to ensure that the port is positioned with the requisite capabilities to supply capacity in the future. To operationalise the framework, a case study in Irish ports is carried out to identify the requisite generic capabilities to supply capacity for freight markets. Using this framework, existing choices on port investment paths are reviewed to explore how ports develop the requisite capabilities across different contexts.

Finally, except for chapter 4, empirical findings are solely generated from case studies in Irish ports. The reliance on case studies limits the generalisability of the findings to the wider populations of ports and port systems as findings generated are necessarily contingent on the context in which they were discovered (Yin, 2013). It is not possible therefore to extrapolate as to whether similar findings would hold, given a change in key geographical and spatial contingent factors. As is described in section 7.3, generalising the empirical findings of the thesis is an important avenue of future research. This will inevitably involve some form of testing of developed constructs in alternative contexts.

## 7.2 - Limitations of the research

Chapter two employs a systematic approach to identify how port performance has been measured in the literature to date. The systematic approach aims to minimise researcher bias, with subjective decision making limited to decisions on search strategy and selection criteria. While every effort is made to maximise coverage of studies reviewed it may not be possible to ensure examination of all sources. For example, macro impact performance studies on a seaport's spatial impact on their urban environment and integration in port cities are not

included in the review; this may be attributable to decisions taken in creating search strategy. Therefore, in interpreting the results, caution is recommended in assuming complete comprehensivity.

Chapter three applies a mixed method approach to examine performance change over an extended period of time. This approach by design, requires sample limitation to a restricted number of ports. Given a limited sample size in the calculation of TFP, it was not feasible to use a frontier approach to estimate a full production possibility frontier. Due to this limitation inference is restricted to change in TFP in each port relative to a TFP in the port in the base year. The advantage of the approach is that it allows for explorative identification of factors that influenced change in TFP over time. To achieve a better interpretation of the strength of the relationship between identified factors and TFP, a more robust approach would be to use a larger sample and frontier methodology. This is what is attempted in chapter four albeit measuring technical efficiency rather than TFP. Further, the study does not measure all aspects of port performance, excluding measures of performance across a number of dimensions of performance identified in in chapter 2. Historical data to measure the performance on such dimensions was not available for this study and would improve future studies if such data was to become available at a later date.

Chapter four applied the commonly applied two-step Simar-Wilson approach to regress the effects of contextual variables on efficiency scores. The chapter purposely samples PA's in Ireland and Northern Spain. A major result is the lack of dis-economies of scale across ports in the sample. Given that data envelopment techniques are largely sensitive to the sample, this result may not be robust if the study was reproduced in another sample of ports. Underlying the Simar-Wilson approach is an assumption regarding separability between the shape of the efficiency frontier and the contextual variables. Examining the relationship between the shape

of the efficiency frontier and the contextual variables was not the objective of the chapter. Accounting for this potential effect however may be important for future studies that are primarily focused on benchmarking performance.

The contribution of chapter 5 was its use of an innovative source of data, there were however several limitations associated with its use. Most prominently it was not possible to identify unique services, forcing us to model choice probability at the vessel rather than service level. Identification of services would better allow us to capture unobserved heterogeneity associated with individual decision-makers thus improving the predictive power of the model. In addition, the data only included information on port calls to Irish ports. However, with further data on onward calls it may be possible to identify the full network. This would allow us to potentially model route rather than terminal choice which again would perhaps be a better approximation to the actual decision-making process. The study was further limited to the inclusion of attributes that could be directly measured given the revealed preference approach. A common approach toward alleviating these issues is the 'data enrichment paradigm', where stated preference data is collected and used in parallel to revealed preference data to facilitate improved attribute trade-offs between alternatives (Hensher et al., 2005). Joint RP/SP approaches are common in the wider literature on demand forecasting and present an interesting avenue for further research in the port context.

Chapter 6 identifies five critical capabilities that determine the overall capability to supply capacity for a given freight market. To facilitate this aspect, a case study methodology was carried out which relied primarily on semi-structured interviews with senior executives. Ten senior executives were chosen in order to prioritise candidates who are primary decision makers in each port.

In terms of the methodology, the major limitation to the interpretation of the results is the limited power of extrapolation available from the finding. All the ports sampled were gateway ports, ports largely peripheral in relation to the global port network and ports that share a common governance system in the same region. There is a case to be made that if the study was repeated in another jurisdiction that alternate capabilities with divergent relationships between them would be found. This is a limitation of this type of case study research more generally. Further case studies in different jurisdictions amongst different types of ports would be a good approach to test this.

Finally, Chapter 3 and Chapter 6 make extensive use of documentary analysis as a qualitative method for analysis. Documentary analysis makes use of text that has been recorded without the intervention of a researcher (Bowen, 2009). In both studies, documentary analysis is used in a triangulation process. In chapter 3, it is used to provide context to observed changes in quantitative measures. In chapter 6, documentary analysis is used as secondary source of data to primary interview data in thematic analysis. A noted drawback of the use of documentary sources, as noted by Yin (2013) is biased selectivity. This refers to the likelihood that published documents (particularly by private corporations) are likely to align with the objectives of the organisation that publishes them. This can create a biased representation of facts and effect the credibility of documents as sources (Yin, 2013). While the combination of documentary sources with other primary sources of data helps alleviate some potential for bias, biased selectivity of documentary sources nonetheless represents a potential limitation of both studies.

### 7.3 - Future Research Avenues

Chapter 2 in many ways sets the tone for the remainder of the thesis. Echoing Vieria et al. (2014b), Brooks et al. (2017a) and Pilcher and Tseng (2017), the chapter calls for a need for more research into what causes performance in a given port context. The chapter concludes that while there has been a proliferation of studies that propose means to measure performance

across an expanding array of dimensions, there is little coherence within the literature in terms of theory development. It is argued therefore that there should be a concerted effort to develop a theory on what causes actors to perform across the various dimensions of port performance.

