THE IMPACT OF PORT TECHNICAL EFFICIENCY ON MEDITERRANEAN CONTAINER PORT COMPETITIVENESS

By

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DEDICATIONS

To my wife and my daughter who have morally supported me with their unlimited love throughout my study at the University of Huddersfield,

I dedicate this work

ACKNOWLEDGEMENT

First and foremost, I give thanks to God Almighty for providing me with the conformation, strength, patience and good health for completing my study successfully.

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ABSTRACT

Port efficiency is a significant element that stimulates port competitiveness and enhances regional development. With increasing international maritime traffic and changing technology in the maritime transport sector, containerisation and enhanced logistic activities, infrastructure might be one of the main determining factors of port competition (Merk & Dang, 2012). Due to the increasing container traffic and the high quality of service required by the shipping lines, Mediterranean container ports are being compelled to enhance port efficiency to improve comparative advantages that will increase cargo traffic and satisfy the customers' requirements. The Mediterranean Sea is a link point between Europe, Africa and Asia. This research aims to examine the impact of ports' technical efficiency on the improvement of Mediterranean container ports' competitiveness. The research analyses the competitiveness and the relative efficiency of the top 22 container ports in the Mediterranean basin using a cross-section, panel data and window analysis application of data envelopment analysis (DEA) for the period between 1998 and 2012. The selected 15 year period enables the analysis of Mediterranean container port market dynamics and the benchmarking of the technical efficiency of the selected ports for three consecutive market cycles. This research can be classified as quantitative analytical research. The research follows the concept of the Industrial Organization (IO) and the Structuralism (Harvard school) methodology that analyses the market Structures, Conduct and Performance (SCP) of market players.

The study conducts a simultaneous three-stage procedure: in the first stage, the competitiveness of the main container ports in the Mediterranean is analysed through the study of market structure and conduct. Market structure is assessed through measuring and analysing market concentration by using four different methods. These methods are: the K-Firm concentration ratio (K-CR), Hirshman-Herfindahl Index (HHI), the Gini coefficient (GC) and the generalized entropy index. Boston Consultant Group (BCG) matrix is also used to visualize the dynamics between ports in the defined market and assess the ports' competitive position. Market conduct is analysed using shift-share analysis (SSA) to get a thorough understanding of the issue of port traffic development.

In the second stage, market performance is analysed through the use of the non-parametric models of Data Envelopment Analysis (DEA) which estimates the relative efficiency scores and ranking seaports according to their efficiency. Five DEA models are adopted for comparative purpose, the DEA- CCR, DEA-BCC, the Super-Efficiency (A&P, 1993), the sensitivity analysis and slack variable analysis models. In the third stage, to examine the impact of port efficiency on port competitiveness, a number of hypotheses are examined through the use of parametric correlation coefficients (Spearman's rank order) and Simar and Wilson (2007) procedure to bootstrap the DEA scores with a truncated regression. Using this approach enables more reliable evidence compared to previous studies analysing the efficiency of seaports.

The main findings demonstrate that the recent deconcentration tendency of the Mediterranean container port market is due to the increased number of market players which will in turn reshape the market structure, change the container port hierarchy and intensify the competition between ports as the market shifts from oligopoly to pure competition. The research findings also reveal the existence of inefficiency pertaining to the management of container ports in the region, since the total technical efficiency is found to be below 50% on average. This relatively limited

technical efficiency of the Mediterranean container ports indicates the need for appropriate capital investments for ports' infra/superstructure. In particular, those ports whose efficiency is not favoured by some factors such as size, geographical position and socio-economic conditions of the region in which they are located, must adopt suitable reform strategies to promptly improve their efficiency and competitive position. What differentiates this work from previous studies on the subject is that both cross-sectional and panel data have been collected and analysed at the level of individual container ports in the Mediterranean. The study is based on a wide range of methodologies, both parametric and non-parametric, that have ensured the validity of the empirical examination that has been undertaken and the results obtained. The research analysed the Mediterranean container ports competitiveness, benchmarked and ranked their efficiency by considering the Mediterranean in its totality, including South Europe, Middle East and North Africa. The study puts forward a way to assess container port efficiency based on simple, yet validated and meaningful physical efficiency measures.

LIST OF PUBLICATIONS

The research carried out and presented in this doctoral thesis has partly been published in the following earlier publications.

1. Elsayeh, M.M., Hubbard, N.J., and Tipi, N.S. (2015) ‘Benchmarking the operational efficiency of the main gateway container ports in the Mediterranean: An application of DEA panel data analysis’. *International Journal of Logistics Research and Applications*. (Forthcoming).

2. Elsayeh, M.M., Hubbard, N.J., and Tipi, N.S. (2014) ‘The impact of port technical efficiency on port competitiveness –The case of Mediterranean container ports’. International conference of Logistics and Research Network (LRN), University of Huddersfield, Huddersfield, UK.

3. Elsayeh, M.M., Hubbard, N.J., and Tipi, N.S. (2012) ‘The Dynamics of market concentration and its impact on Mediterranean container ports' competitiveness’. World Conference of Transport Research (WCTRS), University of Antwerp, Antwerp, Belgium.

4. Elsayeh, M.M., Hubbard, N.J., and Tipi, N.S. (2011) ‘An Assessment of hub-ports competitiveness and its impact on the Mediterranean container market structure’. International conference of Logistics and Research Network (LRN), Southampton University, Southampton, UK.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Symbol	Abbreviation
3PL	third-party logistics service provider
A&P	Anderson & Peterson (1993) DEA model
AE	Aggregate technical efficiency
AHP	Analytic Hierarchy Process technique
ANOVA	Analysis Of Variance
APM	A.P. Moller–Maersk Group
ASEAN	Association of Southeast Asian Nations
BCC	Banker, Charnes and Cooper (1984) DEA model
BCG	Boston Consulting Group matrix
BRIC	The countries of Brazil, Russia, India and China
CCR	Charnes, Cooper and Rhodes, (1978) DEA model
CHKY	(COSCO, Hanjin, K-line and Yang Ming) shipping alliance
CI	Containerisation International
CR	Concentration Ratio
CRS	Constant returns to scale
D&G	Doyle and Green (1994) DEA model
DEA	Data Envelopment Analysis
DMU	Decision Making Units
DP	Dubai Port
DRS	Decreasing Returns to Scale
ECT	European Container Terminal

EDI	Electronic Data Interchange
EI	Entropy Index
EU	European Union
EVA	Economic Value Added
FCL	Full Container Load
FDH	Free Disposal Hull
FDI	Foreign Direct Investment
FEU	Forty foot Equivalent Unit
FMGC	Fuzzy Multi-criteria Grade Classification
FTA	Free Trade Area
GC	Gini Coefficient
GDP	Gross Domestic Production
GRA	Grey Relation Analysis
GRT	Gross registered tonnage
HHI	Hirschman-Herfindahl Index
IE	Industrial Economy
IO	Industrial Organisation
IRS	Increasing Returns to Scale
ITF	International Transport Federation
K-CR	K-firm Concentration Ratio
LCL	Less than Container Load
Lo/Lo	Lift-on, Lift-off

LP	Linear Programs
M/V	Motor Vessel
MCDM	Multi Criteria Decision Making
MERCOSUR	is a Spanish acronym for Mercado Común del Sur including Argentina, Brazil, Paraguay and Uruguay trading block
MITT	Myanmar International Terminal Thilawa
MPSS	Most productive scale size
MSC	Mediterranean Shipping Company
NAFTA	North American Free Trade Agreement
NRT	Net Registered Tonnage
OCRA	Operational Competitiveness Rating Analysis
OECD	Organisation for Economic Cooperation and Development
OLS	Ordinary Least Square
PCD	Port Competitiveness Degree
PRD	Pearl River Delta region
PSA	Port Singapore Authority
PTE	Pure Technical Efficiency
PUC	Port User Cost
R&D	Research & Development
RMGs	Rail-Mounted Gantry cranes
Ro/Ro	Roll On/Roll Off
RTGs	Rubber-Tyred Gantry cranes
RTS	Returns to Scale

RTW	Round The World routes
SBUs	Strategic Business Units
SCCT	Suez Canal Container Terminal
SCP	Structure, Conduct and Performance
SE	Scale Efficiency
SEF	Strongly Efficient Frontier
SFA	Stochastic Frontier Analysis
SIE	Scale Inefficient
SIF	Strongly Inefficient Frontier
SOMs	Self-Organised Maps
SPSS	Statistical Package for the Social Sciences - Software
SSA	Shift-share analysis
SWOT	Strength, Weaknesses, Opportunities and Threats
TE	Technical Efficiency
TEU	Twenty foot Equivalent Unit
TFP	Total Factor Productivity
THC	Terminal Handling Charges
TIE	Technical Inefficiency
UK	United Kingdom
ULCSs	Ultra-large Container Ships
UNCTAD	United Nations Conference on Trade and Development
VRS	Variable Return to Scale

CHAPTER ONE

INTRODUCTION & RESEARCH FRAMEWORK

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INTRODUCTION & RESEARCH FRAMEWORK

1.1 Introduction

Throughout the era of containerisation, maritime transportation of containerised cargoes has significantly improved trade between nations through reduction of handling time, labor costs, and packing costs. Specialisation and technological development in the shipping industry have enhanced the efficiency of international shipping and port operations over the past two decades (Luo et al, 2009). The use of containers allows the integration between freight transportation modes by providing a higher flexibility to movements and a standardisation of loads (Rodrigue et al, 2013). The container has significantly contributed to the adoption of intermodal transportation which has led to great change in the transport sector. Container trade has grown to represent about 17 per cent of international seaborne trade by volume and 52 per cent by value (UNCTAD, 2012).

Container traffic has grown not just at the expense of the break bulk cargoes carried by other means but also through increased international trade. Recent studies explain that while the global seaborne trade doubled from 3.6 billion tons in 1985 tons 7.9 billion tons in 2007, the containerised traffic increased about eight times within the same period from 160 million tons to 1.3 billion tons (UNCTAD, 2008). World container trade grew by 7.1 per cent in 2011, down from a 12.8 per cent rise between 2009 and 2010. Total container traffic amounted to 151 million TEUs in 2011, equivalent to about 1.4 billion tons (UNCTAD, 2013a). The three main trade routes totalled 47.3 million TEUs, while the non-main trades routes reached to 103.3 million TEUs (Clarkson Research Service, 2012). This illustrates the significant role of container transportation and its contribution to the global economy. The containerised traffic expanded in 2012 to reach 155 million TEUs (Clarkson Research Services, 2013). Containerized trade, which accounted for 65 per cent of other dry cargo, increased by 3.2 per cent in 2012, down from 13.1 per cent in 2010 and 7.1 per cent in 2011 (UNCTAD, 2013a).

Over the last few decades, container transport has characterised the development of maritime transport and its importance has grown beyond the most optimistic of expectation. The number of containers handled in ports worldwide was well over 200 million TEUs in the year 2000 and increased up to 300 million TEUs in 2005. World container ports throughput grew by about 3.78 per cent to 601.76 million TEUs in 2012. This increase was lower than the expected 7.3 per cent increase of 2011. The most reliable prediction expects that this figure will reach to 700 million TEUs by 2015 (Degerlund, 2013a). This prediction could be considered rash at a time when the maritime transport sector is often subject to times of uncertainty, but objectively it must be emphasised that the phenomenon is following a growing trend which does not seem to be slowing down.

Container transportation plays a significant role in such development and changes, by and large because of the various economic and technical advantages it has over conventional modes of transportation, standing over the vital interface of land, sea and inland transportation. In terms of traditional port operations, containerisation has significantly enhanced port efficiency and service, mainly because it enables ports to gain the maximum benefits of economies of scale and scope (Cullinane & Wang, 2010). Therefore, shipping lines and container ports are respectively aiming to use container ships and effective container handling systems. On the other hand, many container ports no longer enjoy their monopolistic position of handling cargoes within their hinterland; they are not only interested in whether they can merely handle cargoes, but also whether they can attract such cargoes (Cullinane & Wang, 2010).

The great part of liner traffic based on Round the World routes (RTW), mainly linking the Far East with the North American East Coast through the Pacific Ocean and Panama Canal, has shifted to transatlantic pendulum routes which cross the Mediterranean Sea. As shown in Figure 1.1, the Pendulum routes link three areas: North America, Europe and the Far East, which alone guarantee more than 80% of internationally traded containerised goods in imports and exports.

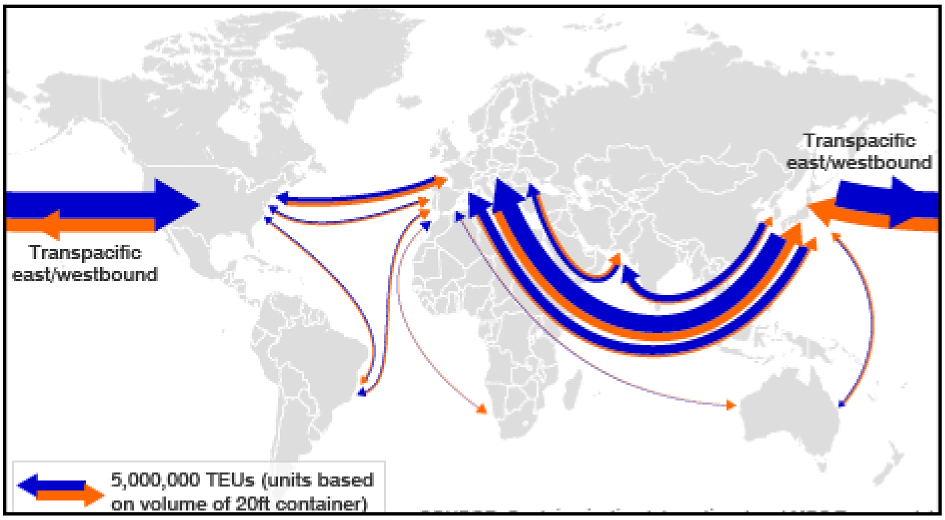

Figure 1.1- Main liner shipping trade routes

Source: Containerisation International and MDS Transmodal (2008). Retrieved from the World Wide Web: http://news.bbc.co.uk/2/hi/business/7700818.stm

Many ports have adapted to this changing pattern of trade by establishing infrastructure development plans to increase their market share of containerised cargoes. Increased port throughput may increase the port's revenue collected through port dues or cargo handling fees. However, increased cargo volumes driven by increased competition between ports could significantly enhance the chances of return cargoes becoming available. This could lead to improved connectivity and lower transport costs per unit, to the benefit of the end customers (UNCTAD, 2013a).

While not every port may have the ability to accommodate the latest ULCS vessel, their existence has an implication for all ports. Only some of the world's biggest ports on the East-West trade routes will be served by ULCSs. However, displaced ships will deploy elsewhere and bring changes to other ports. Drewry shipping consultant (2007) highlighted that the first-generation post-Panamax type vessels with a draft of 14.5 meters, which are too young to be scrapped, are still operating on the main East-West trade routes. These vessels are still too big for the majority of African ports excluding those located in South Africa, Egypt and Morocco. Figure 1.2 illustrates the evolution of container ships over last sixty years (UNCTAD, 2013a).

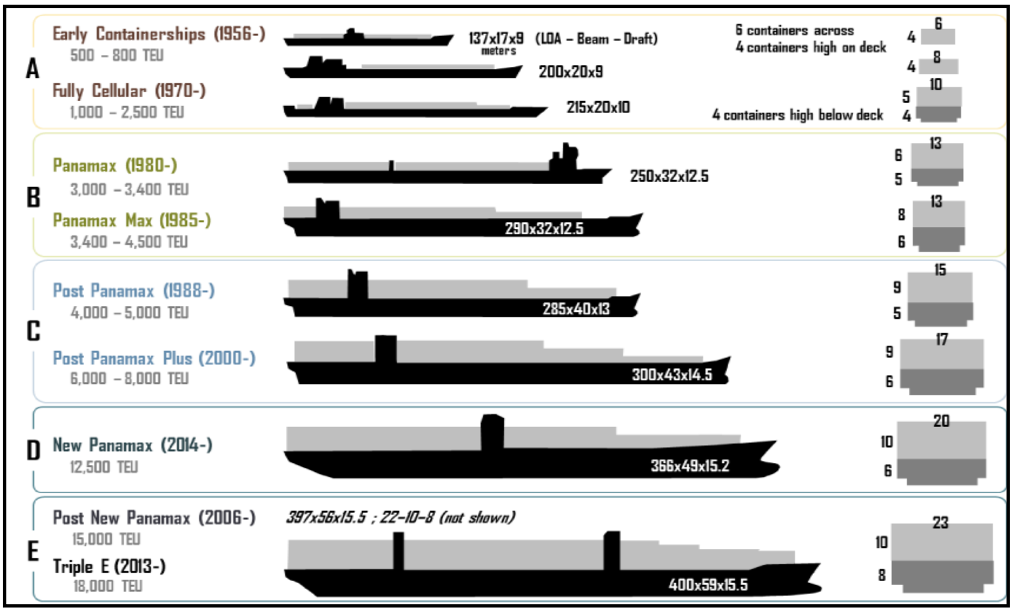

Figure 1.2- Evolution of container ships

Source: Ashar and Rodrigue, (2012). Copyright Dr. Jean-Paul Rodrigue, Dept. of Global Studies & Geography, Hofstra University, New York, USA.

Note: All dimensions are in metres. LOA: Length overall.

The large size of container vessels significantly affects the container ports efficiency. Because ports are location specific, container port competition was not very rigorous. However, with the significant growth of transhipment traffic in relation to the total container port traffic (Drewry Shipping Consultants, 2006), the geo-economic nature of container ports has been changed, and container port competition has intensified (Liu, 2010).

Recently, container ports are not only competing with adjacent ports, but also with ports located in other regions. For example, due to the enhanced land transportation networks and the increased transhipment traffic, the Port of Algeciras, located in Spain in the Mediterranean basin, competes with the Port of Antwerp in Belgium in Northern Europe (liu, 2010; Notteboom, 2012).