Christensen (2006) is illustrative in this regard. Here the author describes the theory as a body of understanding that researchers build cumulatively through the execution of a number of steps, broken into a descriptive stage and a normative stage. The descriptive stage of theory building is a necessary precursor for the construction of normative theory. The descriptive stage requires the proper identification of constructs related to the phenomena of interest, the categorisation of the phenomena through the creation of frameworks or typologies based on attributes and potential outcomes, and finally the association of different attributes and various outcomes through the definition of relationships. The outcome of this inductive stage is the identification of relationships through preliminary statements of correlation. In the early stages of theory building, such relationships need to be tested through deductive methods to ensure reliability and validity underpinning theoretical statements. Christensen describes this as a cycle of induction and deduction until a consensus from the field can be reached on identified relationships. Only when this is achieved can researchers start to make normative statements regarding causation and generative mechanisms and create normative theory.

The remaining four empirical chapters and their contributions to the understanding of respective aspects of port performance can be largely matched against the above process. Using Christianson's description, avenues for further research may be identified, which contribute to the development of theory in the subject area. Chapter 6 is most akin to the descriptive stage of the research. Here a number of new constructs are introduced to the literature as identified through the empirical case study. The framework in itself provides a means to match a particular development path in the context of key influencing variables. The findings indicate

that the nature of the relationship between the capabilities and their criticality will vary contingent on the contextual setting of the port.

Two important forthcoming research avenues are presented. Firstly, further research needs to be conducted to test the validity of the constructs. This may consist of the adoption of further case studies, perhaps in different port systems or larger sample studies to generate statistical inference, as to their applicability. The second research avenue would be to further query the relationship between the criticality of a given capability in a given context. This would present an avenue for a greater understanding of how and why ports respond to challenges in a given way. As outlined in chapter 6, this line of inquiry has the potential to be expanded upon to identify and categorise different capability challenges. This allows for the potential to move toward normative best practices for different scenarios, i.e, best case solutions to specific capabilities related dilemmas.

Whereas chapter 6 is inductive, chapter 5 is primarily deductive in approach. The utility of the chapter in regard to the development of future theory derives from the potential of the approach for replicability. The findings provide a means to relatively inexpensively explore the key drivers of demand and substitutability in a given port network. Testing the nature of these relationships across alternative port networks would provide a means to better identify the effects of market context on the significance of alternative port attributes. In addition, the chapter suggests further means to extend the research, to include the use of stated preference data to enrich the data together with the use of alternative models to query the presence of taste heterogeneity across the market.

Finally, chapters 3 and 4 represent an inductive approach followed by a deductive approach. A critical relationship potentially affecting performance was identified in chapter 2 and then tested in chapter 3. It is argued that this approach towards conducting

research has the potential to improve our understanding of port performance. The port literature, as identified in chapter 2, focuses primarily on the quantitative measurement of aspects of port performance. It is argued that exploratory research and the discovery of potential relationships can act as a means toward developing theory. From both studies, a number of further relationships for future research are identified. Most prominently, the relationship between choice in output mix and efficiency and research into when (or if) dis-economies of scale become an issue in port efficiency.

#### 7.4 - Implications for policy

This thesis introduces a range of tools to foster an understanding of performance in the delivery of port services consistent with the research objectives outlined in section 1.4. A number of direct implications for policymakers are also forthcoming from the empirical research. Chapter 2 highlighted that in line with Brooks and Schellinck (2013) that there is not a clear latent construct of port performance that policymakers can rely on to examine performance. Given the multiple stakeholders affected and subsequent multidimensional nature of port performance, what constitutes performance is largely reflected by the perspective of the concerned stakeholder measuring same performance. Performance as a construct is rather formative, implying that what constitutes performance is determined by what is measured. This places an onus on policymakers to define what performance is in each given context.

Through a longitudinal study, the third chapter illustrated how PAs achieve performance changes over space and time. The study focuses on performance change and using qualitative sources illustrates how port managers influenced productivity change in respect of both challenging and favourable environmental conditions. The study shows how port managers in alternate locations have had to perform in differing ways to achieve productivity gains. This demonstrates adaptive capacities. From a policy evaluation

perspective, it shows the importance of contextualising the effects of macro-environmental changes and demand-side dynamics when considering supply-side performance factors. The general cyclicity in performance over the period is in itself revealing, as all ports were affected by the change. The subsequent changing dynamics, particularly in the unitised sector placed divergent burdens on the respective PAs.

In addition, the chapter highlights a number of pertinent issues related to policy to improve productivity. Firstly, the importance of labour reform in improving productivity across all ports over the period, is arguably a strong endorsement for commercialization. The choice of output mix and the prioritisation of certain cargoes in dominant ports most notably Dublin, poses interesting questions as to the allocation of cargoes across ports in multi-port systems. Finally, it is demonstrated that variant choices in operating model can be linked to the size of operations, particularly in the unitised sector.

The conclusions outlined above suggest an advantage for larger Port Authorities in achieving efficiencies in markets challenged by peripherality. This point is explored in more detail in Chapter 4, particularly in light of recent policy changes in a number of European jurisdictions to concentrate resources in larger ports. Strong evidence of a link between size and efficiency was found in Irish and Spanish ports over the period 2000-2015. Here, scale of operations has been a highly significant predictor of technical efficiency in port operations. This chapter thus has important policy implications for how policymakers structure PAs in peripheral markets where the volume of traffic is limited, with finding suggesting that there is benefits accruing to amalgamating underperforming smaller ports.

Further it is posited that a system of independent competing state ports may not necessarily foster competitive market conditions as is intended by institutional structures that maintain multiple independent PAs. As PAs are legislatively established there is no mechanism

for underperforming ports to exit the market or be absorbed into better performing ports. Thus, smaller inefficient ports can continue to underperform in the long run. This has potential for unnecessary duplication of resources, particularly when port infrastructure is partly or fully state funded. In addition, it is suggested that intra-port coemption between private companies operating within ports, has the potential to offset potential negative welfare effects accruing to concentration of resources in a smaller number of ports.