The trade routes link the Suez Canal and the Mediterranean ports have been very important as they link Asian and European ports. In the era of containerisation, the old Mediterranean container ports have developed their roles; the new ports have established relatively new strategies, such as transhipment and logistics networks. As land-bridges are becoming highly significant in the supply chains, the Mediterranean container ports try also to enhance their position in the new market structure, either by linking southern and northern European markets or by extending their services to the regions far from the main trade route of Suez – Gibraltar (Pace, 2000; Schinas & Papadimitriou, 2003).

Nevertheless, many of them faces different institutional operation patterns, local conditions and, more importantly, some of them are not able to compete for a niche in the international port market. Due to the increased number of container ports and container traffic, the clarity of the Mediterranean container port market becomes more difficult and cargo traffic will follow complex patterns based on cost and efficiency rather than national and cultural fragmentation. The Mediterranean ports will seek for new role in the market; some of these ports will act as hubs and others as local gates (Zohil and Prijon, 1999; Schinas & Papadimitriou, 2003). Academics (Notteboom, 1997, 2009a, 2012; Fageda, 2000) have tried to study whether the Mediterranean basin is a unique market in the sense that markets that are usually affected by political changes and needs are influenced by the ideas of the nations served by the new cargo traffic patterns and finally the applied polices of ports (Schinas & Papadimitriou, 2003).

In this context, competition between ports in the Mediterranean container market is strongly affected by the number of sub-markets that each port is able to compete in. However, the ability of a port to compete depends on various factors such as location, accessibility, connections, equipment, turn-round time, monetary cost, service quality, productivity and others (Notteboom, 2010). These factors together form a market appropriate for each port. To be competitively attractive, ports have to establish and maintain a reputation for reliability and efficiency that enabling the maintenance of competitively low prices so that they can not only retain their existing customers but also attract new business (UNCTAD, 2001).

The studies that focus on the Mediterranean container ports tend to be limited in scope; they use data from one single country such as Italy (Musso et al, 2013) and Spain (Manzano et al, 2009) or use only the Mediterranean ports in the European Union (Notteboom, 2010; 2012). This is mainly due to limitations in data availability and difficulties in collecting data for such a large and diverse group of ports, belonging to various countries and different continents. This research considers the Mediterranean in its totality, including south Europe, Middle East and North Africa. The research tests the theory of industrial organisation and SCP approach and develops a model that can assess the impact of port efficiency on port competitiveness.

This research focuses on studying and assessing the competitiveness and the relative technical efficiency of 22 container ports in the Mediterranean market. These ports are classified into two main categories. The first category presents the existing hub ports including GioiaTauro, Algeciras, Marsaxlokk, Tangier-Med and Port Said. The second category is the gateway ports of Piraeus, Valencia, Barcelona, Ambarli, Genoa, Haifa, La Spezia, Mersin, Izmir, Taranto, Constantza, Livorno, Naples, Alexandria, Damietta, Cagliari and Marseilles. The selection of ports under study is based on their location and the container traffic served, since these ports share the same foreland. Moreover, these ports represent the large and medium-sized container ports in the defined market with container throughput greater than 500,000 TEUs in the year of 2012 (Degerlund, 2013b).

The research assesses the impact of port technical efficiency on port competitiveness in the Mediterranean container market for the 15 year period between 1998 and 2012. The rationale for using the 15 year period is to analyse the market dynamics, ports' competitiveness and to benchmark the ports' technical efficiency for three consecutive market cycles. Using this period also allows the study of market dynamics and technical efficiency before and after the world economic crisis that took place in 2008 and 2009. Moreover, using the panel data for 15 year period enables analysis of the change of the competitiveness and technical efficiency of ports under study.

The aim of this chapter is to provide the theoretical framework of this research. The remainder of this chapter is organised as follows. Section two defines the research importance, problem, aim and objectives. The research questions, hypotheses and the methodological tools employed in this research are illustrated in section three. Section four explains the area of study and the conceptual research framework. Section five illustrates the research significance and contribution and outlines the thesis structure. A summary of the chapter is presented in section six.

1.2 Importance of studying ports' efficiency and competitiveness

Shipping capacity for the trade between the Mediterranean and the Far East is offered by routes connecting both areas directly and indirectly. It also includes the shipping capacity offered by the pendulum services and round-the-world (RTW) services which are passing the Mediterranean thereby connecting it with the Far East and North America (Miglior et al, 2003).

The geographically strategic location of transhipment and some gateway ports in the Mediterranean have encouraged modern liner shipping companies to make short duration calls upon them (Salem et al, 2008).This in turn has intensified the competition between ports in the Mediterranean as a port's main objective is to attract more customers in order to be able to maintain or even enhance its competitive position, increase market share and accordingly maximize profits. In doing so, ports should, to a large extent, be customer oriented by consistently improving operational performance, efficiency and quality of service.

Thus, it is very important to analyse the efficiency of individual container ports for the survival and competitiveness of the industry and its players (Cullinane et al, 2006). Such an analysis can not only provide a powerful management tool for port operators and managers in the Mediterranean market, but it also forms an important input for informing regional and national port planning and operations (Filippini and Prioni, 1994; Oum and Yu, 1994; Regan and Golob, 2000; Adler and Golany, 2001). However, it is important to note, that this research is aimed solely at comparing various estimates of the efficiency of the industry. Alluding to the significant level of competition within the industry provides merely a justification for doing so.

1.3 Research problem

The great part of traffic based on Round the World routes (RTW), mainly linking the Far East with the North American East Coast through the Pacific Ocean and Panama Canal, has shifted to transatlantic pendulum routes which cross the Mediterranean Sea. The Pendulum routes link three areas; North America, Europe and the Far East, which alone guarantee more than 80% of internationally traded containerised goods in imports and exports (UNCTAD, 2013a).

The competitiveness level of the container ports changes as a result of changes in the relative costs of using the ports. Such change may result from many factors, such as changes in port productivity, efficiency, quality of service, port dues, terminal charges and economies of scale effects with respect to main line and feeder lines.

Most port studies conducted in the last decade have realised that a thorough understanding of all these changes is essential for a comprehensive understanding of the adjustments required. Scholars have recently created a series of new concepts aiming to explain these latest trends. These concepts underline ports as elements in supply chains (Robinson, 2002), port regionalisation (Noteboom& Rodrigues, 2005), ports co-opetition (Song, 2003) globalisation of port operations(De Souza et al, 2003; Slack & Fremont, 2005) the need to reduce entry barriers (De Langen & Pallis, 2007) and private entry in container terminal operations (Peters,2001; Olivier, 2005; Midoro et al, 2005).

While these scientific efforts form the current port research agenda, they also underline two issues. Firstly, that the existence of an increased number of players in port service ownership, management and provision needs a re-conceptualisation of the current interface of the public and private sector participation in the port sector. Secondly, that there is a need to inverse the fact that most of port studies have emphasised on port efficiency and have considered the relations between the port service providers and port users involved in a port as of secondary importance (Notteboom & Redrigue, 2005).

Recently the relationship between port operators and port users has taken central stage in determining port efficiency and port competitiveness. Such relationship enables ports, as nodes in the global supply chains, and port users, shipping lines in particular to be able to optimise their resources and set its operational plans that enable them to satisfy their customs needs and requirements (Notteboom, 2012).

This situation has repercussions of immediate significance on container transhipment and brings with it particularly privileged conditions for ports in the Mediterranean, especially those nearest to routes between the Suez Canal and Gibraltar travelled by transoceanic ships. The core objectives of shipping lines to cut times and therefore reduce cost places well-located ports at an advantage. However, the off-route deviation distance for transoceanic ships calling at transhipment ports in the Mediterranean is small in comparison to the length of oceanic route (Notteboom, 2010). This only applies if the ports in question can always guarantee the extremely high level of efficiency demanded.

Ports, as nodes in the global supply chains, and port users, shipping lines in particular seek to optimise their resources and set operational plans that enable them to satisfy their customers' needs and requirements. In this context, this research provides a thorough analysis for Mediterranean container port efficiency and its impact on the dynamics of container port market structure, conduct and performance and the effect of market dynamics on container port competitiveness.

1.4 Research aim and objectives

The Mediterranean is now a growing market that can offer and absorb containers and commodities. Due to its geographical location, it is considered as a strategic link between the East-West trade routes. The transhipment (hub) ports in the region are located on the shortest route that allows the minimum wastage of time for the great ocean-going container lines. The Mediterranean is also boarded by several countries where the pace of growth is estimated to rise remarkably, such as the North African countries and those boarding the Black sea.

This research aims to analyse the impact of ports' technical efficiencies on the improvement of Mediterranean container ports' competitiveness. This study will contribute to assist port managers to optimise their resources and set operational plans that enable them to satisfy their customers' needs and requirements. As such, the research objectives are:

1. To review the literature in port competition and efficiency.
2. To analyse the Mediterranean container ports' competitiveness through studying the dynamics of the Mediterranean container port market.
3. To study the current changes of market structure, conduct and performance.

4. To evaluate and benchmark the technical efficiency of container ports in the defined market.
5. To assess the impact of port technical efficiency on port competitiveness and study the ability of some gateway ports to become future hubs.

1.5 Research questions

Mediterranean container ports need to consider the status of their competitiveness and the level of efficiency and quality of service provided. Optimisation of service is needed for ports to create a customer-oriented market. However, to a large extent, ports are competing in order to attract the big market players and achieving a higher throughput. A few researchers have tried to study the relationship between port efficiency and port competition (Cullinane et al, 2004; Cullinane et al, 2005b; Wang et al, 2005). However, none of these studies addressed such a relationship in the context of the Mediterranean container market. In order to achieve the above mentioned research aim and objectives, the research will try to answer the following questions:

1. What is port competitiveness and competition and how it is assessed?
2. What is port technical efficiency and how can it be evaluated?

This leads to three questions that are going to be verified in the research model and the empirical work of the thesis, namely:

3. What are the main characteristics of the Mediterranean container port market in terms of market structure (ports' competitiveness) and market conduct?
4. What is the relative technical efficiency level of the Mediterranean main container ports?
5. What is the relation between the Mediterranean container ports efficiency and their competitiveness?

To maintain its competitiveness, Mediterranean container ports have to invest in its infra/superstructure to accommodate the largest containerships to enable cost reductions for the container shipping market. It is the intense competition which characterises the container port market (Liu, 1995; Tongzon and Heng, 2005; Yap and Lam, 2006) and this has motivated an obvious interest in the efficiency with which it utilises its resources (Tongzon, 1995a; Martinez-Budria et al., 1999; Coto-Millan et al., 2000; Notteboom et al, 2000; Tongzon, 2001a; Cullinane, 2002; Cullinane et al, 2004).

The rationale for research question 1 and 2 arises from the need to provide a theoretical background about port competitiveness and port efficiency in order to pave the way for finding the relationship between the two in order to find out to what extent the port technical efficiency could affect the port's competitiveness. The rationale for research question 3 arises from the need to update the knowledge of the Mediterranean container port market dynamics in terms of concentration and deconcentration tendency and the changes in market structure and conduct over the past two decades.

The rationale of research question 4 arises from studying the Mediterranean container port market from the demand side. There has been consistent increase in Mediterranean container ports throughput over the past two decades. This in turn highlights the importance of enhancing the ports' technical efficiency in order to be able to meet market demand. Moreover, ports should benchmark their aggregate and pure technical efficiency in order to be able to optimise the resources that enable them to meet their customers' requirements and accordingly enhance their competitive position. The rationale for research question 5 arises from the observation, often addressed in the literature, that most previous studies of port economics addressed the issue of port competition and port efficiency in isolation. As such this research studies the relationship between port competitiveness and port efficiency and establishes a model that can analyse the impact of port competitiveness on port efficiency in the Mediterranean container market.

1.6 Research hypotheses

For a container port, efficiency makes a significant contribution to the port's competitive advantage (Dawoud, 2000). Traditionally, the efficiency of a container port has been measured by calculating and seeking to enhance or optimize the technical efficiency of cargo handling (De Monie, 1987). As such, in the context of this research, nine hypotheses are formulated in order to analyse the impact of port efficiency on port competitiveness. The hypotheses are divided into three groups. The first group constituting hypotheses H1 and H2 is used to examine the Mediterranean container ports' competitiveness and market dynamics. The second group, represented by Hypotheses H3 to H6, forms the hypotheses used to benchmark the relative efficiency of the main container ports in the Mediterranean. The third group, represented by hypotheses H7 to H9, is used to analyse the relation between port technical efficiency and port competitiveness in the defined market. These hypotheses are as follows;

H1: The Mediterranean container port market is moving towards de-concentration and perfect competition.

H2: The competitiveness level, presented by ports' throughput and market share, of the ports under study has changed over the period of study.

H3: The technical efficiency of the Mediterranean main container ports is not related to scale of production.

H4: The technical efficiency of the Mediterranean main container ports has improved over time.

H5: The technical efficiency of the Mediterranean container ports increases as the scale of a container port increases.

H6: The technical efficiency of the Mediterranean container ports is affected by different exogenous variables such as countries' GDP and port location.

H7: Ports technical efficiency could affect container ports competitiveness in the Mediterranean market.

H8: There is a positive relation between the level of ports' efficiency and the competitive position of the container ports in the Mediterranean market.

H9: There is a positive relation between Mediterranean container ports average growth rates and their technical efficiency.

1.7 Research methodology

This research can be classified as deductive positivistic and quantitative analytical research. To assess the impact of port technical efficiency on port competitiveness in the Mediterranean container market, the research follows the concept of Industrial Organization (IO) and Structuralism (Harvard school) methodology that analyses the market Structures, Conduct and Performance (SCP) of market players. The SCP concept assumes that an industry's performance depends on the conduct of suppliers and consumers which, in turn, are determined by the structure of the market (Bain, 1951; 1959; Wang et al, 2005).

In this research, the impact of technical efficiency on port competitiveness among the representative sample of 22 Mediterranean container ports from 1998 to 2012 is analysed using a simultaneous three-stage procedure: in the first stage, the Mediterranean container port market dynamics and port competitiveness is analysed through the study of market structure and conduct. Market structure is assessed through measuring and analysing market concentration. Four different methods will be used to evaluate the dynamics of market concentration for the last two decades. These methods are: the K-Firm concentration ratio (K-CR) (Maunder et al., 1991), Hirshman-Herfindahl Index (HHI) (Hirschman, 1964), the Gini index or Gini coefficient (GC) (Gini, 1921; Brown, 1994) and the generalised entropy index (Shannon, 1948; Curry and George, 1983). In this stage, hypotheses H1 and H2 are used to examine the Mediterranean container port market dynamics and the competitiveness of ports under study. Moreover, the ports' competitive position is also assessed by using port growth rate figures and market share that are used as the main determinants to examine relative changes in ports' competitiveness. In this context, the Boston Consultant Group (BCG) matrix is used to assess and analyse the change of the study ports' competitive position in the period between 1998 and 2012 in the defined market.

Market conduct is analysed by using shift-share analysis (SSA) (Marti, 1988; De Lombaerde and Verbeke, 1989). The 'share' effect represents the estimated growth of container traffic in a port as if it would simply maintain its market share. The total shift implies the total number of containers (TEUs) a port has actually won from or lost to competing ports in the same market, with the estimated container traffic (share effect) as a reference. The 'shift' effect allows a better evaluation of a port's competitiveness as it eliminates the growth of the overall container sector (Notteboom, 1997, 2010).

In the second stage, ports relative technical efficiency, as a proxy of market performance, is assessed and benchmarked through the use of Data Envelopment Analysis (DEA) which estimates the relative efficiency scores and ranks container ports according to their efficiency. Five DEA models are applied for comparative purposes, the DEA- CCR model, Charnes, Cooper and Rhodes, (1978); the DEA-BCC model, Banker, Charnes and Cooper (1984); the Scale-Efficiency DEA model, Doyle and Green (1994), the DEA Super-Efficiency Model, Andersen and Petersen (1993), sensitivity analysis model and slack variable analysis model.

In this context, due to the complexity of the extensive activities carried out at container ports, this research focuses solely on the technical efficiency at the level of container terminals within the port. As such, the term port refers to the aggregate activities of all container terminals that operate within the ports of study.

Moreover, unlike the practice of cross-sectional data analysis, in a DEA panel data and window analysis, originally established by Charnes et al. (1985), applications are used not only to benchmark the efficiency of DMUs (container ports) but also to identify the changes of the DMUs' efficiency scores over a specified time period (Cullinane & Wang, 2010). A set of panel data termed reference observations' subsets (Tulkens and van den Eeckaut, 1995), is used in order to assess the efficiency of an individual DMU. Tulkens and van den Eeckaut (1995) proposed that each observation in a panel can be characterised in efficiency terms through three different kinds of frontiers which are Window, Contemporaneous and Inter-temporal analysis. In this stage the second group of hypotheses, H3 to H6, are used to examine the sample ports' technical efficiency over the period of study.

In the third stage, the impact of port efficiency on port competitiveness is analysed through the use of Simar and Wilson's (2007) procedure to bootstrap the DEA scores with a truncated regression. Applying this approach enables more reliable evidence to be obtained compared to previous research analysing the efficiency of container ports. This is because the Simar and Wilson (2007) procedure ensures the efficient estimation of the second-stage estimators, which is not a property of alternative methods. The three-stage procedure also depends upon other exogenous variables, which are not taken into account in the second-stage efficiency estimation. This implies that the error term must be correlated with the second-stage explanatory variables.

The method established by Simar and Wilson (2007) overcomes these difficulties by adopting a procedure based on a double bootstrap that enables consistent inference within models, explaining efficiency estimates while simultaneously producing standard errors and their confidence intervals. The third group of hypotheses, H7 to H9, is used to examine the relation between ports' technical efficiency and ports' competitiveness through the use of Spearman's rank order correlation coefficient. Finally, the research reliability and validity will be tested through the use of different type of reliability and validity that are relevant to the research type, design and approach.

The above stages of the research methodology are conducted based on data gathered, analysed and evaluated from secondary sources. Secondary data are mainly taken from issues of the Containerisation International Yearbooks. To analyse the dynamics of the Mediterranean container port market, to assess the competitive position of the container ports and to estimate the efficiency of the port sunder study, data for the years from 1998 to 2012 are used. The Banxia Frontier Analysis software was used to solve the two DEA models that explain the return to scale of the ports production function, the CCR model (CRS) and BCC model (VRS).

1.8 Area of study – The Mediterranean range

1.8.1 Definition of range

While there is no formal methodology that defines the extent of a port range, it is usual to consider factors such as access to a specific body of water, port proximity and hinterland as defining factors. The Mediterranean basin has historically and geographically grouped together countries and respective ports around its shores. The Mediterranean basin is the area around the Mediterranean Sea, and reaches three continents: Europe (south), Asia (near east) and Africa (north) (Notteboom, 2012). It is by definition limited by the Strait of Gibraltar to the West, the Suez Canal to the East and the Bosphorus Strait to the Northeast. However, a more encompassing definition of the Mediterranean area of influence includes countries such as Portugal and the Atlantic coast of Morocco, as well as countries around the Black Sea, such as Romania. This latter definition is the one to be taken into consideration in this research.

Traditionally in the port industry, the Mediterranean is not considered a homogeneous range as there is little competition between ports, with each port catering essentially to its domestic hinterland. The liberalization of sea, road and railway transport within the EU and a simultaneous increase in the amount and quality of landside transport infrastructure has had an impact in the enlargement of the ports' catchment areas. Globalization has reinforced the role of the

Mediterranean in international maritime freight transport, nevertheless, traffic growth has mainly involved transit flows, with intra-Mediterranean flows representing less than a quarter of the total (Fageda, 2000). The Mediterranean container ports can basically be divided into two categories: gateway ports serving a hinterland, for example, Genoa and Barcelona have been used primarily as gateway ports for national trade and transhipment hubs used by lines to tranship containers between east–west services and local feeder services, for example, GioiaTauro, Port Said, Algeciras and Marsaxlokk (UNCTAD, 2008).

1.8.2 Reasons for the focus on the Mediterranean container market

The reasons for the focus in the Mediterranean are manifold. Firstly, the Mediterranean has a strategic geographical location that makes it one of the preferable transhipment areas in the world. It is located along one of the major shipping trade routes: from Southeast Asia to Northern Europe and to America's West coast. Secondly, there is a significant increase in local origin and destination (O&D) traffic. Currently, around the Mediterranean there are significant and growing origin and destination markets in Southern Europe, North Africa and Middle East. The volume of goods transported by sea within the Mediterranean region has grown on average by 5% per annum in the decade preceding the international economic crisis of 2008. The growth of container traffic was particularly high, expanding by over 10% a year (Gouvernal et al, 2005).

Thirdly, the Mediterranean container market structure is changing. In order to accommodate the increasing local and transhipment demand, a vast hub/feeder container system and short sea shipping network has developed in the Mediterranean since the mid-1990s. Earlier, Mediterranean ports were typically bypassed by liner vessels between Northern Europe and the Far East (Notteboom, 2010). Fourthly, although globalization has strengthened the role of the Mediterranean in the international maritime transport of goods, this port range is still one of the least studied regions, especially when compared with the Hamburg-Le Havre range, the Asian or North American ports (Notteboom, 2012).

1.9 Research conceptual framework

Scherer and Ross (1990) provided valuable guidance for any discussion of the container port industry and its market structure. The market structure of the container port industry can be analysed from the viewpoint of an individual port, nation, and continent or even from a global perspective. The former refers to the various parties and their relationship within a port, while the latter refers to a situation in which a port is regarded as a unit under a national administration and competes or cooperates with other ports. As competition is one of the most important concepts in the context of market structure, port competition can be simply explained as the competition between different ports (within the context of this work, the discussion is obviously limited solely to container ports (Wang & Cullinane, 2005).

One of the most important factors for deciding whether two container ports are competing with each other is to study whether they serve the same or overlapping hinterland or foreland (Ng, 2006b). From this perspective, studies that analyse the competition between the ports of Hong Kong and Singapore such as Fung (2001) are not relevant here since these two ports serve the trade of completely different hinterlands; while the gateway port of Hong Kong serves mainly the cargo traffic from southern China, the hub port of Singapore mainly serves the cargo traffic to and from Southeast Asian countries, such as Malaysia and Indonesia, as well as the North–South traffic to Australasia. Goss (1990a) highlighted that the ability of port to compete varies according to a number of factors such as its geographic location and the nature of the cargoes that move through it.

In this context, one should differentiate between port competition and competitiveness. Schlie (1995, p. 105) stated that competitiveness is "*The ability to get customers to choose a particular service over competing alternatives on a* *sustainable basis*". Thus, in the long term, ports should invest for the future even at the expense of short term profits. However, port competition can be defined as a process to maintain customers, market share and hinterland over which ports might have complete or partial control (Marlow &Paixao, 2001).

Such distinction between port competition and competitiveness allows using any port's capabilities at the utmost. The port's power to compete relies not only on its own strengths, but also on the way it succeeds in coping with its weaknesses and the ability to transform threats into opportunities. However, the port competitive position depends on port selection criteria determined by shipping companies and shippers as ports have become crucial links in almost every supply chain. As such, they have obtained a meaning beyond transport and transhipment itself (Winkelmans, 2003).

Hence, the importance of port competition far exceeds the competition between any port actors. Port efficiency reflects better the competitiveness of the port. From this perspective, this research analyses the competitiveness of major Mediterranean container ports by considering the Mediterranean in its totality, including south Europe, Middle East and North Africa. The study puts forward a way to assess container port efficiency based on simple, yet validated and meaningful competition measures.

1.10 Research significance and original contribution

The significance and original contribution of this research is as follows:

1. It consolidates and summarizes the vast existing literature on container port competition and efficiency.
2. It validates the concept that the container ports in the Mediterranean market can be treated as one single geographic entity that by and large are facing the same market challenges over the last two decades.

3. It uses the industrial organization concept, structuralism that uses structure, conduct and performance to study the Mediterranean container ports market dynamics.
4. It studies the impact of port technical efficiency on port competitiveness through the use of various parametric and non-parametric tools.

Furthermore, this thesis considers the Mediterranean in its totality, including south Europe, Middle East and North Africa. The research puts forward an innovative way to assess container port efficiency based on simple yet validated and meaningful physical data. It proposes to build a bridge between academia and industry, the former being known for the complex econometric efficiency models and the latter for easy-to-use analytical tools that vary according to the entity measuring them and thus often lack consistency for inter-port comparability.

1.11 Research structure and plan

The research structure shows the plan that has been undertaken to test the hypothesis, answer the research question and achieve the aim and objectives. The structure of the thesis depicted in Figure 1.3 indicates that chapter one constitutes the research theoretical framework. Chapters 2 and 3 establish the background and foundation of this study. Chapter 4 represents the methodological framework and research model. Chapters 5, 6 and 7 provide the application of the assessment of port competitiveness, technical efficiency analysis and the assessment of the impact of port efficiency on port competitiveness in the Mediterranean container port market. Chapter 8 provides conclusions, recommendations and areas for further research.

This thesis can be outlined as follows:

Chapter 1 constitutes a general introduction about the research topic. It also provides an overview of the research importance, problem, aim, objectives, methodology and originality. In addition, it outlines the thesis structure and clarifies the conceptual framework of the research topic.

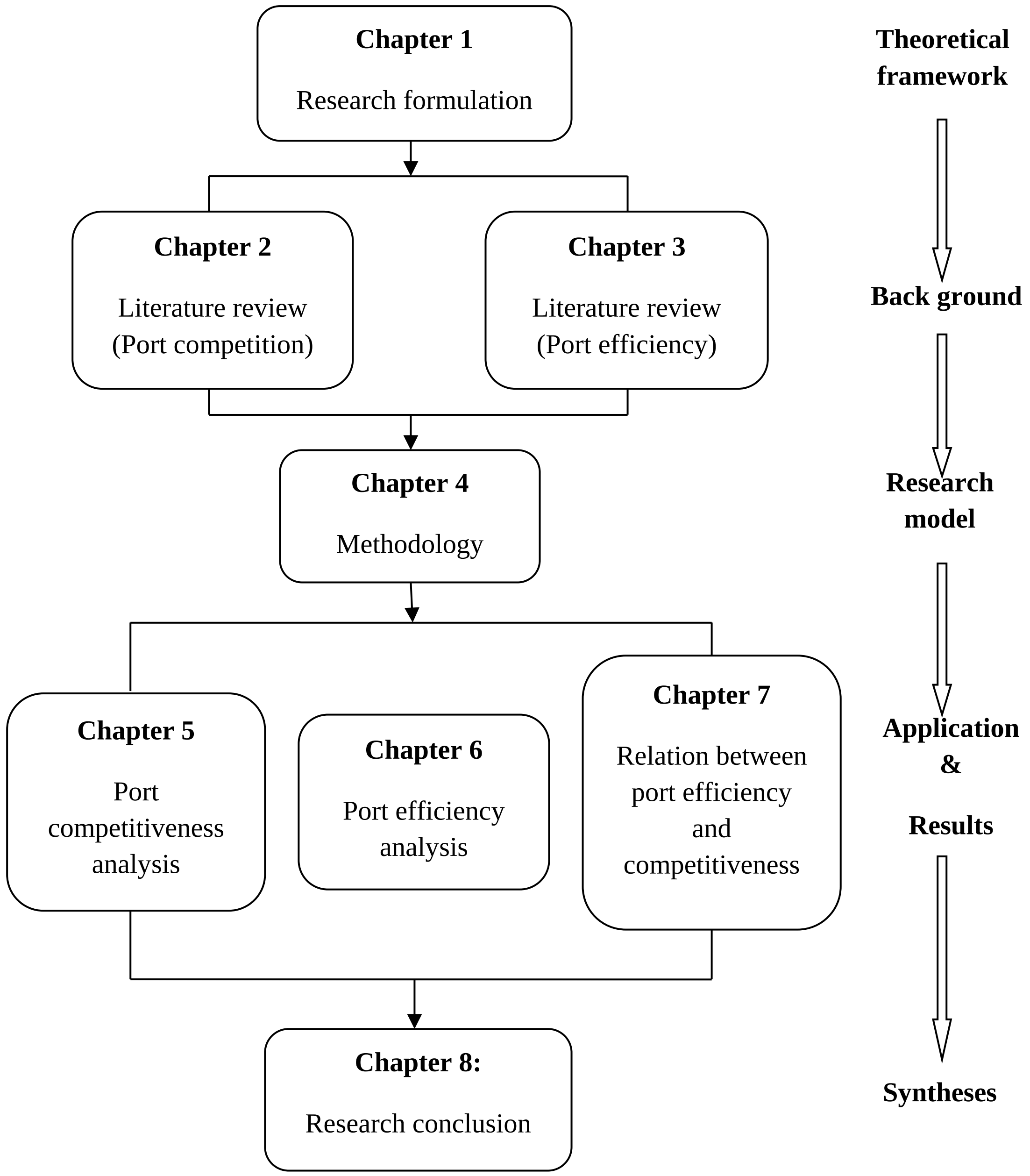

Figure 1.3 - Research structure and procedures

Chapter 2 provides a comprehensive theoretical back ground on the conceptual definition of port competition and competitiveness, different types of port competition and factors affecting port competitiveness. The chapter critically reviews the literature in the areas of port competition and competitiveness in terms of previous studies' scope objectives and the assessment tools being used to analyse port competition.

Chapter 3 provides a thorough understanding of the concepts, definitions, types and theories of port efficiency. It reviews and analyses the literature on port efficiency and efficiency measurement and evaluation tools. This chapter also indicates the variable specifications in the existing literature and conducts a gap analysis between the previous studies and this research.

Chapter 4 identifies the research scope, philosophy, approach and strategy, on which the theoretical framework is formulated and the methods, models and techniques used in creating it are discussed. It also demonstrates the specifications of variables that are used to assess ports' competitiveness and efficiency and provide a brief explanation on data collection and software used to measure port efficiency.

Chapter 5 provides a thorough analysis of structural changes and development of the Mediterranean container port market demand. The chapter analyses the Mediterranean container port market structure through the use of five methods. These methods are: the K-Firm concentration ratio, the Hirschman-Herfindahl index, Gini coefficient, Entropy index and BCG matrix. It also analyses the Mediterranean container port market conduct through the use of shift-share analysis.

Chapter 6 benchmarks the relative technical efficiency of ports under study through the use of five DEA models. The DEA-CCR model is used to assess the aggregate technical efficiency, the DEA-BCC model is applied to assess the pure technical efficiency, return to scale analysis is utilised to find out the status of return to scale of each port and super-efficiency (A&P) analysis is conducted to rank the efficient ports. A sensitivity analysis is used to distinguish between variables that have larger weights in terms of efficiency and slack variable analysis is used to identify potential areas of improvement for inefficient ports.

Chapter 7 tests the research hypotheses that examine the impact of port efficiency on port competitiveness. It also examines the impact of some exogenous factors on port efficiency through the use of the bootstrapped truncated regression in order to test the potential for some ports under study to be a future hub. The reliability and validity of the research design and results are also tested.

Chapter 8 summarises the research and presents the research conclusions, limitations of the study, recommendations for port managers and operators that enable them to enhance their ports' technical efficiency and competitiveness. The chapter also highlights the potential areas for further research.

1.12 Chapter summary

This chapter introduced the research topic and based on this the research aim and objectives have been defined. It highlighted the research importance and clarified the original contributions to knowledge which would be reached on realisation of the aim and objectives. The chapter also presented the research methodology and processes by which the research aim and objectives will be achieved. Finally, the outline of the research structure and design was presented.

The next chapter will synthesise published literature in relation to port competition and competitiveness in order to illustrate how this study would differ from, support, add to or even derive from previous studies. Based on a literature review, the research gap will be identified in a way that clarifies how this research will contribute to knowledge. Also, based on this review, the foundation of the research framework will be created and the best suited data collection techniques for this research will be selected.

CHAPTER TWO

PORT COMPETITION AND COMPETITIVENESS

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PORT COMPETITION AND COMPETITIVENESS

2.1 Introduction

In recent decades, globalisation, shift in the worldwide production and consumption centers and the development of the international transport network have increased the role of ports as nodes in the global logistics and supply chain systems. Meanwhile, seaports encounter greater challenges, uncertainties and risks than ever before. The development of different markets has contributed to intensify the competition in the port industry (Haezendonck & Notteboom, 2002). Containerisation and inter-modality have extensive impact on port markets. The reform of the liner shipping service networks as well as the increased bargaining power of the shipping lines contributed to the deterioration of existing ports and to the development of new ones that, in turn, caused a continuous change in the market structure and port hierarchy (Notteboom, 2012).

Container ports, in particular, not only encountered competition from the large load centers in the same port range but also from the medium and small load centers having the same hinterland and, to some extent, from load centers in other port ranges. The hub-and-spoke system that has emerged in liner shipping operation patterns has put increased pressure on the supply chain network around load centers. Thus, the concept of containerisation has enlarged the geographical coverage of seaports to the extent that the concept of a captive market is no longer valid (Fageda, 2000).

The aim of this chapter is to review and analyse the literature in port competition. The approach of reviewing the literature is based on looking at the theoretical arguments and premises of port competition concepts and definitions, the various types of studies on port competition (qualitative and quantitative) and the development of the previous research in port competition in terms of research objectives, paradigms, methodologies and measures used to assess port competitiveness. In doing so, this chapter is divided into four main sections. The first section discusses the conceptual definition of port competition. The second section illustrates the different types of port competition. The third section reviews the literature in the international competitiveness of seaports and the different methodologies and approaches used in the assessment of port competitiveness and competition. Chapter summary and gap analysis is provided in section four.

2.2 Conceptual definition of port competition

Words in common usage tend to have a variety of meanings. Competition is no exception. Although many hints are attached to the term, most researchers attempt to define competition as either a process or a state of affairs. When competition is demonstrated as a process, some treatises express entrepreneurs as the key to success (Haezendonck & Notteboom, 2002). Knight (1921) focused on the notion of risk. He asserted that risk taking is the function of the entrepreneur success for their efforts. The common theme of this debate is that a competitive market system is one where entrepreneurs contend freely with each other for success. The struggle represents market contestability in which the intense competition is characterised the market.

Schumpeter (1942) described the competitive struggling process as one that revolved around innovation, technology and economic progress as the ultimate important form of competition creates from the new product, technology, and new source of supply and reform of organisation. Hayek (1948) and Kirzner (1973) emphasised competition between individual entrepreneurs and typified this tradition. However, economists have provided not only descriptions and definitions of competition but also model for the processes. Steindle (1965) asserted that competition should be regarded as a stochastic process. He associated the underlying stochastic events to firms' growth and decline process.

Another customary and more traditional way of illustrating competition is to explain it as a state of affairs. The fierceness of competition is evaluated by capturing a snap shot at a point in time. Those who assigned to this view point advocate the view that the dimensions of the competitive system can be categorised by a set of structural elements of the market. Adherents of this view place the focus on such features as the number of firms, concentration, marketing ratios and other structural variables. These variables are proxies for the intensity of the competitive process. Substantial efforts have been devoted to demonstrating that these features are related to cross-sectional differences in profitability. Nevertheless, this is considered as an indirect way of proving that these measures are related to the fierce of competitive process that has been assumed to affect cross-industry differentials in profitability (Haezendonck & Notteboom, 2002).

At a conceptual level, the two approaches to illustrating competition may be at a conflict as to what represents highly competitive markets. Scholars who had to rely on measures of market structure and other static features are emphasising a state of affairs. By using such measures they presume that these measures represent the fierce of competition within the industry (Baldwin, 1995). Castillo-Manzano et al. (2009) defined port competitiveness as the ability of a port to create added value, create core business and produce productive activity within its market. As such, the most competitive port will be able to establish a differentiated policy and gaining more customers than its rivals (Teng et al., 2004; Yeo and Song, 2006; Castillo-Manzano et al, 2009).