Chapter 6 provides a tool for identifying the critical relationship that underlies plans to deliver capacity in a given port. Importantly, from a policy perspective, the case study demonstrates (in the Irish context at least), that in evaluating the future capacity of a port to supply port services in freight markets, policymakers must consider a wide range of resources and capabilities extending beyond capacity in physical infrastructure. The framework provides a tool for identifying those that are most critical in a given port context. Moreover, common institutional arrangements related to the governance of PA activity have varying effects across port contexts on port capacity development. Two examples were prominent; the divergent effect of planning regulations and policy regarding exchequer funding. This may potentially lead to market distortions across ports where policy frameworks unintentionally favour one port over another.

The capabilities approach and framework provides a means to examine for this through examining the likely effect of a given policy framework on a given ports critical capabilities. The capabilities approach and framework provides a means to examine for this through examining the likely effect of a given policy framework on a given ports critical capabilities. Relating this to the key challenges in designing port policy interventions as outlined the framework has potential utility for policy makers in identifying policy interventions that may improve the functioning of the port system.

To illustrate this, consider the divergent effect the divergent effect of planning regulations in the Irish context. The efficiency of planning procedures has been identified as major choke point in the Irish context. Since National Ports Policy (2013), the Marine Planning and Development Management Bill 2019 has been approved by the Irish government (Merrion Street, 2019). The purpose of this bill is to streamline the development consent process for the foreshore including, the integration of certain parts of the foreshore consent process with the existing on-land planning system. Through reducing some of the uncertainty surrounding obtaining regulatory consent, such an action could potentially reduce supply side uncertainty and improve resilience across the network through increasing capability to leverage the SLTO.

Chapter five recommends several implications for policymakers. The findings point towards the importance of Dublin's access to hinterland markets as driving demand in the port network. Therefore, in accommodating future growth in the LoLo sector, it would make sense, in the long run, to focus capacity development for LoLo traffic in Dublin port. Given fierce competition for limited land resources both from other port modes (specifically RoRo traffic) and other land use demand (social housing and urban development), further developing LoLo capacity in Dublin ports existing location may not be economically viable. In the event of such a scenario, there are a number of potential adaptations which may enable a continued functioning of the market, without relative loss of value for customers. As argued above, the major loss in value is likely to arise from a loss in hinterland accessibility. Loss of value could be substituted by an increase in other port attributes. Increased motorway access to other terminal locations as outlined in the latest National Planning Framework (Department of Housing, Planning and Local Government Dublin, 2018) could improve accessibility to the port of Cork and therefore help alleviate value lost from diverting away from Dublin. Similarly, the promotion of port-centric logistics activity (a relatively underdeveloped activity

surrounding Irish ports), and the utilisation of cross-docking at other terminal locations could further substitute losses to carriers from moving from Dublin.

## 7.5 - Conclusion

To conclude, the aim of this thesis was to contribute towards an understanding of how to evaluate port performance as it pertains to policy design. A number of illustrative themes emerge from the findings. Firstly, there is an onus on policy makers to define what constitutes performance as a formative construct in relation to the effects of a given policy measure. Defining what constitutes performance is necessary to provide a gauge by which the efficacy of action can be identified. Secondly, identifying performance requires an understanding of the capability of the organisation to attain performance which is strongly influenced by spatial and temporal factors. Chapter 3 demonstrates the effect of macro-environmental change on achievable productivity across a number of heterogeneous ports. Chapter 4 points to differing capabilities of achievable technical efficiencies amongst ports of various sizes in limited port markets. In turn, Chapter 5, by analysing the drivers of demand, identifies the clear link between geographical location and capability to attract traffic. Chapter 6 illustrates, through case study, that underlying decisions to develop capacity across port settings are a wide scope of environmental factors, that act to constrain the possible actions available to port managers. Failure to control for environmental factors in performance analysis, has clear implications for the usefulness of any performance evaluation. This thesis provides a variety of means by which policy makers can achieve this. Perhaps more importantly, it provides direction to guide future enquiry into research on port performance.

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## Appendix A – Search Strings Used in Database Queries

The selected databases all had different search options which restricted the ability to apply the exact same search to each database. However the three following preliminary conditions were established and applied to the searches in turn.

Condition 1. The review must always be practically limited to studies that have bearing on its specific research question. Initially all articles not related to seaport performance were automatically excluded.

Condition 2. Only articles published in peer reviewed articles were included for review. This is to improve quality control in the initial search.

Condition 3. The applicability of articles is confirmed by the presence of three selected key terms in the title, abstract and keywords.

Condition 4. Only articles in English were selected.

All searches applied conditions 2-4, while condition 1 was applied iteratively and in line with the functionality of the database in question.

### 1. Scopus

Scopus features over 20,800 peer reviewed journals

(Scopus applies stemming)

No.	Search String	Action	Result
1.	TITLE-ABS-KEY ( (port OR seaport OR "container Terminal" OR "port terminal") AND ( performance OR efficiency OR effectiveness OR productivity OR competitiveness OR "Economic impact" OR 'Environmental impact" ) AND ( evaluat* OR measur* OR analy* OR apprais* OR metrics OR indicators) ) AND ( LIMIT-TO(DOCTYPE,"ar" ) ) AND ( LIMIT-TO(SRCTYPE,"j" ) )	N/A	7,631 Articles identified
2.	TITLE-ABS-KEY ( (port OR seaport OR "container Terminal" OR "port terminal") AND ( performance OR efficiency OR effectiveness OR productivity OR competitiveness OR "Economic impact" OR "Environmental impact" ) AND ( evaluat* OR measur* OR analy* OR apprais* OR metrics OR indicators) ) AND NOT ( Microwave OR Antenna OR Robotic OR (Port AND WINE) OR cylinders OR "Diesel engines" OR "Combustion" OR "Packet switching" OR "Telecommunication traffic" OR Chromatography OR "spectrometry" OR "Nonhuman") AND ( LIMIT-TO(DOCTYPE,"ar" ) ) AND ( LIMIT-TO(SRCTYPE,"j" ) )	Several keywords identified from search 1, were excluded from the search string on the basis of condition 1, as they had no connection to seaport performance measurement	4,459 Articles identified
3.	TITLE-ABS-KEY ( (port OR seaport OR "container Terminal" OR "port terminal") AND ( performance OR efficiency OR effectiveness OR productivity OR competitiveness OR "Economic impact" OR "Environmental impact" ) AND ( evaluat* OR measur* OR analy* OR apprais* OR metrics OR indicators) ) AND NOT ( Microwave OR Antenna OR Robotic OR (Port AND WINE) OR cylinders OR "Diesel engines" OR "Combustion" OR "Packet switching" OR "Telecommunication traffic" OR Chromatography OR "spectrometry" OR "Nonhuman") AND ( LIMIT-TO(DOCTYPE,"ar" ) ) AND ( LIMIT-TO(SRCTYPE,"j" ) ) AND ( EXCLUDE(SUBJAREA,"MEDI" ) OR EXCLUDE(SUBJAREA,"PHYS" ) OR EXCLUDE(SUBJAREA,"AGRI" ) OR	Several subjects were excluded on the basis of condition 1, as they had no connection to seaport performance measurement	2,388 documents were returned

	EXCLUDE(SUBJAREA,"MATE" ) OR EXCLUDE(SUBJAREA,"BIOC" ) OR EXCLUDE(SUBJAREA,"CENG" ) OR EXCLUDE(SUBJAREA,"CHEM" ) OR EXCLUDE(SUBJAREA,"HEAL" ) OR EXCLUDE(SUBJAREA,"NURS" ) OR EXCLUDE(SUBJAREA,"PHAR" ) OR EXCLUDE(SUBJAREA,"NEUR" ) OR EXCLUDE(SUBJAREA,"IMMU" ) OR EXCLUDE(SUBJAREA,"PSYC" ) OR EXCLUDE(SUBJAREA,"DENT" ) OR EXCLUDE(SUBJAREA,"VETE" ) ) AND ( EXCLUDE(SUBJAREA,"ENER" ) )		
4.	TITLE-ABS-KEY ( (port OR seaport OR "container Terminal" OR "port terminal") W/30 ( performance OR efficiency OR effectiveness OR productivity OR competitiveness OR "Economic impact" OR "Environmental impact" ) ) AND ( evaluat* OR measur* OR analy* OR apprais* OR metrics OR indicators ) ) AND NOT ( Microwave OR Antenna OR Robotic OR (Port AND WINE) OR cylinders OR "Diesel engines" OR "Combustion" OR "Packet switching" OR "Telecommunication traffic" OR Chromatography OR "spectrometry" OR "Nonhuman") AND ( LIMIT-TO(DOCTYPE,"ar" ) ) AND ( LIMIT-TO(SRCTYPE,"j" ) ) AND ( EXCLUDE(SUBJAREA,"MEDI" ) OR EXCLUDE(SUBJAREA,"PHYS" ) ) OR EXCLUDE(SUBJAREA,"AGRI" ) OR EXCLUDE(SUBJAREA,"MATE" ) OR EXCLUDE(SUBJAREA,"BIOC" ) OR EXCLUDE(SUBJAREA,"CENG" ) OR EXCLUDE(SUBJAREA,"CHEM" ) OR EXCLUDE(SUBJAREA,"HEAL" ) OR EXCLUDE(SUBJAREA,"NURS" ) OR EXCLUDE(SUBJAREA,"PHAR" ) OR EXCLUDE(SUBJAREA,"NEUR" ) OR EXCLUDE(SUBJAREA,"IMMU" ) OR EXCLUDE(SUBJAREA,"PSYC" ) OR EXCLUDE(SUBJAREA,"DENT" ) OR EXCLUDE(SUBJAREA,"VETE" ) ) AND ( EXCLUDE(SUBJAREA,"ENER" ) )	Search 3 provided a high proportion of Articles unrelated to seaports, in order to reduce the number of results, proximity operators were chosen to connect the key terms Port and Performance.	1,476
5.	AND ( EXCLUDE(EXACTSRCTITLE,"Microprocessors and Microsystems" ) OR EXCLUDE(EXACTSRCTITLE,"Electronics Letters" ) OR EXCLUDE(EXACTSRCTITLE,"Icic Express Letters" ) OR EXCLUDE(EXACTSRCTITLE,"IEEE Transactions on Power Electronics" ) OR EXCLUDE(EXACTSRCTITLE,"Computer Networks" ) OR EXCLUDE(EXACTSRCTITLE,"IEEE ACM Transactions on Networking" ) OR EXCLUDE(EXACTSRCTITLE,"Ocean Engineering" ) ) AND ( EXCLUDE(EXACTSRCTITLE,"Journal of Parallel and Distributed Computing" ) OR EXCLUDE(EXACTSRCTITLE,"Atmospheric Environment" ) OR EXCLUDE(EXACTSRCTITLE,"Computer Communications" ) ) AND ( EXCLUDE(EXACTSRCTITLE,"IEEE Transactions on Very Large Scale Integration VLSI Systems" ) OR EXCLUDE(EXACTSRCTITLE,"Journal of Supercomputing" ) OR EXCLUDE(EXACTSRCTITLE,"International Journal of Electronics" ) OR EXCLUDE(EXACTSRCTITLE,"Earthquake Spectra" ) OR EXCLUDE(EXACTSRCTITLE,"Journal of Propulsion and Power" ) OR EXCLUDE(EXACTSRCTITLE,"Journal of Systems Architecture" ) OR EXCLUDE(EXACTSRCTITLE,"International Journal of Refrigeration" ) OR EXCLUDE(EXACTSRCTITLE,"IEICE Transactions on Communications" ) OR EXCLUDE(EXACTSRCTITLE,"IEICE Transactions on Electronics" ) OR EXCLUDE(EXACTSRCTITLE,"Electronics and Communications in Japan Part II Electronics English Translation of Denshi Tsushin Gakkai Ronbunshi" ) OR EXCLUDE(EXACTSRCTITLE,"IEEE Journal of Solid State Circuits" ) OR EXCLUDE(EXACTSRCTITLE,"Computers and Operations Research" ) OR EXCLUDE(EXACTSRCTITLE,"Journal of Circuits Systems and Computers" ) OR EXCLUDE(EXACTSRCTITLE,"Journal of Computational Information Systems" ) OR EXCLUDE(EXACTSRCTITLE,"ACM Transactions on Design Automation of Electronic Systems" ) OR EXCLUDE(EXACTSRCTITLE,"IEEE Transactions on Vehicular Technology" ) OR EXCLUDE(EXACTSRCTITLE,"International Journal of Automotive Technology" ) OR EXCLUDE(EXACTSRCTITLE,"Applied Soft Computing Journal" ) OR EXCLUDE(EXACTSRCTITLE,"International Review of Electrical Engineering" ) OR EXCLUDE(EXACTSRCTITLE,"Information	Several journals were excluded on the basis of condition 1, as they had no connection to seaport performance measurement.	1,133