However, in general, Voorde and Winkelmans (2002) defined port competition as the competition between ports undertakings involved in the same traffic and terminal operators who are involved in the organisation of the whole transport chain, with respect to certain transactions. It should be kept in mind that every operator's main objective is to maximize his profit and to increase his throughput and market share.

Song and Yeo (2004, p. 35) stated that "*port competition refers to the development and application of differentiated strategic alternatives so as to attract more customers to competitive ports".* Therefore, it is crucial for a port to obtain and/or maintain a competitive boundary over its competitors. Meersman and Voorde (2002) referred to Verhoff's (1981) definition of competition who explained that port competition unfolds under four different levels, namely: competition between port undertakings; competition between ports; competition between port clusters, a group of ports in the same market with common geographical features and competition between ports share the same hinterland or positioned at the same coastline.

These different levels of competition interact with each other so that they cannot be evaluated individually. However, such a definition does not consider the composition of traffic structure of port undertakings, which is very important as far as port competition is concerned. The definition also does not differentiate between different types of traffic in which ports and port undertakings are specialised. It treats them as if they were similar, but in reality, for instance, container terminal operators do not compete with liquid/dry bulk terminal operators (Voorde & Winkelmans, 2002). Nevertheless, a modern definition of port competition should include all the above mentioned aspects as ports are considered to be the competing bodies. Next section illustrates the various types of port competition with a given examples of each type.

2.3 Types of port competition

Port competition can be classified into three main types that represent the comprehensive concept of seaport competition and explain the relationship between ports and port undertakings (Wang et al, 2005). These types are: inter-port competition, intra-port competition, and inter-port competition at port authority level. Inter-port competition can be defined as the competition between various ports. The most significant factor for determining whether two ports are competing with each other is to find out whether they share the same or overlapping hinterland or foreland (Cullinane et al, 2005; Ng, 2006a).

Traditionally, before the development of containerisation, inter-port competition was not significant. Port markets used to be recognised as being either monopolistic or oligopolistic due to the concentration of port traffic and the limited and fixed geographical location of the port (Cullinane et al, 2005). However, developments in containerisation and intermodal transportation have significantly changed this situation. Recently, terminal operators are not only concerned with their productivity but also whether they can compete or not.

Referring to Verhoff's (1981) definition, inter-port competition can be classified into three subcategories (Figure 2.1). The first is competition between whole port range and coastlines; the perfect example of such type is the competition between ports in the Hamburg-Le Havre range. Another example can be provided by increasing evidence that the present inter-container port competition between ports on the West and East coast of North America. This competition has been intensely increased by the development of both the multimodal and long-distance transport systems. The second type is the competition between ports in different countries such as the competition between Rotterdam in the Netherlands and Antwerp in Belgium or between Tacoma and Seattle in the United States and Vancouver in Canada. The third type is the competition between individual ports in the same country where ports have the same or overlapping hinterlands, such as the competition between Los Angeles and Long Beach in California or between Qingdao and Dalian in Northern China. (Wang et al, 2005).

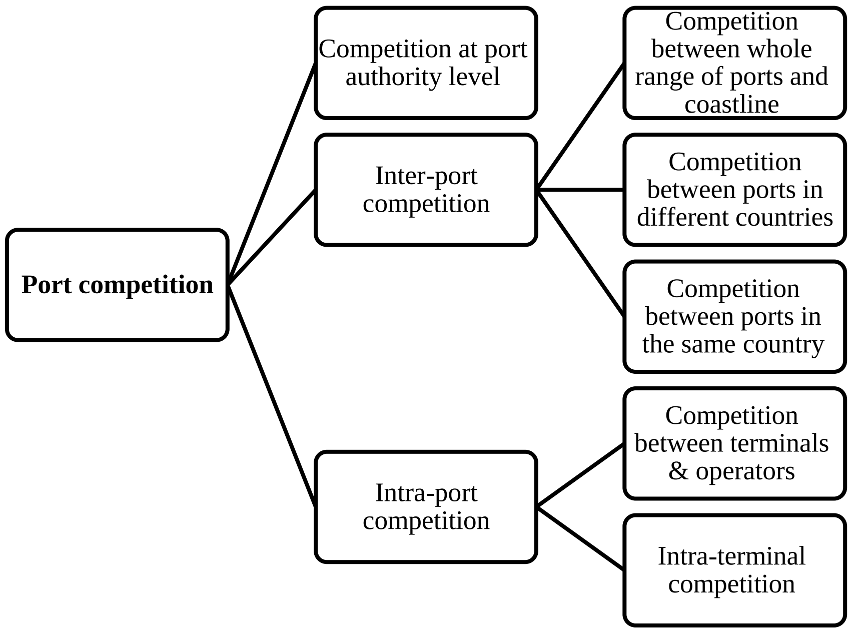

Figure 2.1– Types of port competition.
Source: Adapted from Wang, T-F., Cullinane, K., and Song, D-W. (2005) 'Container port production and economic efficiency', Palgrave Macmillan, New York, USA.

One of the negative aspects of inter-port competition is that it may put a port at high risks (Heaver, 1995; Cullinane et al, 2005). In order to maintain its competitiveness, a port should greatly invest in its infra/superstructure to be able to accommodate the largest container vessels. Moreover, in a competitive environment, ports might face the risk of losing their customers where shipping lines have the power of choosing among ports that satisfy their requirements such as the efficient cargo handling, short ship turn-round time in port and low port charges and match their criteria in terms of port location, accessibility and hinterland connections (Cullinane et al, 2005; Ng, 2006a; Notteboom, 2010).

The second type of port competition is intra-port competition. This type of competition is mainly related to port administration, ownership and terminal operators. Ports can be categorised according to their type of administration and ownership (Cullinane et al, 2005). Goss (1990b) illustrated that, administratively, ports are classified into three main types. First is the comprehensive (public) port, when all/or most of the port activities are carried out by port authority. Second is the landlord port, when part of port activities are controlled by the private sector, third is the hybrid port, when the majority of port activities are allocated and controlled by the private sector.

In this context, intra-port competition can be classified into two categories. The first is known as intra-terminal competition, where two or more operators within a single terminal compete with each other. It is considered to be a micro level of competition that offers high level cost efficiency. However, this type of competition does not provide the flexibility required for the terminal operator. Accordingly, the lower the level of intra port competition, the higher the flexibility of the port as far as pricing is concerned (Slack, 2007).

The second category is the competition between terminals' operators within the same port such as the competition within the port of Antwerp between container terminals operators like Hessenatie, Noord Natie and Katoenatie. Another example is the competition between APM and ECT in Rotterdam. However, Voorde & Winkelmans (2002) explained that intra-port competition can be recognized in a broader form. Port authorities and undertakings may indirectly compete within a single port if a port authority has shares in port undertakings or terminal operators.

Despite the fact that conventional industrial organisation theory explains that competition has its pros and cons in any firm. In the context of intra-port competition, it can be agreed that intra-port competition enhances port efficiency (Cullinane et al, 2005). Goss (1990c) expressed that comprehensive ports accomplish their efficiency by direct management while landlord ports achieve their efficiency by motivating competition. The role of port authorities, in this regard, is to promote and ensure the existence of competition.

On the other hand, privatisation is an effective approach to presenting intra-port competition. Leaning towards the port privatisation in order to enhance their efficiency reveals the growing recognition of the significance of intra-port competition. Nevertheless, privatisation cannot always enhance port efficiency (Song et al., 2001). Port privatisation is usually associated with a long contract between private firms and governments or ports authorities. Per se, a new oligopoly or monopoly within the port might exist (Cullinane et al, 2005). For instance, if there is neither inter nor intra-port competition, it is difficult to decide whether public management will do better than private management (Baird, 1997).

As far as the managerial implications of intra-port competition are concerned, national port policies should seek to enhance the performance and the efficiency of the whole port activities within the country. By definition, intra-port competition occurs within a port; therefore it is not directly affected by specific aspects of national policies and regulations. However, port authorities should ensure that the internal market within the port is contestable. Meanwhile, Wang et al. (2005) argued that a port authority should play an effective role in promoting cooperative activities that achieve economies of scale and scope within the whole port.

The third type of port competition is inter-port competition at port authority level. This type of competition exists between port authorities at a national, local, regional or international level. It can be clearly identified when the competing ports share the same target market and handle the same type of cargo. A good example of such type of competition is the competition between ports within the Hamburg-Le Havre range and, as in the focus of this research, competition between container ports in the Mediterranean. These ports, to a large extent, compete for containers and are investing to keep pace with the future demand and to increase their throughput and market share. Another example is the competition between Hong Kong and Singapore in the Far East and between New York and Halifax on the East coast of North America (World Bank, 2001). Next section revises and analyses the literature on ports competition.

2.4 Review the literature on port competition

Port competition and competitiveness have been evaluated and analysed from various perspectives. This section reviews the literature in port competition by classifying and categorizing the previous studies on port competition according to their objectives and scopes. The objectives of research in port competition have evolved over times and extended to studying the effect of infrastructure investment on port competition (Chang, 1978; Nir et al, 2003), evaluating the impact of shipping lines' port selection criteria on port competition (Heaver, 2002; Parola and Musso, 2007), analysing the key factors affecting and determining ports' competitive advantage (Porter, 1990; Chou et al, 2003), exploring the key elements that affect port competition (Notteboom et al, 1997; Yeo and Song, 2005), studying the impact of work environment on port competitiveness (Song, 2003; Cullinane et al, 2005a; Musso et al, 2013), assessing port competition from the port users' perspectives (Meersman & Voorde, 2002; Yap and Notteboom, 2011), modeling strategic competition using capacity investment and pricing for different purposes including transportation network congestion and strategic capacity expansion (De Borger et al, 2005, 2007) analysing the competition between ports serve a common hinterland with separable transportation networks (De Borger et al, 2008), evaluating port competition through generic elements such as variations in market shares and changing in market dynamics (Lam and Yap, 2008; Wu and Tu, 2013) and studying The role of container ports as strategic units in changing the value chain and market structure (Asgari et al, 2013; Tian et al, 2015).

Container port competition has been analysed through various methods, including time series analysis (Yap et al, 2006), Analytic Hierarchy Process (AHP) (Song & Yeo, 2004; Yanbing et al. (2005); Yeo & Song, 2006), Data Envelopment Analysis (DEA) (Cullinane et al, 2005), multi-criteria evaluation (Manzano et al, 2009), survey of shipping lines and logistics managers (Zondag et al, 2010; Yeo et al, 2011; Cheraghi et al, 2012), shift-share analysis and diversification indexes like Herfindahl-Hirschman (Notteboom, 1997, 2010; 2012). The methodology used depends on the objectives, data availability and hypotheses that each study considers. This chapter provides a comprehensive analysis on the objectives, scopes and methodology of research in port competition and its evolution over time.

A series of studies developed models of port competition, but they certainly regard infrastructure investment as an external market, rather than internal strategic phenomenon (UNCTAD, 1976; Chang, 1978; Plumlee, 1979; Thomas, 1985; Hanelt & Smith, 1987; Dowd, 1990; and Nir et al, 2003). Hoffman (1985) and Tongzon (1995a) explored port performance by using ship, berth or terminal indicators. Sachish (1996) and Robinson (1999) extended their analysis to comprise production elements or productivity indicators to evaluate ports productivity. An exception is Zan (1999) who established a multi-level market game of port services prices, liner scheduling and pricing and shipper liner selection. In the leader-follower game applied, the port administrator determines a level of infrastructure and port service prices, the shipper then decides routes, frequencies and transport costs, and shippers then select shipping lines according to cost and time. Although this model is exceedingly detailed, it is one of the few models of game theory applied to port competition.

Port selection is considered as the main consequence of the dynamics of port competition. In the 1980s, studies of port competitiveness mainly focused on port selection criteria. Pearson (1980), Willingale (1981), Collison (1984), Slack (1985) proposed various components of port selection which covered Europe, America and South-east Asia. Dutta and King (1980) and Karnani (1984) applied game theory in the assessment of market dominance under oligopolistic competition to evaluate competition strategies. Brooks (1984, 1985) analysed the main elements influencing port selection criteria. Oral and Dominique (1989) embraced Total Factor Productivity (TFP) to establish an analytical model for competitive strategies of business enterprises.

In the 1990s, Peters (1990), Murphy et al. (1988, 1989, 1991, 1992), UNCTAD (1992), and McCalla (1994) addressed major factors affecting port selection criteria. Studies in the 1990s included American studies of the geographic location of ports, inland railway transportation, investment in port facilities and the stability of port labour (Starr, 1994).

From a shipping line perspective, Heaver (2002) asserted that the creation of strategic alliances, mergers and acquisitions in the liner shipping market has significantly increased the bargaining power of shipping lines vis-à-vis ports. Shipping lines became the key players in deciding the ports of call. This position resounded with the results of Parola and Musso (2007) who argued that the results of port competition would be affected by the port's strategic match with major shipping lines. Strategic elements at company level such as availability of hinterland connections, feeder connectivity, reasonable tariffs, alliance structure and the total portfolio of the port are essential in port selection (Robinson, 1998; Wiegmans et al, 2008; Yap & Notteboom, 2011).

Veldman and Buckmann (2003) highlighted the issue of port competition by using the logit model applied to Rotterdam port to quantify the routing selection and develop a demand function for port traffic forecasting and for the financial and economic assessment of container port projects. Notteboom (2006c) argued that shipping lines' decisions to call at a port could be affected by a number of operational and commercial factors including distribution and pattern of cargo flows over the port's hinterland, cargo-generating potential of the port and the port's nautical access. In the same context, Huang et al. (2008) established a model of transhipment port competition in order to study the shipping lines port selection criteria. The model is examined and applied on Taiwan international ports.

The literature further implies that container ports which had the ability to adapt to the integration process within the liner shipping market and add value to the strategic, commercial and operational interests of shipping lines would be considered as more attractive as a port-of-call, relative to their rivals (Yap & Notteboom, 2011). Asteris and Collins (2010) highlighted the bargaining power of the shipping lines and its impact on the competitiveness of UK ports. The research revealed that the UK's container traffic is dominated by ports in the South East of England. In order to accommodate both trade growth and the increasing size of container ships, UK ports have recently been put forward several investment plans.

Most researchers in international business and management who are interested in the issue of competition have shifted their focus from comparative advantage to the factors affecting and determining competitive advantage. Porter (1990) has effectively followed such a stream in his endeavours to answer the question of why certain nations seem successful in particular industries and surpass other countries in the international market. Porter's (1990) perception on the origins of competitive advantage is, to some extent, similar to Krugman's (1991) clustering approach.

Porter's diamond framework (1990) explains the main elements affecting and contributing to a nations' competitive achievement. In his framework, four main interconnected building blocks represent the significant sources of the competitive advantage of nations in particular industries. The four determinants of the diamond are: the factor conditions, demand conditions, supporting industries condition and relevant strategies, structure and competition condition. The factor condition relates to the means of port services.

Rugman and D'cruz (1993) and Cartwright (1993) argued that Porter's diamond did not perfectly take into account the characteristics of the international and multinational activities. For instance, as the core competence of many ports is directly associated with international traffic, the achievements and developments of such enterprises are affected by the international factors.

Rugman and D'cruz (1993) and Dunning (1996) introduced the double diamond model that expresses the nature of international competition in the port market. To be internationally competitive, the double diamond model proposes that port managers and decision makers should establish their own national and international diamond. This should be achieved in line with the logistics and supply chains concept as the weakness of any node within the chain will directly affect the performance of other nodes (Moon et al, 1998).

In order to include internationality as a basic concept of port competitiveness, Rugman and Verbeke (1993) developed a model based on the Porter diamond. They established a local, regional, foreign and global category for each corner of the diamond. They added such categories to the Porter diamond with a belief that some firms compete at a local level while others compete at the international level. The inclusion of these categories to Porter's diamond formed the so called extended diamond which made the model quite relevant to the global economy. Although Porter's frame work emphasised the home base country as the key element of competitive advantage, Dunning (1997) has expressed that other nations rather than the home country may affect the competitive position of a firm in a particular market. However, Heaver (1995) inquired whether ports could be at an advantage if they were involved in greater cooperation rather than competition. In the same context, Song (2002, 2003) assessed the possibility of cooperation among container terminals in Hong Kong and Shenzhen using Porter's five forces model.

Kuroda and Yang (1995) and Yang (1999) utilised the Stackerlberg equilibrium to create competition models for a port's carrying volume and also to examine the operational strategies of container terminals. Huang et al. (2003) developed a multi-criteria assessment model by developing Fuzzy Multi-criteria Grade Classification (FMGC) to assess the competitiveness of eight East Asian container ports by partial order based on five categories: DEA and operational competitiveness; rating analysis to assess operational efficiency; Game theories, productivity analysis; and multi-criteria decision making (MCDM) methods that focus on quantity decisions under a competitive environment. Chou et al. (2003) used Strength, Weaknesses, Opportunities and Threats (SWOT) analysis to explain competitiveness of four Asian container terminals.

As shown in appendix 2.1, a series of studies addressed the issue of port competition in a particular port market or range and explained key factors that could encourage or deter port competitiveness. Many researchers have tried to ascertain the significance of port location as a decisive factor in port competitiveness. Miyajimi and Kwak (1989) implied that containerisation is one of the most influential exogenous factors that contribute to changing the competitive position of ports. Warf and Kleyn (1989) examined the competition between eight main ports of the United States and focussed on comparing handling quantities and benefits of the ports. Hayuth and Fleming (1994) argued that the geographical location is the main element that determines a port’s competitive position.

Hoyle and Charlier (1995) investigated the port market in East Africa and indicated that inter-port competition has encountered significant problems due to specific historical events that took place in that region. Baird (1996) explained that shipping lines growing trend towards increasing container vessels' capacity and the need for shorter turn-round time have limited the competitive advantage of river ports with constrained maritime accessibility. Chen (1997) explored port service competitive advantages, port location, container terminal service, and geo-economic conditions. Huang et al. (1997) had divided port assessment indicators into two categories which are efficiency and effectiveness. Effectiveness indicators were further classified into two groups, the total cost incurred in a port and the cost encompasses congestion, waiting time and ship mean time in port.

Nevertheless, Notteboom et al. (1997) indicated that there are influential factors other than port location that could intensify port competition, such as port infra/superstructure, hinterland accessibility and productivity. Coeck et al. (1997) stated that the competitive advantage of a port could also be expressed according to different types of cargo traffic. In their study of port competition between Western Europe and the United States, Fleming and Baird (1999) provided six groups of factors that could explain why particular ports could have competitive advantages over their rivals.

Jayanthi et al. (1999) chose Total factor productivity (TFP) in their analysis of competition of firms for comparison with Operational Competitiveness Rating Analysis (OCRA) and concluded that there was a relationship between TFP and OCRA. Oral et al. (1999) analysed enterprises' productivity and competitiveness and deduced that productivity and competitiveness were highly correlated. However, Anderson et al. (2008) highlighted that these techniques do not consider competition with respect to financing methods, cost recovery and impacts on port service quality that determine whether a port's operations are profitable and sustainable.

Haezendonck & Notteboom (2002) addressed the issue of factors influencing competition between ports that may vary from one level of competition to another. The study revealed that competitiveness of individual undertakings within a port is determined mainly by specific in puts such as skilled labor, capital and technology.

On the other hand, competition between ports, port clusters and port ranges is also influenced by some regional factors such as port location, the availability of infra/superstructure, the degree of industrialisation, the government policy, port performance, which is usually measured by using alternative variables, such as the frequency of liner services, the transhipment cost, storage capacity and hinterland transportation. Such a traditional approach to port competition paves the way for another approach based on competition between logistics chains in which container ports are links. The most important element that should be considered is the total cost of the transport chain. It is inescapable that, besides port throughput, the logistics factors such as warehousing, distribution of cargoes and hinterland transportation are also very vital and essential factors affecting competition between ports.

At managerial and port authority levels, Voorde & Winkelmans (2002) asserted that port competition is also influenced by other factors such as the port organisational structure, the political and regulatory framework, the socio-economic stability, the know-how of port authorities and their management system, the implementation of EDI, government intervention, the existence of niche markets, port productivity, quality of port facilities and the creation of added value. Haralambides (2002) evaluated port competition and port overcapacity for various pricing methods under various financing structures. The results highlighted that marginal cost pricing is the most suitable way to attain cost recovery and fair competition among ports.

Winkelmans (2003) explained that the competitiveness level of a port depends on the way a large number of elements are used and brought into force. Efficiency oriented ports achieve their competitiveness either by cost leadership, by becoming the lowest cost service provider, or by differentiation, achieved by offering specific port services in market niches different from those services provided by other ports.

In the same context, Song and Yeo (2004) grouped the most important factors for the assessment of port competition into five groups. The first group is the cargo volume which indicates the ability of ports to handle more cargoes including imports, exports and transhipment. The second group is the port facilities which constitute port infra and superstructure in the sense that the greater the capacity, the higher the port competitiveness. The third group comprises port location which clarifies the significance of the geographical location and accessibility of a port in port competition. The fourth is the quality of service as the higher the level of services provided to the port users, the higher the competitiveness level of the port. The fifth group is the port costs which encompass port dues, handling charges in the sense that the cheaper the port expenses, the higher the port competitiveness.

Teng et al. (2004) identified the port competitiveness characteristics by applying Grey Relation Analysis (GRA) model to eight East Asian container terminals. The evaluation of port competition indicated the effectiveness type of criterion as the principal and the efficiency type of criterion as a minor. Table 2.1 illustrates the elements that should be considered when evaluating port competitiveness. These elements are identified through the questionnaire survey conducted by Yeo and Song (2005). Since port operations have some barriers to the general public in terms of expert knowledge, the surveys were provided to the understanding of the group of expertise. The group was selected from ship owners, shippers, terminal operators, national research institutes, and local government research centers.

In the context of this research, these elements are classified into four groups. These groups can be further divided into two categories which are the endogenous elements, over which ports have control, and exogenous factors over which they have no control. The first group comprises the socio-economic factors that affect port competitiveness such as financial factors, port management and ownership, port tariff and price competitiveness which are mainly endogenous in nature while changes in social environment, economics of scale of hinterland, trade markets and status of national economy may be considered as exogenous.

The second group constitutes the operational factors that are, to a large extent, endogenous in nature such as the berth availability, port productivity, port service level, loading time and port congestion. However, the frequency of ships calling at the port is considered as an exogenous factor as it is mainly determined by the shipping lines and consequently affects berth utilisation and port service levels. The third group presents the elements that are related to port geographical location and port accessibility. Some of these elements are endogenous such as port location and port's rail/road connections. Other elements are considered as exogenous, such as the capacity of transportation connectivity, market position within the port area, nearness to hinterland, nearness to main trunk and port accessibility. The fourth group presents the technological factors that affect the port competitiveness. These elements are also endogenous in nature such as the application of EDI system, building the port MIS, existence of cargo tracing system and existence of terminals operation system.

Table 2.1- List of the elements of port competitiveness

Type	Category	Type	Category
Socio-Economical		**Operational**	
Financial factors of port	Endogenous	Average hours of port congestion	Endogenous
Handling charge per TEU	Endogenous	Berth/terminal availability	Endogenous
Internal politics	Endogenous	Capacity/status of facilities available	Endogenous
Port marketing	Endogenous	Cargo volume of handling transhipment	Endogenous
Port operation by government	Endogenous	Dredging: yes or no (?)	Endogenous
Port operation by local autonomous entity	Endogenous	Effectiveness of terminal operations	Endogenous
Port operation by private sectors	Endogenous	Free time of freight station	Endogenous
Port ownership	Endogenous	Handling volume of export/import cargo	Endogenous
Port tariff	Endogenous	Loading time	Endogenous
Price competitiveness	Endogenous	Ability of port personnel	Endogenous
Response of port authorities concerned	Endogenous	Port congestion	Endogenous
Types of port operation/management	Endogenous	Port facilities	Endogenous
Changes in social environment	Exogenous	Port operation	Endogenous
Changes in transport and cargo function	Exogenous	Port operation time	Endogenous
Concentration of volume by export/import	Exogenous	Port productivity	Endogenous
Economic scale of hinterland	Exogenous	Port service level	Endogenous
Inland transportation cost	Exogenous	Securing deep draft	Endogenous
Mutual agreement of port users	Exogenous	Securing exclusive use of equipment	Endogenous
Number of liners calling at ports	Exogenous	Securing fairway	Endogenous
Status of national economy	Exogenous	Securing navigation facilities/equipment	Endogenous
Trade market	Exogenous	Sufficiency of berth	Endogenous
Trade/commerce policy	Exogenous	Terminal facilities	Endogenous
World business	Exogenous	Frequency of ships calling	Exogenous

Table 2.1 - List of the elements of port competitiveness (Cont.)

Type	Category	Type	Category
Location and Accessibility		**Technological**	
Port type; river/sea port	Endogenous	Application of EDI system	Endogenous
Securing railroad connection	Endogenous	Building port MIS	Endogenous
Capacity of transportation connectivity	Exogenous	Customs clearance system	Endogenous
Complete preparation of multimodal transport	Exogenous	Existence of cargo tracing system	Endogenous
Easy access to port	Exogenous	Existence of terminal operating system	Endogenous
Existence of port hinterland road	Exogenous	Extent of port EDI	Endogenous
Existing pattern of navigation routes	Exogenous	Possibility of mutual reference of electronic computation network	Endogenous
Inter-linked transportation network	Exogenous	Sufficiency of securing information equipment	Endogenous
Location factors of the port concerned	Exogenous	Technical factors of port	Endogenous
Market position within the area	Exogenous		
Navigation distance	Exogenous		
Nearness to hinterland	Exogenous		
Nearness to main trunk	Exogenous		
Port accessibility	Exogenous		
Road network to be fully equipped	Exogenous		
Sea transportation distance	Exogenous		
Transportation distance	Exogenous		

Source: Adapted from Yeo, G-T, Song, D-W. (2005) 'The hierarchical analysis of perceived competitiveness: an application to Korean container ports'. *Journal of the Eastern Asia Society for Transportation Studies*, 6, 866 – 880.

Some scholars have assessed the impact of work environment on port competitiveness. Technological development, deregulation, logistics integration and new organisational structures have significantly reshaped the port and maritime industries(Notteboom, 2004).Song (2003) asserted that the horizontal integration (strategic alliances, mergers and acquisitions) has led to more concentration of demand for port services which not only decrease the number of players seeking services from ports but also drastically increases competition between ports.

In the Far East market, Huang et al. (1999, 2001, 2002) utilised AHP and Gray Theory to assess the competitiveness of East Asian container ports. The Gray theory, initiated by Julong (1982), is a tool used to explain and model a market that is under the status of uncertain or imperfect information and transfer the uncertainty of information to clear instruction (Tai & Hwang, 2005). Slack and Wang (2002) emphasised inter-port competition, local and regional, encountered by the ports of Hong Kong, Singapore and Shanghai from their competing ports of Shenzhen, Tanjung Pelapas and Ningbo respectively. Cullinane et al. (2004) deduced that the port of Hong Kong will maintain its competitive position as a regional hub in spite of Shenzhen's apparent competitive advantage.

Some researchers devised approaches utilising routing strategy, efficiency of transportation networks, concerns for shipper requirements and port productivity to assess port competitiveness (Baird, 2002; Cullinane, 2002; Haralambides et al, 2002; Zeng and Yang, 2002; Luo and Grigalunas 2003; Sanchez et al. 2003; Tiwari et al, 2003; and Veldman and Buckmann, 2003), whilst De Langen (2002) used cluster analysis and Flor and Defilippi (2003) took a game-theoretic approach.

Kleywegt et al. (2002) indicated the strengthening of competition between Singapore and Tanjung Pelepas, while Wu and Kleywegt (2003) provided an evaluation of port charges for a number of ports in Asia. They observed that cost of calling at Northport was cheaper compared to Hong Kong, Dubai, Chittagong and Kaohsiung. Lobo and Jain (2002) expressed, through a survey conducted among port users, that Tanjung Pelepas charged relatively lower terminal handling charges and storage costs for its services compared to Singapore although Singapore was seen to offer better connectivity, frequency of sailing and employee knowledge.

In the context of port competitiveness, Paixao and Marlow (2003) illustrated that ports should become more agile to compete and become key logistics nodes in transport chains. Such a transformation would enable ports to keep pace with the future trends of supply chains, such as time-based strategies to reduce inventory costs along the logistics chain, and to reduce both transit times in ports and lead times.

Cullinane et al. (2005a) evaluated the relative competitiveness between ports of Shanghai and Ningbo in terms of price and quality of service. Yap et al. (2006) analysed the development in container port competition among the top five ports in East Asia. They observed that although the mainland Chinese ports are increasingly attractive as direct ports of call, these ports are expected to handle an emerging share of transhipment traffic.

Yeo and Song (2006) empirically identified container ports' competitiveness in Asia by studying factors affecting the competitiveness of each port using the Hierarchical Fuzzy Process. This analysis is distinctive in that the 'human-perceived' competitiveness on Asian container ports is assessed under the quantifiable framework. The results revealed that Singapore is the most competitive port among the study ports.

Acosta et al. (2007) investigated the factors that affect port competitiveness from the supply perspective. They employed Porter's extended diamond model to assess the competitive advantage of Algeciras port in Spain against its competitors in the Mediterranean container market. While Vassilis et al. (2007) offered a new methodology, based on the benchmarking technique, to measure the competitiveness of 13 ports in the Mediterranean at a port authority level. Similarly, Pardali and Michalopoulos (2008) proposed a model for port services positioning in the Mediterranean port market. The model is applied on the Port of Piraeus. The main features of this model categorised into three levels: first, the port can assess its competitiveness using the Port Competitiveness Degree (PCD). Second, the results provided are indirect indicators for measuring port performance. Finally, this model can be used as a strategic method for the recognition of operational weaknesses to be confronted in order to achieve best relative efficiency.

Gaur et al. (2011) highlighted how the container ports in the developing countries should consider and define capacity as an important factor affecting port competitiveness. They established an Efficiency Index for Indian ports and recommended institutional collaboration among ports to achieve potential and absolute capacity. Cheraghi et al. (2012) explored the main factors which affect the competitiveness of the container terminals at Shahid Rajaee. They employed factor analysis that enabled them to propose and apply the profound marketing strategy to get the maximum demand to this port. The results revealed that port strategy and policy, port logistics, hinterland condition, shipping maritime service, shipping agreement and port connectivity are the main determinants of port competitiveness in the Shahid Rajaee Port in Iran.

Musso et al. (2013) carried out an empirical analysis to examine the external and internal factors that can affect the competitiveness of Italy's ports. The study proposed a number of potential strategies that may be applied to increase the competitiveness of the Italian ports. Such as cost reduction programmes, capacity increase, and stimulating collaboration between ports and focusing on system strategies.

Some studies addressed the issue of port competition from the port users' perspectives. Meersman & Voorde (2002) highlighted that it is very important for port managers to know who the port users are, who takes the decision of choosing a particular port and how such decisions are made. However, the term port users constitute a wide range of potential players including shipping lines, shippers, cargo consigners and cargo handlers. Lombaerde and Verbeke (2002) explained that the port managers' ultimate objectives are often to increase port profitability, market share and to enhance the degree of traffic structure diversification. In the context of fierce competition between transhipment container ports, the port managers, in most cases, try to minimize the cost of transhipment as well as the port delay in order to be able to maintain their existing customers and to attract new clients to the ports.

From the shippers' perspective, elements found to be important in determining port selection included port charges (Yang, 1999), cargo volume and level of connectivity (Zeng and Yang, 2002; Lam, 2011), distance to the market (Tiwari et al, 2003), service sensitivity to time (Lu, 2003), commodities involved (Luo and Grigalunas, 2003) level of port efficiency (Clark et al. 2004), turnaround time on cargo (Lee et al, 2006), adequacy of infrastructure (Ugboma et al, 2006), inland transit time (Wong et al, 2008), schedule reliability (Anderson et al, 2009) and presence of viable alternative routings (Fan, 2009). Magala and Sammons (2008) highlighted that shippers no longer select a port for itself but rather focus on the package of logistics activities provided by the supply chain.

Nir et al. (2003, p. 165) argued that the most significant elements that determine the competitiveness level of a port from shippers point of view are "*the shipment information, loss and damage performance, low freight charges, equipment availability, convenient pickup and delivery, claims handling ability, special cargoes handling ability, large volume shipment, large and odd-sized freight"*. The shipment information, the loss and damage performance are the foremost important criteria from shippers' perspective.

Ng (2006a) explained that port reliability, efficiency, quality of service, shipping frequency, port congestion, port infra and superstructure and port location are still highly recognised factors for shippers. In the era of globalisation of production, the value added service provided by ports is considered to be one of the most important factors that give a port a competitive advantage over other ports in the same market. Notteboom and Rodrigue (2008) also expressed that trade imbalances, port congestion, increasing oil price, environmental constraints and complicated security problems would hinder the supply chain and thereby affect the container port competition.

Yap and Notteboom (2011) explained that the effect of shippers on port selection criteria could be weakening as container freight from the origin to final destination may be determined by one shipping line, a supply chain coordinator or a third-party service provider using different transport measures and various routings planned to minimize logistics cost and maximize value for both the supplier and customer.

In the European port market, Meersman et al. (2008) expressed the relationship between port competition and hinterland connections. The analysis was based on expected trends in maritime transport and the likely consequences for seaports. The research has shown capacity to be the key to success, both in maritime throughput and in hinterland transportation services. Manzano et al. (2009) evaluated the competitiveness level of the Spanish ports by using decision theory methodology with multiple objectives. The study revealed that Spanish Port Authorities encounter a wide range of complexities in their decision-making processes, as they have to satisfy several port management objectives that may contradict with one another. Low et al. (2009) assessed the hub status among Asian ports and proposed a novel network-based hub port assessment model through clear formulations of connectivity and cooperation indices.

Tovar et al. (2015) analysed the impact of port connectivity on the competitiveness ofthe53mainCanarianportsby using the graph theory. The results revealed that Canarian port authorities should differentiate themselves by specialising in certain valued added services and increasing traffic in these services. This would reduce the risk of a destructive competition between them to attract transhipment traffic. The port authorities should be proactive in enhancing the main Canarian ports' connectivity.

From the macro-economic perspective, some scholars have tried to assess port competition through generic elements such as variations in market shares and changing in market dynamics. Fung (2001) tried to examine to what extent the growth of South China ports would influence the demand for Hong Kong container terminals using a vector error correction model. Yap and Lam (2004) investigated the competition between ports in East Asia by using indifference analysis.

Song and Yeo (2004) assessed container port competition in China including Hong Kong from the outsiders' perspectives using AHP. Yanbing et al. (2005) developed an index system to assess container port competition ability and provide theoretical framework foundation for regional ports' integration. AHP technique is also applied to quantify the index system and provide a comprehensive score of each port. Cariou (2006) asserted that ports are a significant source of economic value to the local, national and global economies and that port facilities are crucial for achieving an efficient trading network.

Lam and Yap (2006) highlighted that the high degree of interdependence among terminal and port operators creates a situation of oligopolistic competition where they could either involve themselves in severe competition or collaborate to maximize revenues. Notteboom (2006b) discussed container inequality of traffic in the North American and European container ports by using inequality decomposition analysis. The results showed that the increased concentration in cargo traffic in the North American container ports is related to robust changes in inter-range market structure whereby some port are increasingly controlling the whole port market.

Frémont and Soppé (2007) argued that port market concentration has taken a new shape which is that of shipping lines concentration featured by the setting up of dedicated terminals. While there is a chance for assessing ports as clusters of terminals with their own discrete logics (Olivier and Slack, 2006; Slack, 2007), However, the research of port market concentration is still valid due to the ports’ geographical features, the study of groups of gateways in relation to the hinterland and the foreland, and from the port authorities’ viewpoint who manage the whole port.

Lam and Yap (2008) analysed the port competition in Southeast Asia for three selected ports, Singapore, Port Klang and Tanjung Pelepas, by using the annual slot capacity deployed by all shipping lines in the period between 1999 and 2004. The analysis concluded that competition from Port Klang and Tanjung Pelepas had a negatively affected Singapore's transhipment performance.