Technology Journal" ) OR EXCLUDE(EXACTSRCTITLE,"Optical Switching and Networking" ) OR EXCLUDE(EXACTSRCTITLE,"Journal of High Speed Networks" ) OR EXCLUDE(EXACTSRCTITLE,"Proceedings of the Institution of Mechanical Engineers Part A Journal of Power and Energy" ) OR EXCLUDE(EXACTSRCTITLE,"Journal of Optical Communications and Networking" ) OR EXCLUDE(EXACTSRCTITLE,"Chinese Journal of Mechanical Engineering English Edition" ) OR EXCLUDE(EXACTSRCTITLE,"SAE International Journal of Materials and Manufacturing" ) OR EXCLUDE(EXACTSRCTITLE,"Chinese Journal of Electronics" ) OR EXCLUDE(EXACTSRCTITLE,"Journal of Fluids Engineering Transactions of the ASME" ) )		
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## 2. Academic Search Complete

No.	Search String	Action	Result
1.	TI ( ((port OR seaport OR "container Terminal" OR "port terminal") N30 ( performance OR efficiency OR effectiveness OR productivity OR competitiveness OR "Economic impact" OR "Environmental impact" )) AND ( evaluat* OR measur* OR analy* OR apprais* OR metrics OR indicators) ) OR AB ( ((port OR seaport OR "container Terminal" OR "port terminal") N30 ( performance OR efficiency OR effectiveness OR productivity OR competitiveness OR "Economic impact" OR "Environmental impact" )) AND ( evaluat* OR measur* OR analy* OR apprais* OR metrics OR indicators) )) NOT TX ( (Microwave OR Antenna OR Robotic OR (Port AND WINE) OR cylinders OR "Diesel engines" OR "Combustion" OR "Packet switching" OR "Telecommunication traffic" OR Chromatography OR spectrometry OR Nonhuman)	N/A	1,377
2.	TI ( ((port OR seaport OR "container Terminal" OR "port terminal") N30 ( performance OR efficiency OR effectiveness OR productivity OR competitiveness OR "Economic impact" OR "Environmental impact" )) AND ( evaluat* OR measur* OR analy* OR apprais* OR metrics OR indicators) ) OR AB ( ((port OR seaport OR "container Terminal" OR "port terminal") N30 ( performance OR efficiency OR effectiveness OR productivity OR competitiveness OR "Economic impact" OR "Environmental impact" )) AND ( evaluat* OR measur* OR analy* OR apprais* OR metrics OR indicators) )) NOT TX ( (Microwave OR Antenna OR Robotic OR (Port AND WINE) OR cylinders OR "Diesel engines" OR "Combustion" OR "Packet switching" OR "Telecommunication traffic" OR Chromatography OR spectrometry OR Nonhuman)	<b>Limit to Subject:</b> - analytic hierarchy Process, transshipment, transportation industry, regression analysis, performance, operations research, methodology, economic policy, production (economic theory), management, industrial productivity, harbor security, environmental impact analysis, empirical research, shipment of goods, sensitivity analysis, multiple criteria decision making, estimation theory, data analysis, stochastic analysis, stakeholders, materials handling, logistics, loading & unloading, business logistics, port districts, container ships, computer simulation, numerical analysis, marine terminals, containers, terminals (transportation), strategic planning, economic impact, economic development, supply chains, industrial efficiency, competition (economics), infrastructure (economics), comparative studies, cost effectiveness, freight & freightage, cargo handling,	177

		decision making, mathematical optimization, containerization, data envelopment analysis, transportation, mathematical models, algorithms, container terminals, performance evaluation, shipping (water transportation), research, simulation methods & models, harbors	
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### 3. Business Source Complete

No.	Search String	Action	Result
1.	TI ( ((port OR seaport OR "container Terminal" OR "port terminal") N30 ( performance OR efficiency OR effectiveness OR productivity OR competitiveness OR "Economic impact" OR "Environmental impact" )) AND ( evaluat* OR measur* OR analy* OR apprais* OR metrics OR indicators) ) OR AB ( ((port OR seaport OR "container Terminal" OR "port terminal") N30 ( performance OR efficiency OR effectiveness OR productivity OR competitiveness OR "Economic impact" OR "Environmental impact" )) AND ( evaluat* OR measur* OR analy* OR apprais* OR metrics OR indicators) ) ) NOT TX ( (Microwave OR Antenna OR Robotic OR (Port AND WINE) OR cylinders OR "Diesel engines" OR "Combustion" OR "Packet switching" OR "Telecommunication traffic" OR Chromatography OR spectrometry OR Nonhuman)	N/A	649 Articles
	TI ( ((port OR seaport OR "container Terminal" OR "port terminal") N30 ( performance OR efficiency OR effectiveness OR productivity OR competitiveness OR "Economic impact" OR "Environmental impact" )) AND ( evaluat* OR measur* OR analy* OR apprais* OR metrics OR indicators) ) OR AB ( ((port OR seaport OR "container Terminal" OR "port terminal") N30 ( performance OR efficiency OR effectiveness OR productivity OR competitiveness OR "Economic impact" OR "Environmental impact" )) AND ( evaluat* OR measur* OR analy* OR apprais* OR metrics OR indicators) ) ) NOT TX ( (Microwave OR Antenna OR Robotic OR (Port AND WINE) OR cylinders OR "Diesel engines" OR "Combustion" OR "Packet switching" OR "Telecommunication traffic" OR Chromatography OR spectrometry OR Nonhuman)	<b>Limit to Subject:</b> - maritime management, economic aspects, developing countries, bootstrapping (statistics), harbors -- india, harbors -- economic aspects, unitized cargo systems, cranes, derricks, etc., containers , comparative studies, marine terminals, competition, data envelopment analysis, container terminals, harbors	224 Articles