Anderson et al. (2008) established a game theoretic best response model for studying how competitors in port market will respond to development of a certain port and whether this port will be able to gain market share through building additional capacity. The model is applied to the competition in the ports of Busan and Shanghai. In the same context, Yeo et al. (2008) empirically established a framework for assessing container ports in South Korea and China using factor analysis to identify factors which affect competitiveness. Their analysis showed that hinterland condition, logistics cost, regional centre and connectivity are the main factors for port selection and competitiveness in such region.

Rimmer and Comtois (2009) highlighted that the role of gateway ports determining the main elements justifying traffic volumes. Today, port competition gives more importance to nautical accessibility and technological efficiency within the port. The features of liner shipping operational patterns, scale increases in container ship size and a reduction in the number of port calls have a significant impact on port competitiveness and the flow of container traffic within the port market.

Fan et al. (2009) forecasted prospective traffic flows through the logistics channels for container traffic to US markets. They developed an optimisation model that assesses port congestion and demand uncertainty. The results showed that inter-port competition is intensifying. Prince Rupert could become a significant competitor to US ports and the expansion of the Panama Canal could have similar impacts. Zondag et al. (2010) developed a port forecasting approach that models port competition. The model followed the logistic chain approach and aimed to measure the impacts of wide range of policy measures. The model applicability is tested on the ports of Antwerp, Rotterdam, Bremen and Hamburg.

Notteboom (2010) updated the container traffic analysis established by Notteboom (1997) by expanding the analysis to the period 1985–2008 and to 78 container ports. The study aimed at defining key trends and issues explaining present improvement in the European container port market such as the creation of multi-port gateway regions, changes in the orientation of ports' hinterland and port regionalisation processes. The results illustrated that models on port market development under estimate the role of institutional and political elements. Current port market dynamics are highly affected by port reform, governance models and legal frameworks (Wang, 1998; Airriess, 2001; Jacobs, 2007; Brooks and Cullinane, 2007).

Yap and Notteboom (2011) assessed container port competitiveness by suggesting a practical and direct annual slot capacity approach based on revealed preferences of shipping lines with respect to container shipping service dynamics. The study showed that this approach provides a thorough understanding on the evolution of competition between ports. Yeo et al. (2011) presented an approach to measuring container port competitiveness. The study applied a trapezoidal fuzzy methodology to analyse port competition based on the expert judgments of logisticians. The study acknowledges a linguistic expression of the expert judgments of five of the world's top six container ports in terms of container throughputs, including Hong Kong, Busan, Shanghai, Kaohsiung, and Shenzhen. The research findings revealed that Hong Kong attained the highest rank on port service but on hinterland connections Shanghai scored highest and Busan the lowest. Hong Kong achieved the first place on the availability element and the convenience factor, but scored the lowest on logistics cost.

Luo et al. (2012) highlighted that many research implement a two-stage game to model strategic port competition using both capacity investment and pricing for different objectives, including transportation network congestion and taxing strategies, pricing in congested transport corridors and strategic capacity expansion (De Borger et al, 2005, 2007). The competition is between ports which serve a common hinterland with divisible transportation networks (De Borger et al., 2008) and the effect of efficiency in oligopolistic competition (Acemoglu et al., 2009).

Along the same lines, Notteboom (2012) applied shift-share analysis to analyse the dynamics of competition between European container ports. The results revealed that the success of the port is strongly influenced by the ability of the port managers to develop synergies with other players within the logistics networks of which they are part. The study also highlighted the theoretical models emphasis on cargo traffic concentration at the level of a container port market.

Such studies can assist decision makers with different business and economic conditions to establish the most appropriate competition strategy in today's increasingly integrated global economy (Luo et al, 2012). However, the prevailing supposition that containerisation would increase port concentration is not a definite fact. The container port witness a gradual cargo deconcentration process as there are significant market-related elements reinforcing a relatively high level of traffic concentration in the container market (Notteboom, 2010).

Luo et al. (2012) applied a duopoly game to explain the development of a new port in the ex-monopoly market in the Pearl River Delta region (PRD) in China, by analysing the pricing and capacity expansion plans between two ports with different competitive conditions. The study is unique in considering a duopoly market where each port has different internal conditions, operating and investment cost variance, and external conditions such as price sensitivity and location. Ishii et al. (2013) applied a non-cooperative game theoretic approach to examine the effect of inter-port competition between port of Kobe in Japan and Busan in South Korea. The results showed an evidenced relationship between the timings of capacity investment and port charges in the context of dynamic settings.

Wu and Tu (2013) chose data of foreign direct investment (FDI) from year 1990 to 2011 in the (PRD) port group. They use the Granger test to examine the causal relationship between the FDI and port market concentration in the (PRD) port group in China. The study concluded that FDI in the (PRD) port group reduced market concentration. Wilmsmeier and Monios (2013) analysed and identified the potential deconcentration of container traffic within the UK port market. The results revealed that such deconcentration has potential advantage for regional UK container ports, many of which are conducting significant port expansions to get the benefits of these trends. The study thus raises questions about port strategy and both public and private sector responses to the change of UK port market geography.

The role of container ports as strategic units has changed to reflect a converging value chain position (Choi and Valikangas 2001), and many ports now collaborate in order to exploit their combined know-how and share complementary resources (Song and Panayides, 2008; Notteboom, 2009a). However, many smaller regional ports have simply been left as 'pawns in the game' (Slack, 1993) in terms of responding to competitive dynamics. In this context, Asgari et al. (2013) developed a game theoretic network design model to investigate the collaboration and competition strategies amongst three parties: two major container hub ports which are Singapore and Hong Kong and the shipping companies. The results revealed that cooperation rather than competition with regional ports can be a good strategy since port capacity can be constrained by geography such as Singapore.

Mclaughlin and Fearon (2013) applied a new conceptual collaboration/competition matrix to assess the reactive strategies of ports to inter-port competition and changing maritime competitive dynamics and to study some of the key alternatives in which ports have developed from a position of direct competition to increasing cooperation in order to maintain its competitive position in a fast-changing world. The results highlighted that a sustainable strategic reaction should be able to balance private and public sector stakeholder interests. Bae et al. (2013) developed a two-stage duopoly model of container port competition for transhipment cargos. The linear container demand function, among others, was derived to facilitate a two-stage game analysis. The results showed that shipping lines have a tendency to assign more port calls to the port that offers a cheaper price and a larger storage capacity.

Similarly, Zhuang et al. (2014) used alternative duopoly games, namely a Stackelberg game and a simultaneous game, to model inert-port competition, where ports provide differentiated services in the sectors of containerized cargo and dry-bulk cargo. The analysis revealed that inter-port competition can lead to port specialization in three ways which are type of cargo, port capacity and services. Yip et al. (2014) analysed the dynamic effects of competition for the port authorities and terminal operators by modeling the profits for two terminal operators serving two adjacent ports. The research results revealed that when a port authorities have considerable market power, they prefer to encourage inter and/or intra-port competition, rather than allowing one operator to be in a monopolistic situation by controlling and operating all terminals.

Do et al. (2015) analysed the competition between Hong Kong Port and Shenzhen Port. An uncertain payoff two-person game model is employed where an uncertain element of demand is involved. In applying Uncertainty theory (Liu, 2013), the uncertain statistics and the expected Nash Equilibrium strategy are applied. The research results produced meaningful proposal for future competition plan for the two ports under study. The study concluded that Shenzhen is the dominant port in this long-term strategy. Compared to existing studies on the same topic, this research is distinctive in studying the latest competitive situation in relation to the uncertain demand in the game model.

In the same context, Tian et al. (2015) suggested a new transformation method to explain the growth of container transport demand, define the quantitative measures of the competition relationship and port competitiveness, and provide an analytical framework with econometric tests and models to understand the true relationship between port of Hong Kong and Shenzhen Port. The results revealed that the two ports exhibit strong competition when the effect of demand growth is excluded. However, when transhipment traffic is considered, the results showed that the impact of Shenzhen Port on Hong Kong is negative in transhipment but complementary in direct shipment.

Oliveira and Cariou (2015) investigated how the degree of competition measured at different levels (local, regional and global level) affects the efficiency of container ports under study. A truncated regression with a parametric bootstrapping model is applied to 200 world container ports in 2007 and 2010. The study results revealed that port efficiency decreases with competition intensity when measured at a regional level; and the impact of competition is not significant when competition is measured at a local or at a global level.

2.5 Chapter summary

As illustrated in this chapter, globalisation and containerisation are major factors that have significantly affected the competitiveness level of ports. The horizontal and vertical integration between the different actors in the maritime industry as well as port privatisation have drastically magnified the competition between ports. Inter-port competition, for instance, is no longer limited to competition between ports in the same range but also to other ports in different regions.

Competition between ports can be regarded as a battle to maintain or if possible, increase market share and to gain more customers. The concept of port competition varies from one port user to another. As such, researchers have evaluated port competitiveness from different perspectives.

Scholars also highlighted that many of endogenous and exogenous elements determine the competitive position of a port. These factors are either qualitative such as reliability, quality and efficiency of port services or quantitative such as throughput, market share and ports' infra and superstructure. Nevertheless, the increasing trend towards the integration of supply chains has forced ports to compete not as individual firms but within supply chains as port users are no longer choosing a port for itself but rather a supply chain. That has in turn, intensified the competition between ports and induced port managers and researchers to continuously analyse the competitiveness level of ports. Such assessment and analysis can be carried out by different tools and techniques such as the Multi Criteria Analysis (MCA), Analytic Hierarchy Process (AHP), Data Envelopment Analysis (DEA), Strategic Positioning Analysis (SPA), port performance indicators and questionnaire as well as various models of port competition and market concentration. The literature explains that the methods used to assess port competitiveness vary according to the objective of each study.

The literature demonstrates that research on port competition has focused on specific objectives such as analysing the competitiveness level of ports in a particular market or region, exploring the factors affecting port competitiveness and developing models for port competition. It also reveals that most studies on port competition have focused on specific markets such as the Far East and Chinese container ports, European container market and US container ports. The above illustrated literature reveals that there is a lack of research that address the issue of port competition in the Mediterranean container market. This research analyse the competitiveness of major Mediterranean container ports by considering the Mediterranean in its totality, including south Europe, Middle East and North Africa. The study puts forward a way to assess container port efficiency based on simple, yet validated and meaningful competition measures. Moreover, the significance of this research, on one hand, can be realised in its contribution in not only assessing the competitiveness level of the top 22 container ports in the Mediterranean but also in analysing the dynamics of this market through measuring the market tendency towards concentration or deconcentration.

On the other hand, as far as the research methodology is concerned, the research uses a new approach for evaluating ports competitiveness and market dynamics which is the structure, conduct and performance (SCP) approach that derived from the industrial organisations theory. That will pave the way, later in this research in chapter six, to examine the impact of port efficiency on port competitiveness. In this context, the next chapter reviews the literature on port efficiency concepts and methods and analyses the development of research objectives and methodologies used to assess port efficiency from various perspectives.

CHAPTER THREE

LITERATURE REVIEW ON PORT EFFICIENCY

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LITERATURE REVIEW ON PORT EFFICIENCY

3.1 Introduction

The container port industry is characterised by severe competition that has inspired an explicit interest in the efficiency with which it utilises its resources. The study of the efficiency of individual container ports is of great importance for the endurance and competitiveness of the port industry and its players. Not only can such research offer a powerful management tool for port managers, but it also comprises an important input for informing national and regional strategic port planning (Cullinane and Wang, 2006).

In this context, the aim of this chapter is to review and analyse the literature in port efficiency form various perspectives. In doing so, this chapter is organised in five sections. The first section discusses the concepts, definitions, types and theories of port efficiency and productivity. The second section reviews the literature on port efficiency. The third section explores and analyses the literature on port efficiency measurement and evaluation techniques. The fourth section indicates the variable specifications of the existing literature and finally, the gap analysis and chapter conclusion are provided in the fifth section.

3.2 Port productivity and efficiency

Productivity and efficiency are considered as the two most important concepts in traditional economics in terms of performance measurements and are usually used interchangeably. However, efficiency is a primary concept in the field of economics and is basically focused on the economic utilisation of resources for production (Cullinane & Wang, 2007). Leibenstein (1966, p.392) clearly mentioned that *"at the core of economics is the concept of efficiency"*. Forsund and Sarafoglou (2002) also argued that *"efficiency and productivity are concept of economics"*.

Farrell (1957) classified the notion of efficiency into two main types, allocative efficiency and technical efficiency, which in combination present a comprehensive evaluation for economic efficiency. He described economic efficiency as the ability of a company to create a pre-planned amount of output at minimum possible cost for a given level of technology. An accurate stipulation of both allocative and technical efficiency is vital for income efficiency, cost efficiency and benefit efficiency to exist (Infante & Gutiérrez, 2013). Thus, Pinzon (2003, pp.17) explained that "*economic efficiency is considered to be the achievement of maximum production at the lowest price possible*".

Infante and Gutiérrez (2013) explained that the first element of economic efficiency is productive or technical efficiency. Koopmans (1951) stated that a production unit is technically efficient if output maximisation or an input minimisation requires an increase in at least one input or a reduction in at least one output. Yarad (1990) asserted that technical efficiency entails achieving maximum physical production from specific number of inputs. Gonzalez-Paramo (1995) confirmed that technical efficiency in a firm is attained by its ability to convert inputs such as infrastructure capital, labour, and other elements into outputs, products or services, which can be summarised with a production function setting maximum value of achievable output within a certain group of inputs.

In the vein of performance measurement, Lovell (1993) argued that a distinction should be made between the two concepts, efficiency and productivity, as both are used as indicators of the success of production units. They enable decision makers to find out hypotheses related to the sources of discrepancy between measuring the productivity and efficiency of a firm. Considering such sources are essential in the process of introducing public and private polices that could improve performance as macro-performance depends on micro-performance.

Coelli et al. (1998) defined productivity as the ratio of output to input or as total factor productivity (TFP). These respectively are inconsistent with the situation where there is a single input and output or where there are several inputs and outputs. However, efficiency is a comparative concept that can be measured through a process of comparisons or benchmarking. Efficiency can be classified into three main types which are technical efficiency, scale efficiency and allocative efficiency (Infante & Gutiérrez, 2013).

Lansink et al. (2001) indicated that technical efficiency can be expressed as the relative productivity over time and/or space. It could be classified into intra and inter-firm measures of efficiency. Intra-firm measures comprise assessing the potential production of a firm by calculating its productivity level over time in relation to the firm highest level of historic productivity. In contrast, inter-firm measures of productivity evaluate the performance of a specific firm in relation to its best correspondents in the industry.

The notion of technical efficiency is also connected with two main concepts which are the production frontier and the cost frontier. The former presents the recent status of technology in an industry and it is related to the set of maximum outputs given various levels of input while the latter implies the set of minimum inputs given different levels of output. Technical efficiency can be distinguished as output and input-oriented efficiency. The firm could either increase outputs given the same level of inputs or decrease the inputs given the same level of outputs (Schøyen & Odeck, 2013).

De Borger et al. (2002) explained that scale efficiency refers to a feasible difference between actual and best output. Scale efficiency is applicable when production technology offers variable returns of scale. This type of efficiency explains if the analysed productive firm has achieved optimal scale level. Scale efficiency results from equally raising the quantity of all measures affect the production function. Varian (1998) expressed that there are three kinds of scale efficiency. First is the Constant Return to Scale (CRS) that means if the value of each element increases, production rises in the same proportion. Second is the Decreasing Return Scale (DRS) which means when the value of each element increases, production rises in a lesser proportion. Third is the Increasing Return to Scale (IRS) that means if the value of each element rises, production increases in a greater proportion (Infante & Gutiérrez, 2013).

The best configuration corresponds to the long-term competitive balance, when the main feature of production is the constant return to scale. An enterprise is scale efficient if its selection of outputs and inputs is placed in that part of a frontier, either production or cost, that generate constant return to scale.

Hernandez-Laos (1981) explained that allocative efficiency concerns the distribution of resources, which means allocating a certain number of resources in changing situations in order to maximize the quantity of output, whether the analysis emphasises on the consumption or the production area. Yarad (1990) claimed that allocative efficiency related to the fact that the total investment in inputs used to produce a minimum amount of products according to the price of such inputs.

Infante and Gutiérrez (2013) illustrated that allocative efficiency emphasises the costs of production provided that information on prices is available which is considered as a behavioural hypothesis, such as cost minimisation or profit maximization, that could be appropriately established and accordingly suitable assumption can be formulated. Allocative efficiency can be achieved under three basic conditions: Consumer Efficiency, which arises when consumers fail to enhance after re-evaluating their budgets. Marginal cost equality such as cost of producing an additional product including marginal social benefit and external costs. Economic Efficiency, which encompasses technical efficiency and the use of production elements in such proportions in which costs are reduced (Infante &Gutiérrez, 2013).

Gonzalez-Paramo (1995) asserted that allocative efficiency occurs when a firm minimises costs or maximises profits: when the decision makers of a firm have succeeded to not only reaches the production frontier but also selects the set of elements that enables them to minimise costs at a certain production level (Bosch et al, 1999). As such, it can be noticed that allocative efficiency differs from technical and scale efficiencies as the former focuses on issues like costs or profits, while the latter certainly deals with physical quantities and technical relationships (Infante & Gutiérrez, 2013). For instance, allocative efficiency in input choices arises when the selection of inputs such as labour, materials and capital provides certain amount of output at a minimum cost, given the current prices of all inputs (Coelli et al., 1998).

De Monie (1987) asserted that there is a need to measure and enhance port efficiency. He also asserted that any effort to analyse port efficiency is formidable due to the various numbers of parameters involved, as well as the unavailability of reliable data. Trujillo and Nombela (1999) explained that there are many methods for measuring port efficiency or productivity. These methods can be classified into three main categories which are physical indicators, factor productivity indicators, and economic and financial indicators. Physical indicators signify time measures that are mainly related to the ship such as ship turnaround time in port, ship waiting time and berth occupancy ratio. Co-ordination with land modes of transport is also measured such as cargoes dwell time, the duration between cargos being unloaded from a ship until it leaves the port (Infante & Gutiérrez, 2013).

Factor productivity indicators also emphasise on port operations. For instance, to analyse both labour and capital required to handle cargoes from ships. Economic and financial indicators are usually focus on the sea access; for example, operating surplus or total revenue and expenses related to gross registered tonnes (GRT), a ship's total internal volume, or net registered tonnes (NRT), ship’s spaces that are not available for carrying cargo such as engine rooms and fuel tanks, or charge per TEU, fees for handling one twenty feet container. The economic impacts of a Port are sometimes evaluated to assess the socio-economic influence of a port on its respective foreland or hinterland (Bichou & Gray, 2004).

Trillo (2002) asserted that the assessment of technical efficiency mainly emphasises on the use of human resources or capital in the production of one or many products and services. The notion of efficient production function reveals that technical efficiency in any firm is evaluated in relation to the set of firms from which such function has been estimated. If any more firms are added in the analysis, they could cause a decrease in the technical efficiency of a certain firm (Infante & Gutiérrez, 2013). Appendix 3.1 provides a thorough understanding of efficiency measurement concepts as well as the different aspects of efficiency evaluation and benchmarking.

Next section review and analyse the literature in port efficiency from different perspectives. The analysis demonstrates the evolution of research in port efficiency over time in terms of research scope, objective, methodology and factors being used to assess and benchmarking port efficiency.

3.3 Literature review on port efficiency

Recently, remarkable achievements have been made in research examining the productivity and efficiency of the port market. That is, by far and large, due to the technological development and innovation processes taking place in the maritime and port industries. Gonzalez and Trujillo (2009) asserted that transformation in the organisation of ports structures have changed and modified the nature of port operations. That, in turn, have effectively affected the productivity and efficiency of port operations and promoted a greater specialisation of the production inputs.

The objectives and scope of research in port efficiency have evolved over time. Studies have explored the determinants of port efficiency, benchmarked ports' relative efficiencies and analysed the effect of port ownership and administration structure on port efficiency. Rankings of ports have emerged along with assessments of the effect of port reform processes on efficiency. However, the methods used for assessing port efficiency are generally distributed between Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). The methodology used depends on the objective and hypotheses that each study considers.

In this context, Roll and Hayuth (1993) used the DEA-CCR model; that is established by Charnes, Cooper and Rhodes (1978) to assess the aggregate technical efficiency (TE), under constant return to scale (CRS), to replicated data of container ports for emerged economies in order to indicate to what extent this method is convenient for measuring port efficiency. However, their work was considered as a theoretical analysis of applying DEA to the port industry rather than as realistic application since no data were gathered or investigated. Tongzon (1995b) applied multiple linear regressions and DEA to introduce a model of port efficiency and predict the relative efficiency of world's top 23 international container terminals. The results explored the determinants of port performance and efficiency.

Some researchers have tried to study the relation between port size and port efficiency(Liu, 1995; Martinez-Budria et al, 1999; Notteboom et al, 2000; Cullinane et al, 2002 and Sohn & Jung, 2009). They mostly indicated that the larger the port, the greater its efficiency as a result of the learning effect presented by the higher activity levels. Ports are forced to intensely invest in infra/superstructure to be able to keep pace with the estimated growth of future demand that could lead to ports having excess capacity at the time of making such investment. That could create some difficulties in achieving satisfactory levels of scale efficiency. In addition, while some large ports reach to the maximum substantial limit of their growth, and accordingly cannot increase their efficiency, smaller ports could find opportunities for further growth and reach optimum scales. All these factors make it difficult to find a rational relation between efficiency and port size (Gonzalez & Trujillo, 2009).

In this context, Martinez-Budria et al. (1999) classified Spanish port authorities into three harmonized groups (large, medium, and small) by applying criteria of complexity that take into account port size and constitution of the output vector. They examined the efficiency of these ports by using DEA-BCC model, that is developed by Banker, Charnes and Cooper (1984), to evaluate the pure technical efficiency (PTE) under variable return to scale (VRS). The outcomes explained that larger ports are the most efficient and have the greatest efficiency enhancements. Smaller ports are in the second category; with a remarkable decline in efficiency while medium ports are in the last category with the lowest development in efficiency.

In contrast, Coto-Millan et al. (2000) evaluated the efficiency of the port authorities and tried to find out whether the type of organisation and port size can justify the variances observed in the economic efficiency measures. Their analysis indicated that small ports under study are more efficient than the larger ones. Nevertheless, after studying various elements that could affect the degree of economic efficiency, they asserted that port size is not the major factor.

Notteboom et al. (2000) compared the technical efficiency of the main European container terminals with the four largest container terminals in Asia. They examined the impact of some elements that can influence the operational efficiency of the (large/small terminals; hub/feeder ports; private/public; Northern Europe/Southern Europe). The research findings explained that the existence of severe intra-competition among small terminals within a port creates higher levels of efficiency. They also provided another outcome related to size which was inconsistent with the findings of Cullinane et al. (2006), is that terminal efficiency in hub ports is higher than in feeder ports, even though with greater levels of diffusion within each group. That might relate to the severe inter-port competition among hub ports.

Tongzon (2001a) had the same results and asserted that port size is not the main decisive factor of port efficiency. He used the DEA-CCR and DEA-additive models to assess the efficiency of four Australian and 12 other international container ports for the year 1996. The study indicated that there are as many hub ports as feeder ports considered as the most efficient ports. The massive port infrastructure presents the existence of economies of scale in ports. These results oppose the results of Bonilla et al. (2002) and Gonzalez and Trujillo (2008) who indicated that the most efficient ports embrace both large and small ones, and alike occurs with the least efficient.

Tongzon and Heng (2005) applied the SFA, Stochastic Cobb-Douglas model, and competitiveness regression to benchmark the efficiency and competitiveness of the world's top 25 container ports. The study introduced an explicit relationship between technical efficiency and port size. Cullinane and Song (2006) also employed the SFA for benchmarking the technical efficiency of European container terminals. The analysis expressed that the terminal size is highly correlated with its efficiency. Wang and Cullinane (2006a) applied the DEA-CCR/BCC models to 104 European terminals, with throughput greater than 10,000 TEU in 2003. The study revealed that most of the container ports that have massive production scale also have higher efficiency scores. Cullinane et al. (2006) explained that large ports have made significant investments in infra/superstructure that enable them to grow, but once they reached a certain limit, they find that it is hard to keep growing; that express why the majority of these ports operate at their designed capacity.

Cullinane and Song (2006) estimated the relative technical efficiency of a number of European container ports using the cross-sectional version of the stochastic frontier model. The results revealed that the size of a port is positively correlated with its efficiency. Sohn and Jung (2009) observed that large Asian ports are more efficient and have a greater market share in container transhipment than the small ports in the market. The SFA and panel data analysis were used to study the relationship between efficiency and container transhipment traffic.

In contrast, Al-Eraqi et al. (2010) applied the DEA window analysis model that provide information on seaports efficiency based on the analysis of outputs and inputs of 22 ports of the Middle East and East Africa. The analysis indicated that small ports are more efficient than large ports and noted that the throughputs of ports in this market are not stable due to the instability in the region. Gaur et al. (2011) studied the effect of port size on port efficiency throughout the study of port capacity. They developed an Efficiency Index for Indian ports based on the data between 2004 and 2009 and recommended institutional collaboration among ports to attain potential capacity and learn from the best international practices to achieve absolute capacity.

Some researchers focused on assessing the impact of changes in port regulation on port efficiency. Valentine and Gray (2001) used the DEA-CCR model to 31 container ports out of the world's top 100 container ports for the year 1998 to analyse the relationship between port efficiency and specific types of ownership and organisational structures. The study concluded that such relationships lead to higher efficiency. After attaining an average annual growth rate of the efficiency of Mexican ports of 5 to 6 per cent, Estache et al. (2002) concluded that the Mexican port reform of the early 1990s created positive impacts in all of the port authorities. As such, they suggested that reforms that promote autonomy in port management can generate considerable improvements in the sector.

There are also some other investigations on the Spanish port system. Banos-Pino et al. (1999) tried to figure out if there are any constraints in adjusting capital in the short term. Martinez Budria et al. (1999) and Bonilla et al. (2002) analysed the relative efficiency of Spanish port authorities. Martin (2002) showed that, right after the port development of the 1990s, Spanish port authorities made considerable progress in productivity and improvements in technical efficiency which occurred in a relevant manner after 1997.

In the same context, Cullinane et al. (2002) claimed that the level of deregulation has a positive impact on port efficiency and the transfer of property ownership from the public to the private sector in the main container terminals in Asia enhances the economic efficiency of terminals. The study also indicated that there is a direct relation between terminal efficiency and terminal size. Similarly, Dıaz (2003) evaluated the effect of the organisational restructure of the stevedoring sector in Spain between 1990 and 1998. The results showed that efficiency gains led by technological improvements and through the benefits of economies of scale. The study also showed that allocative efficiency is higher than technical efficiency in this sector.

Barros (2003a) applied the DEA-CCR/BCC and allocative efficiency models to evaluate the efficiency attained by some Portuguese ports to deduce the role of the motivations established by the Portuguese regulation. The research concluded that the improvement made by the Portuguese port authorities have positioned those ports beyond the efficiency frontier. However, the research recognised that due to the limited size of the sample and the heterogeneity of the study ports, the results should be taken with caution. Through the use of cross-section data model, Cullinane and Song (2003) also indicated that the greater the level of private sector participation, the higher the level of efficiency. They also noticed that terminal efficiency in South Korea was enhanced with the promotion of competition in the market. Nonetheless, these outputs should cautiously be introduced since the sample only includes five terminals and the category of terminals varies when a panel data model is employed.

Barros and Athanassiou (2004) also recognised the same problem in their research when they employed the DEA-CCR/BCC models to evaluate the efficiency of two Greek and four Portuguese ports. The study produced a ranking of the study ports and identified the ports that have achieved remarkable improvements in their efficiency. Scale efficiency was suggested as the main aim for the defined ports and privatisation was promoted as the most effective approach for attaining economic efficiency.

Similarly, Estache et al. (2004) concluded that port reforms motivate port operator to enhance efficiency and generate technological progress. Park and De (2004) introduced a new alternative model for evaluating the efficiency of ports that can effectively be used by port authorities for evaluating the comparative efficiency of their ports. In order to conquer the limitations of basic DEA models, they established a four-stage DEA model that includes productivity, marketability, portability and overall efficiency.

In the last decade, research in port efficiency has extended to not only benchmarking the relative efficiency but also ranking (in)efficient ports. Wang et al. (2003) and Cullinane et al. (2005) applied DEA-CCR/BCC models in order to measure and rank the efficiency of major international container ports. Similarly, Wang and Cullinane(2006a) applied the same models to rank the efficiency of 104 European container terminals in relation to location and terminals' throughput. So et al. (2007) analysed and ranked the efficiency of 19 main container ports in NE Asia by using the DEA CCR/BCC super efficiency models. Wu et al. (2009) used a DEA cross efficiency evaluation method to assess and rank the efficiency of 28 Asian container ports.

Research on port efficiency has further evolved to analyse the relation between port efficiency and port ownership. The majority of these studies have explored this relationship in the container port market. Although there is no consensus on whether there is a correlation between port ownership and efficiency, results of previous studies assert that port efficiency has, by far and large, enhanced with the increasing trend towards privatisation in container port terminals (Gonzalez & Trujillo, 2009).

Within the applications of SFA in the port industry, Liu (1995) examined the hypothesis that ports, managed and operated by public sector, are intrinsically less efficient than ports in the private sector. A group of panel data of the outputs and inputs of 28 UK ports over the period from 1983 to 1990 was gathered for investigation. The analysis revealed that there is no correlation between port ownership, as a significant factor in production, and port.

In the same context, Cullinane et al. (2005a) examined the relationship between privatisation and efficiency within the container port sector. The study applied DEA-CCR/BCC models and panel data analysis to the world's top 30 container ports for the period between 1992 and 1999. The study rejected the hypothesis that greater private sector participation in the container port industry irrevocably leads to enhanced efficiency. Cullinane et al. (2005b) also employed an international sample that includes the world's top 57 ports to compare the results obtained using various linear programming techniques, DEA-CCR/BCC and Free Disposal Hull (FDH). Their analysis did not also find any relation between privatisation and efficiency which is consistent with the results obtained by Cullinane and Song (2002).

In contrast, Tongzon and Heng (2005) illustrated that there is a positive relation between technical efficiency and privatisation in container terminal. They asserted that the best property ownership for container terminals is the public/private partnership or purely private. The study revealed that a port authority should only have control over port legal framework and promotes the involvement of private investment in port operations. Cullinane et al. (2006) applied DEA and stochastic production frontiers on the top world container ports to analyse the impact of privatisation on port efficiency. The study asserted that, apart from port of Singapore, the most efficient ports are those with the high percentage of private participation. Similarly, So et al. (2007) had the same conclusion when they employed the output oriented DEA-CCR/BCC models to analyse the efficiency of 19 main container ports in Northeast Asia including China, Korea and Japan. The analysis also showed that the facilities and scales of the ports under study were almost the same.

Rodriguez-Alvarez et al. (2007) assessed both the technical and the allocative efficiency of the three main container terminals of the Port of Las Palmas in Spain. Alonso and Bofarull (2007) applied DEA models to evaluate the efficiency of ports of Bilbao and Valencia in Spain to analyse the extent to which investment has led to improving efficiency and how far this improved efficiency has enhanced the port attractiveness. The results of both studies revealed that investment is not the only factor that could improve port technical efficiency.

The above outcomes contradict Gonzalez and Trujillo (2008) who indicated that most Spanish ports operate with increasing returns to scale. They also examined if the port development process of the 1990s has enhanced the Spanish port efficiency. The results confirmed that the Spanish ports development created enhancements in the efficiency of the port authorities via technical progress. This conclusion is consistent with other studies of both Spanish and foreign ports. Such as the research conducted by Jara Diaz et al. (1997) who got the same result within the Spanish ports market after predicting a multi-output cost function. Martinez-Budria et al. (1999) and Banos-Pino et al. (1999) also observed that the inefficiencies discovered in Spanish ports are related to excess capacity which reduces with the increase in port activity.

Cheon et al. (2010) evaluated how port institutional developments affected efficiency gains between 1991 and 2004. They composed a panel data for port ownership, corporate structure and port inputs and outputs for 98 main world ports and applied the Malmquist Productivity Index (MPI) model. The results illustrated that ownership restructuring stimulated optimisation of container ports operation, particularly for large ports, as it enabled specialized private entities to focus on port operation and cargo handling services. In contrast, Khin and Yang (2010) reviewed the experience of ports in Myanmar in relation to privatisation and enhancement of relative efficiency among those ports. The study concluded that the type of port ownership does not positively affect port efficiency.

Studies on port efficiency have also focused on analysing ports' scale efficiency. Hung et al. (2010) analysed the operational efficiency and the scale efficiency of 31 Asian container ports. The traditional DEA CCR/BCC models, most productive scale size concept, return to scale approach and bootstrap method are employed to evaluate the operational efficiency and determine the efficiency ranking of the defined ports. The results explained that the overall inefficiencies of Asian container ports are mainly due to pure technical inefficiencies rather than to scale efficiencies. The results also provided an insight to port managers into port resources allocation and port competitive advantage.

The same outcomes are also observed by De Neufville and Tsunokawa (1981) by applying a Cobb–Douglas production function. Through the use of the same approach, Chang (1978) asserted that the Port of Mobile (Alabama) has increasing returns to scale. Wang and Cullinane (2006b) observed economies of scale in a group of European container terminals and indicated that the scale of production affects the efficiency level. Turner et al. (2004) reached to the same conclusion when measuring the efficiency of some of North American container terminal ports.

Gao et al. (2010) applied DEA-CCR model to assess the scale efficiency of Shenzhen port in China in different years. DEA with cross evaluation was applied to benchmark the efficiency of five ports. The conclusion of this analysis provided reasonable theoretical support for port managers to enhance management strategy. Wu and Goh

(2010) compared the efficiency of container port operations in emerging markets, BRIC and the next 11 emerging nations with the more emerging markets (G7)[1]. They applied DEA-CCR/BCC output oriented model to assess the efficiency of such ports based on the import/export cargo traffic in 2005. The analysis argued that none of the ports in the defined markets are role models for the field.

Choi (2011) presented an empirical analysis on the efficiency of the 13 container ports in Northeast Asia in the period between 2005 and 2007. The study analysed empirical results on the efficiency of main ports by using DEA-CCR/BCC, Malmquist and Tobit models. The results revealed that most ports exhibited higher scores in pure efficiency, but low scores in scale efficiency. The study concluded that investment in infrastructure does not enhance efficiency.

Apart from the assessment of container port efficiency, De Oliveira and Cariou (2011) used DEA-CCR/BCC, scale efficiency and return to scale models to assesstheefficiencyof122coal andironoreportsin2005.The results revealed that the main reason of inefficiency in bulk terminals is due to the scale. They identified relevant input and output variables when applying DEA to bulk terminals and provided a methodology to quantify the relative efficiency of ports when aggregated at the country level. This provides a means for estimating a performance index of the competitiveness of countries.

Wanke et al. (2011) reported on the use of various models for evaluating the efficiency of main Brazilian ports. They performed two approaches, DEA and SFA, on data gathered from 25 ports in 2008. The results indicated that most of Brazilian ports have shortage in capacity due to the increased export that has taken place over the last few years and the lack of investment in capacity expansion. Lu et al. (2015) applied the DEA models to benchmark the technical efficiency of the top 20 world leading container ports for the year of 2009. Empirical results revealed that substantial waste exists in the production process of the container ports under study. Analytical

[1]The **Next Eleven** (known also by the numeronym (**N-11**) are the eleven countries – Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, Turkey, South Korea, and Vietnam – identified by Goldman Sachs investment bank and economist Jim O'Neill as having a high potential of becoming, along with the BRICs/BRICS, the world's largest economies in the 21st century.

results also revealed that the study ports were found to exhibit a mix of increasing and constant returns to scale at current levels of output.