### 4. Econlit

No.	Search String	Action	Result
1.	((port OR seaport OR "container Terminal" OR "port terminal") N30 ( performance OR efficiency OR effectiveness OR productivity OR competitiveness OR "Economic impact" OR "Environmental impact" )) AND ( evaluat* OR measur* OR analy* OR apprais* OR metrics OR indicators) ) OR AB ( ((port OR seaport OR "container Terminal" OR "port terminal") N30 ( performance OR efficiency OR effectiveness OR	N/A	232 Articles

	<p>productivity OR competitiveness OR "Economic impact" OR "Environmental impact" ) ) AND ( evaluat* OR measur* OR analy* OR apprais* OR metrics OR indicators) ) ) NOT TX ( (Microwave OR Antenna OR Robotic OR (Port AND WINE) OR cylinders OR "Diesel engines" OR "Combustion" OR "Packet switching" OR "Telecommunication traffic" OR Chromatography OR spectrometry OR Nonhuman) ) Scholarly (Peer Reviewed) Journals on 2015-09-10 08:07 AM"</p>		
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# Appendix B – Interview Guide

## Introduction

In preparation for this interview you are asked to consider how the Port Company makes decisions to develop capacity over a standard strategic/master planning time horizon (10-15, years) and in the context of the Port Company's longer term vision for port development.

In particular please consider how the Port Company has chosen to pursue its current development option<sup>36</sup>.

To facilitate this process, please consider the port's current capacity development cycle and subsequent development plans in the context of the following questions.

## Questions:

1. How does the Port Company plan for capacity development?
2. What are the capacity development requirements identified by the Port Company?
3. What criteria are relevant to the Port of X when making decisions between various capacity development options?
4. What influences the relative importance of these criteria?
5. How does the Port Company evaluate the existing performance of the port?

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<sup>36</sup> Development options refer to any combination or program of structural and non-structural measures as part of a port investment strategy.

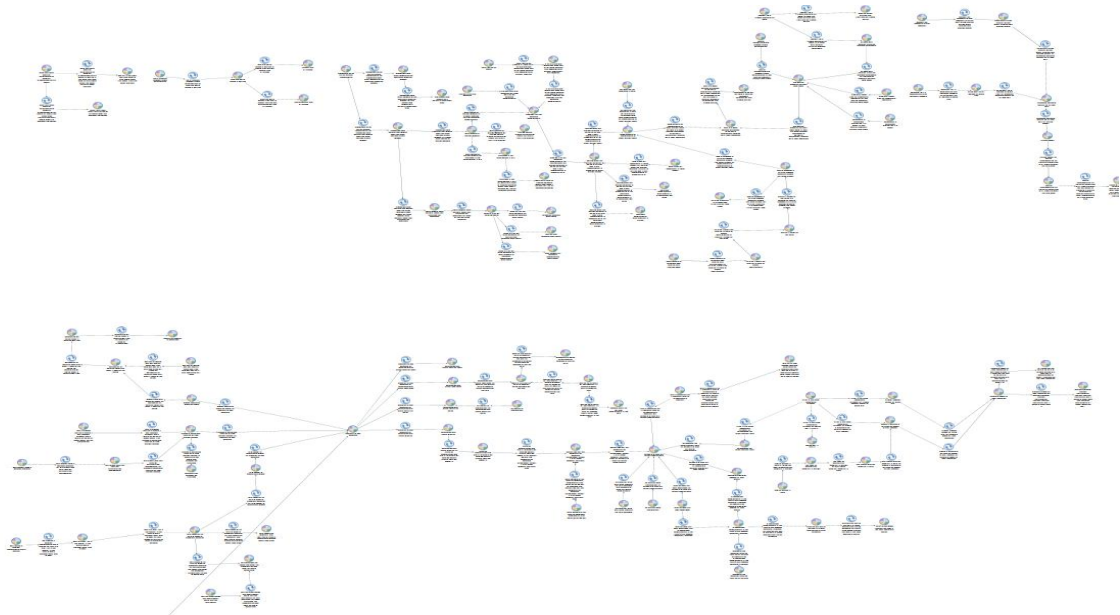
Structural measures refer to projects that expand the ports fixed capacity and generally require a high level of capital investment.

Non-structural measures are designed to increase utilisation of existing capacity and generally relate to technological, managerial, economic and regulatory measures that a) improve the handling capability of the port, or b) affect port users' behaviour.

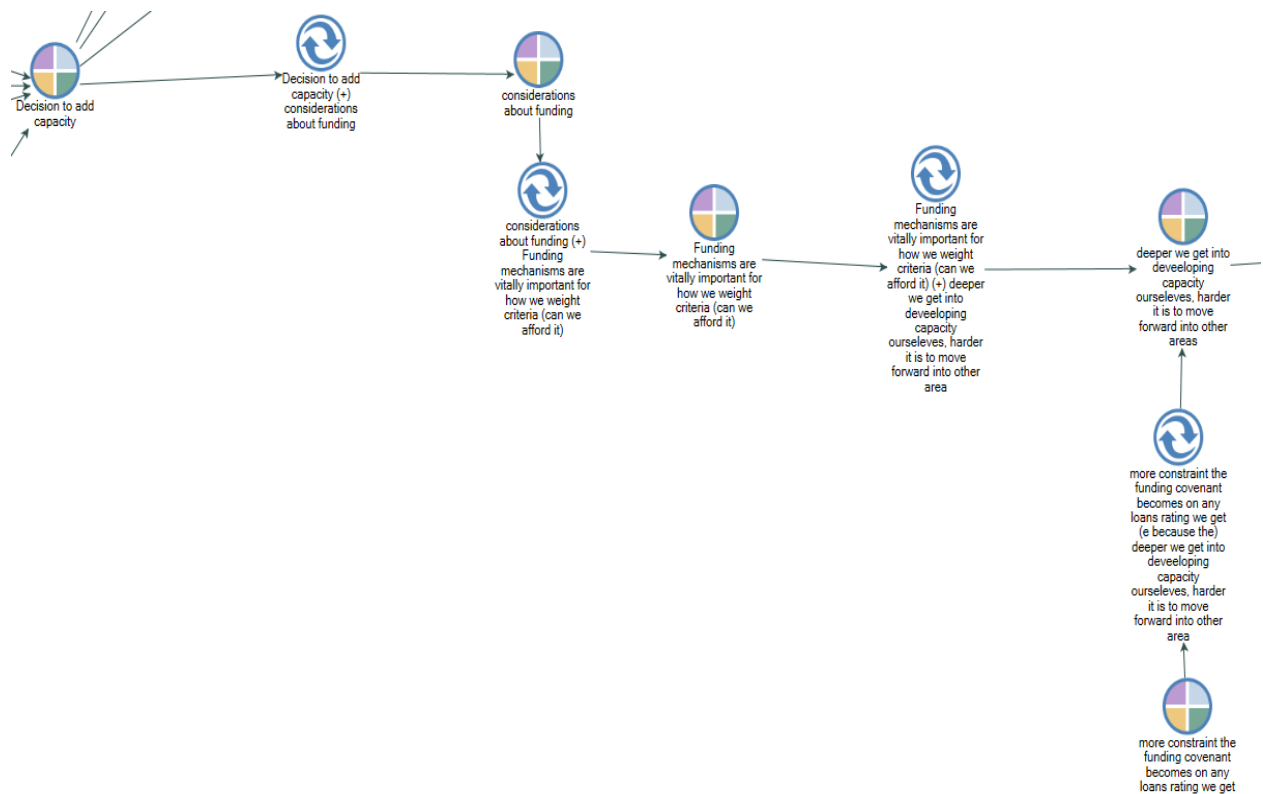
Measures may also include efforts to develop infrastructure not fully under the control of the port authority but deemed essential for port development (e.g., transport infrastructure connecting the port to its hinterland.)

# Appendix C- Sample of Generated Causal Map

## A. Broad overview of a Section of Causal map



## B. Sample of Causal map



**Interpretation of B:** Here the interviewee is discussing the significance of the capability to fund development as a critical criteria for deciding between development options. Multi-coloured shapes indicate concepts while the blue cycle shapes signify the nature of the relationship between concepts.

The relationship types adapted from Huff et al., 1990 in Huff (ed) Mapping Strategic Thought, John Wiley and Sons, Chichester are listed below.

1. /+/
  - Positively affects
  - Facilitates
  - Advances
  - Increases
  - Makes better
  - Helps
  - Promotes
  - Expediates
  - Makes possible
  - Is necessary for
2. /-/
  - Negatively affects
  - Makes difficult
  - Hinders
  - Hurts
  - Impedes
  - Prevents
  - Inhibits
  - Changes for the worse
3. /0+/
  - Won't positively affect
  - Wont help
  - Wont promote
  - Is of no benefit to
  - (construct negatives of /+/ above)
4. /0-/
  - Wont affect negatively
  - Wont hurt
  - (construct negatives of /-/ above)
5. /m/
  - Affects in some nonzero way
  - Somehow affects
  - In some way affects
6. /O/
  - Has no effect on
  - Has no relation to
  - Does not matter for

7.  $/=$ 
  - is equivalent to
  - is the same as
  - is defined as
8.  $/\neq$ 
  - is not the same as
9.  $/\in$ 
  - is a member of
  - is an example of
  - belongs to set
10.  $/\notin$ 
  - is not a member of

## Appendix D – Documentary Sources Used in Chapter 6.

<b>Title</b>	<b>Reference</b>	<b>Available</b>
Dublin Port Masterplan Internal Report #1 Analysis of Ro-Ro Requirements	Dublin Port Company. (2011) <i>"Dublin Port Masterplan Internal Report #1 Analysis of Ro-Ro Requirements"</i>	<a href="https://www.dublinport.ie/masterplan/masterplan-documents/">https://www.dublinport.ie/masterplan/masterplan-documents/</a>
Dublin Port Masterplan Internal Report #2 Analysis of Lo-Lo Requirements	Dublin Port Company. (2011) <i>"Dublin Port Masterplan Internal Report #2 Analysis of Lo-Lo Requirements"</i>	<a href="https://www.dublinport.ie/masterplan/masterplan-documents/">https://www.dublinport.ie/masterplan/masterplan-documents/</a>
Dublin Port Masterplan Internal Report #3 Analysis of Options for Cruise Facilities	Dublin Port Company. (2011) <i>"Dublin Port Masterplan Internal Report #3 Analysis of Options for Cruise Facilities"</i>	<a href="https://www.dublinport.ie/masterplan/masterplan-documents/">https://www.dublinport.ie/masterplan/masterplan-documents/</a>
Dublin Port Masterplan Internal Report #5 Trade Cars 27th September	Dublin Port Company. (2011) <i>"Dublin Port Masterplan Internal Report #5 Trade Cars 27th September"</i>	<a href="https://www.dublinport.ie/masterplan/masterplan-documents/">https://www.dublinport.ie/masterplan/masterplan-documents/</a>
Dublin Port Masterplan Internal Report #6 Oil Zone	Dublin Port Company. (2011) <i>"Dublin Port Masterplan Internal Report #6 Oil Zone"</i>	<a href="https://www.dublinport.ie/masterplan/masterplan-documents/">https://www.dublinport.ie/masterplan/masterplan-documents/</a>
Dublin Port Masterplan Internal Report #7 Franchises and Pricing Incentives	Dublin Port Company. (2011) <i>"Dublin Port Masterplan Internal Report #7 Franchises and Pricing Incentives"</i>	<a href="https://www.dublinport.ie/masterplan/masterplan-documents/">https://www.dublinport.ie/masterplan/masterplan-documents/</a>
Dublin Port Masterplan Internal Report #8 Integrating the Port with Dublin City and its people Societal integration and the soft values	Dublin Port Company. (2011) <i>"Dublin Port Masterplan Internal Report #8 Integrating the Port with Dublin City and its people Societal integration and the soft values"</i>	<a href="https://www.dublinport.ie/masterplan/masterplan-documents/">https://www.dublinport.ie/masterplan/masterplan-documents/</a>
Dublin Port Master Plan Issues Paper Unitised Trade Trends Report	Hobbs, Kevin. (2011) <i>"Dublin Port Master Plan Issues Paper Unitised Trade Trends Report"</i>	<a href="https://www.dublinport.ie/masterplan/masterplan-documents/">https://www.dublinport.ie/masterplan/masterplan-documents/</a>
Medium to long-term prospects for bulk trade volumes at Dublin Port	DKM Consultants. (2011) <i>"Dublin Port Master Plan Issues Paper Unitised Trade Trends Report"</i>	<a href="https://www.dublinport.ie/masterplan/masterplan-documents/">https://www.dublinport.ie/masterplan/masterplan-documents/</a>
DUBLIN PORT COMPANY MASTERPLAN 2012-2040	Dublin Port Company. (2012) <i>"DUBLIN PORT COMPANY MASTERPLAN 2012-2040"</i>	<a href="https://www.dublinpo*rt.ie/masterplan/masterplan-documents/">https://www.dublinpo*rt.ie/masterplan/masterplan-documents/</a>

Dublin Port Masterplan 2040 Reviewed 2018	Dublin Port Company. (2018) " <i>Dublin Port Masterplan 2040 Reviewed 2018</i> "	<a href="https://www.dublinport.ie/masterplan/masterplan-documents/">https://www.dublinport.ie/masterplan/masterplan-documents/</a>
Dublin Port Annual Report (2010 -2018)	Dublin Port Company. (2010 -2018) " <i>Dublin Port Annual Report</i> "	<a href="https://www.dublinport.ie/about-dublin-port/annual-reports/">https://www.dublinport.ie/about-dublin-port/annual-reports/</a>
Dublin Port Company Franchise Review Consultation Document	Dublin Port Company. (2014) " <i>Dublin Port Company Franchise Review Consultation Document</i> "	No longer available online, however available from author on request.
RINGASKIDDY PORT REDEVELOPMENT	Port of Cork. (2014) " <i>RINGASKIDDY PORT REDEVELOPMENT</i> "	<a href="https://www.portofcork.ie/index.cfm/page/strategicdevelopmentplan20101">https://www.portofcork.ie/index.cfm/page/strategicdevelopmentplan20101</a>
Port of Cork Annual Report (2010 -2018)	Port of Cork. (2010-2018) " <i>Port of Cork Annual Report</i> "	<a href="https://www.portofcork.ie/index.cfm/page/strategicdevelopmentplan20101">https://www.portofcork.ie/index.cfm/page/strategicdevelopmentplan20101</a>
Strategic Development Plan 2010	Port of Cork. (2010-2018) " <i>Strategic Development Plan 2010</i> "	<a href="https://www.portofcork.ie/index.cfm/page/strategicdevelopmentplan20101">https://www.portofcork.ie/index.cfm/page/strategicdevelopmentplan20101</a>
Vision 2041	Shannon Foynes Port Company. (2013) " <i>VISION   2041</i> "	<a href="https://www.sfpc.ie/about-us/port-development/sfpc-masterplan/">https://www.sfpc.ie/about-us/port-development/sfpc-masterplan/</a>
Shannon Foynes Port Company Annual Reports (2010 -2018)	Shannon Foynes Port Company. (2010 -2018) " <i>Shannon Foynes Port Company Annual Reports (2010 -2018)</i> "	<a href="https://www.sfpc.ie/information-publications/annual-reports/">https://www.sfpc.ie/information-publications/annual-reports/</a>
SHANNON FOYNES PORT COMPANY ECONOMIC IMPACT ASSESSMENT	Shannon Foynes Port Company. (2016) " <i>SHANNON FOYNES PORT COMPANY ECONOMIC IMPACT ASSESSMENT</i> "	<a href="https://www.sfpc.ie/information-publications/sfpc-port-economic-activity-impact-study/">https://www.sfpc.ie/information-publications/sfpc-port-economic-activity-impact-study/</a>
Corporate Plan 2017 – 2021	Port of Waterford. (2017) " <i>Corporate Plan 2017 - 2021</i> "	<a href="http://www.portofwaterford.com/uploads/download/PoW_Corporate_Plan_2017-2021.pdf">http://www.portofwaterford.com/uploads/download/PoW_Corporate_Plan_2017-2021.pdf</a>
Port of Waterford Annual Reports (2010 -2018)	Port of Waterford. (2010-2018) " <i>Port of Waterford Annual Reports (2010 -2018)</i> "	<a href="http://www.portofwaterford.com/corporate-documents">http://www.portofwaterford.com/corporate-documents</a>

<p>Iarnród Éireann Annual Reports (2010-2018)</p>	<p>Iarnród Éireann. (2010-2018)  <i>"Iarnród Éireann Annual Reports (2010-2018)"</i></p>	<p><a href="https://www.irishrail.ie/About-Us/Company-Information/Iarnrod-Eireann-Annual-Reports">https://www.irishrail.ie/About-Us/Company-Information/Iarnrod-Eireann-Annual-Reports</a></p>
<p>Strategic Review on Ownership and Operations of Rosslare Europort</p>	<p>Department of Transport Tourism and Sport (2013)  <i>"Strategic Review on Ownership and Operations of Rosslare Europort"</i></p>	<p><a href="http://dttas.old.gov.ie/sites/default/files/foi-decisions/2017foi214-combined-redacted.pdf">http://dttas.old.gov.ie/sites/default/files/foi-decisions/2017foi214-combined-redacted.pdf</a></p>