In order to overcome the limitations of DEA analysis that are based on cross-sectional data, when time is ignored, Cullinane et al. (2004) applied the DEA-CCR/BCC output oriented model of panel data and window analysis to assess the technical efficiency of the world's top 25 container ports in the period between 1992 and 1999. The results indicated that the majority of ports have persistent returns to scale, which explains that the scale of production is not the main reason for inefficiency. The study also explained that the terminals' efficiency is not affected by the size.

Cullinane et al. (2005) applied a variety of DEA panel data approaches to benchmark the efficiency of the world's major container ports. Thus, the development of the efficiency of every container port in the sample could be traced over time and, then, the efficiency outcomes are presumably more realistic. Al-Eraqi et al. (2007) evaluated the operational efficiency of 22 container ports in the East Africa and the Middle East regions. They also compared the location of ports situated on the maritime East-West trade route. The study employed the DEA on data for 6 years from 2000 to 2005. The analysis concluded that berth length and ships call, as indicators for port efficiency, play a significant role for waiting time and congestion in the ports. Liu (2008) applied CCR/BCC and 3-stage DEA models to assess the variation in efficiency that have taken place between 1998 and 2001 in 10 ports in the Asia Pacific market using cross-period data. The results showed that different models will lead to different result.

Al-Eraqi et al. (2008) extended their study in 2007 to benchmark the efficiency of 22 ports in the Middle East and East Africa by using the DEA standard and window analysis methods. The study highlighted the pros and cons of using the two methods in analysing the ports efficiency. Yan et al. (2009) developed stochastic frontier model to evaluate production efficiency, efficiency changes and the time persistence of efficiency after considering the individual heterogeneity in technology and technical changes of container port operators.

Al-Eraqi et al. (2010) have further developed their analysis of 2007 and 2008 to assess the efficiency and super-efficiency scores of 22 cargo ports in Middle East and East Africa by using DEA panel data and window analysis. The research concluded that the number of efficient ports under super-efficiency is greater than the number of ports under normal efficiency. Cullinane and Wang (2010) benchmarked the efficiency of 25 world leading container ports by using DEA panel data analysis to assess their efficiency and their competitiveness for benchmarking best practice and indicating particular reasons of inefficiency. The empirical results revealed that the time factor is significant in port efficiency and competitiveness evaluation. The panel data analysis allows tracing the development of port efficiency and considers the market contestability due to fierce competition between container ports.

Bichou (2011) empirically analysed the impacts of port security regulations on the operational efficiency of container terminals. A stepwise Malmquist DEA model is used to track productivity changes of 420 worldwide container-terminals from 2002 to 2008, both on a multi-year basis and on a regulatory-run basis. The analysis showed that the efficiency estimates differs significantly by type of regulation and terminal.

However, Maidamisa, et al. (2012) developed a methodology for the selection of window width in DEA by employing the Analytic Hierarchy Process (AHP). The selected width is examined by using panel data and the results showed robustness in the efficiency evaluation. AHP is also used by Ugboma et al. (2006) to rank shippers' port selection criteria. The results indicated that shippers focus greatly on port efficiency, frequency of ship calls and adequate port infrastructure.

Research on port efficiency has further developed to assess the impact of the external environment, exogenous factors, on port efficiency. In this context, Barros and Managi (2008) analysed efficiency drivers of a representative sample of Japanese ports by using the two-stage procedure developed by Simar and Wilson (2007). In the first stage, the technical efficiency of the study ports is assessed using various models of data envelopment analysis (DEA). In the second stage, a truncated bootstrapped regression is applied to bootstrap the DEA scores to identify efficiency drivers. The results showed that the ports which have adopted strategic procedures, such as hub strategy, are more efficient than those which do not adopt this strategy.

Niavis and Tsekeris (2012) benchmarked and identified major determinants of the technical efficiency of container ports in the South-Eastern Europe region, including the Italian ports which directly affect competition in the East Mediterranean Sea. The study employed both non-parametric (standard and super-efficiency DEA) models and bootstrapped parametric models to provide a more holistic approach and useful insight into the analysis. The results indicated that the relatively low average total technical efficiency of the sample container ports can be related to both the lack of managerial skills and scale effects.

Yuen et al. (2013) studied the effect of intra- and inter-port competition on container terminal efficiency in China and its neighbouring countries. The operational efficiency of sample container terminals was measured by DEA panel data for the period between 2003 and 2007. Regression analysis was also used to examine elements affecting container terminal efficiency. The study concluded that Chinese port-ownership may enhance container terminal efficiency. It is also found that intra- and inter-port competition may improve container terminal efficiency. Wanke (2013) also analysed the efficiency of 27 Brazilian ports for the year of 2011 by using a two-stage analysis. The first stage was the physical infrastructure efficiency followed by the shipment consolidation efficiency. Results indicated that ports that are managed by private sector have higher physical infrastructure efficiency levels.

Bichou (2013) applied a series of DEA models to evaluate the operational efficiency of 420 international container terminals from 2004 till 2010. The study formulated some operational hypotheses to test the sensitivity of benchmarking results to port market such as production scale, transhipment ratio, cargo mix, operating configurations, and working procedures. The results showed that variations in operating conditions significantly affect terminal efficiency.

Tovar and Wall (2015) applied a directional technology distance function to analyse the technical efficiency and production technology of 20port authorities in Spain for the period 1993–2012.The results showed that the ports under study are technically inefficient. An implication of such result is that there is a potential for specialization on the part of sample ports without a need for new investment in infrastructure.

Ju and Liu (2015) employed a two-stage procedure, DEA and regression analysis, to investigate the efficiency of 14 port-listed companies in China for the period between 2001 and 2011. The results demonstrated that the ratio of state-owned shares, debt asset ratio and operating costs ratio are negatively related to efficiency. On the contrary, port size, ratio of outside directors and human capital are positively correlated with efficiency. Results of the panel data model illustrated that a long-term equilibrium relationship exists between efficiency and its influencing elements.

Within the application of SFA in the port sector, Cullinane et al. (2002) applied SFA models to benchmark the efficiency of 15 container ports in Asia between 1989 and 1999 by using three distributions (half-normal, exponential, and truncated normal). Cullinane and Song (2003) also used the same hypothesis in their analysis to benchmark the efficiency of two Korean container ports and three UK container ports between 1978 and 1996 based on the study of stochastic production frontier. Cullinane et al. (2006) applied SFA and DEA to assess the efficiency of 28 world's most important commercial ports. Their analysis indicated that the SFA model was adequate when evaluating port operations as the assumption of constant returns to scale in the production frontier could not be eliminated.

Yan et al. (2009) developed an empirical model under the stochastic frontier framework to evaluate operational efficiency, efficiency changes and the time persistence of efficiency after considering the individual heterogeneity in technology and technical changes of container operators from the world's top container ports in the period between 1997 and 2004. The analysis concluded that the mean efficiency of container operators slightly changed with time.

Medda and Liu (2013) examined how the typology and operation of terminals and the level of scale efficiency that a terminal can achieve represent significant factors in the development and growth of the container terminal industry. The analysis is based on the assessment of 165 container terminals worldwide. They developed the estimation through the application of SFA. The results revealed that container terminals are more efficient than multi-purpose terminals. The study provided empirical suggestion that could enable resource-constrained container terminals in the Mediterranean Basin to improve their scale efficiency and identify general strategies related to container terminal investments.

Chang and Tovar (2014) benchmarked the efficiency and performance of Peruvian and Chilean ports terminals (SFA). A distance function was used on a sample of 14 ports terminals observed over the period 2004–2010. The study revealed that the terminals improved their technical efficiency during the period of analysis, with Chilean terminals being more efficient than the Peruvians. Tovar and Rodríguez-Déniz (2015) categorised and classified the Spanish port authorities by establishing a model that combines SFA, clustering and self-organized maps (SOM).The analysis of the structure and efficiency of Spanish port authorities concluded that there is a number of well-defined sets of ports with similar characteristics that depend on scale of production. Next section explores and analyse the evolution of literature in port efficiency in terms of the assessment methods and techniques being used to assess and benchmark port efficiency.

3.4 Literature review on port efficiency assessment techniques

Studies and research on port efficiency can be classified into three main groups. The first is research that use partial productivity indicators of the port system (Suykens, 1983; Talley, 1994; Tongzon, 1995a) and total factor productivity (TFP) that is employed by Kim and Sachish, (1986) for the first time as an applied methodology to the port sector. The second group is studies that use simulations and queuing theory (De Neufville and Tsunokawa, 1981; Sachish, 1996). The third group is the most recent research that uses technological frontier estimates from which efficiency indicators of port firms are derived. Notwithstanding, Chang (1978) has taken the initiative in measuring the production functions in the port area. Irrespective of the approach used, the main interest was in developing instruments that could help in decision-making process, both from a management and an economic policy perspective (Gonzalez & Trujillo, 2009).

Different approaches and techniques have been used to measure and evaluate the various types of port efficiency, the performance of ports has been diversely assessed by measuring cargo-handling productivity at berth (Bendall and Stent 1987, Tabernacle 1995, Ashar 1997), by evaluating single factor productivity (De Monie, 1987) or by benchmarking actual with optimum throughput within a certain period of time (Talley, 1998). Recently, remarkable development has been made in relation to efficiency measurement of the productive activities. Two complex holistic models have been widely used to measure port efficiency. These models are data envelopment analysis (DEA) and stochastic frontier analysis (SFA).

The concept of DEA was first applied by Farrell (1957) but it was primarily limited to the performance evaluation of firms with multiple inputs and a single output. Charnes, Cooper and Rhodes (1978) developed a model that incorporated multiple inputs and multiple outputs. This model validated the use of DEA in performance measurement. DEA is a non-parametric technique that applies the concept of 'Pareto optimization' for efficiency measurement (Forsund et al, 1980). It enables the identification of a firm (DMU) as an efficient or an inefficient unit and can explain how a given DMU's efficiency might be enhanced (Lin & Tseng, 2007).

Basically, there are two DEA models used to assess port efficiency. The first is the CCR model that is established by Charnes, Cooper and Rhodes (1978) to assess the aggregate technical efficiency (TE) under constant return to scale (CRS). The second is the BCC model that is developed by Banker, Charnes and Cooper (1984) to evaluate the pure technical efficiency (PTE) under variable return to scale (VRS) (Fare et al, 1994).

In this context, as showed in appendix 3.2, Roll and Hayuth (1993) applied a DEA-CCR model to simulated data with the aim of explaining the ultimate fitness of this approach for evaluating port efficiency, and the use of efficiency indicators. While Poitras et al. (1996) applied the DEA-CCR input oriented model to assess the aggregate technical efficiency, Valentine and Gray (2001) used the DEA-CCR output oriented model to benchmark the operational efficiency.

The DEA-CCR model is also used by Tongzon (2001a) and Barros (2003b), who compared the results with those attained after the usage of the additive model (Charnes et al, 1985). Bonilla et al. (2002) used the DEA-CCR model and criticized the result obtained by the model application which is that the DEA scores are deterministic as it lacks a statistical base. From this perspective, the study of Bonilla et al. (2002) is a novel contribution, since the use of bootstrap techniques enables statistical inference to be made in the non-parametric estimates, attaining confidence intervals of the efficiency results. Sharma and Yu (2009, 2010) and Gao et al. (2010) applied the DEA-CCR output oriented model to compare the operational efficiency of container ports. The studies allowed an objective assessment of the overall efficiency and identified the sources of inefficiencies.

Yip et al. (2010) used the DEA-CCR model and Ordinary Least Square (OLS) model. The significance of that research can be showed in the use of the DEA and regression applications. Such approach, as explained in Arnold et al. (1996) takes a two-stage procedure as follows: Stage one uses DEA to determine efficient and inefficient DMUs. Stage two integrates these results in the form of dummy variables in the equivalent regression.

Martinez-Budria et al. (1999) used the DEA-BCC model to compare the efficiency of port authorities under study. They divided the sample into four categories according to complexity. Rios and Macada (2006) used the same approach to analyse the relative pure technical efficiency of 23 container terminals in Latin America. The use of DEA-BCC model in both studies allowed for analysing the efficiency of ports of study under variable return to scale (VRS). The results obtained from the application of both models, DEA-CCR and BCC, are compared by Park and De (2004), Barros and Athannasiou (2004), Cullinane et al. (2004, 2005a, and 2006) and Wang and Cullinane (2006a). Similarly, Liu (2008), Koster et al. (2009), Wu and Goh (2010), Jiang et al. (2012) and Ju and Liu (2015) also used the DEA CCR and DEA-BCC models to compare the aggregate technical efficiency under (CRS) versus pure technical efficiency under (VRS).

Some studies introduced extensions to DEA. Martin (2002) applied the model developed by Banker and Morey (1986), since it matches the assumption established, Malmquist index is used for determining if there have been enhancements in efficiency, and conducted a decomposition isolating the technical progress of the efficiency enhancement. Cullinane et al. (2004) carried out a dynamic analysis applying the DEA windows analysis. Park and De (2004) applied a four-stage DEA:

alternating the importance of the variables as inputs and outputs. Estache et al. (2004) used the Malmquist index built from distance functions and calculated by DEA to identify the sources of the productivity gains and decomposing the change in TFP into its main components.

Researchers have further developed port efficiency benchmarking methods by comparing between the results obtained by the DEA and other assessment technique. Wang et al. (2003) and Cullinane et al. (2005a, 2005b) compared the results attained by the DEA-CCR/BCC models with those obtained by the Free Disposal Hull (FDH), whose measurement is more traditional than DEA. The FDH model presumes robust input and output disposability. That means any given output(s) remains viable if any of the inputs is increased, similarly, with given inputs it is always viable to reduce output(s). Both analyses asserted that FDH model was an inadequate approach due to the nature of its fundamental logic and step function solution algorithm. Certainly, the FDH model indicated that DMU was efficient when it was truly not.

Agreement with the debate on analogous data that can only be obtained at the level of container terminals rather than ports, (Goss, 1990a; Heaver, 1995; Alderton, 1999; Heaver et al, 2000, 2001), Cullinane and Wang (2006) emphasised on evaluating the efficiency of container terminals in Europe using the DEA-CCR, BCC, scale efficiency and return to scale models by arising efficiency estimates for a sample includes 69 container terminals in Europe with throughput of over 10,000 TEUs. The scale properties of container terminal productivity are also deliberated.

Rios and Macada (2006) introduced a model to assess the relative efficiency of the MERCOSUR[2], applying the DEA-BCC model. They asserted that DEA is beneficial for both port authorities and port operators in measuring technical efficiency. As an extension to their studies in 2005, Cullinane et al. (2006) used both the DEA and the FDH model to 57 of the world's top container ports to analyse the advantages and disadvantages of employing alternative non-parametric models including DEA to the container port market. Their results figured out that the presented mathematical

[2]MERCOSUR is a Spanish acronym for Mercado Comúndel Sur including Argentina, Brazil, Paraguay and Uruguay trading block.

programming methodologies reflected discrete results and that the determination of input and output measures was a critical factor in conducting expressive applications of DEA and FDH.

In the same context, in order to add the stochastic nature to the linear programming approach and to equip the stochastic approach with more flexibility in the parametric structure, Lin and Tseng (2005) and Cullinane et al. (2006) compared between the results obtained by the DEA-CCR and BCC models and the efficiency scores attained by the SFA. Khin and Yang, (2010) and Wanke et al. (2011) used alternative models to assess the efficiency of container ports. In doing so, they compared between the efficiency scores obtained by the DEA-CCR, BCC, scale efficiency and return to scale models and the efficiency scores attained by the application of SFA. Choi (2011) compared the results obtained by the application of DEA-CCR, BCC models and Malmquist and Tobit models

In addition to the use of DEA-CCR and BCC models to analyse the TE and PTE of the seaports, Barros (2006) used the scale efficiency and super efficiency model, first developed by Andersen and Petersen, A&P (1993). The former allows the determination of an inefficient DMU as being technically inefficient (TIE) or scale inefficient (SIE), while the later is applied to provide further distinctions among the efficient DMUs. The A&P model eliminates efficient DMUs, and then evaluates the production frontier again. The new efficiency score can thus be greater than one.

So et al. (2007) also used the DEA-CCR/BCC output oriented model, super-efficiency analysis to rank the efficient ports. In order to provide a variety of complementary efficiency analyses for ports, Lin and Tseng (2007) also compared between the efficiency scores attained by the DEA CCR, BCC, A&P, SCE, D&G models. Cullinane and Wang (2006) and Al-Eraqi et al. (2007) applied the DEA-CCR, BCC, scale efficiency and return to scale models to benchmark the efficiency of container ports. Wu et al. (2009) extended the DEA model of Doyle and Green (1994) by considering sets of DMUs that can enhance the cross efficiency assessment method.

In the same context, Sharma and Yu (2009, 2010) have attempted to prioritize the variables of DMUs in DEA-CCR output oriented model. They provided a decision tree based DEA model to improve the flexibility and capability of classical DEA. Their approach assists decision makers in container ports to determine the opportunities and threats affecting their business. De Oliveira and Cariou, (2011) have used the same approaches to assess the operational efficiency of 122 worldwide coal and iron ore ports (54 loading and 68 unloading ports).

Niavis and Tsekeris (2012) applied a two-stage procedure to benchmark and identify main determinants of the technical efficiency of 30 container ports in the South-Eastern Europe, including the Italian ports which directly affect competition in the East Mediterranean Sea. The research employed non-parametric standard, DEA-CCR/BCC, DEA-super-efficiency and scale efficiency models to benchmark the ports technical efficiency. In the second stage, a parametric bootstrapped truncated regression methodology is adopted to determine the impact which various factors, beyond the control of port authorities, have on the efficiency and, subsequently, the competitive position of ports. In this way, the proposed approach uniquely addresses potential problems of small-sample bias typically met in standard parametric estimates and consistently supports management decisions of port operators regarding the internal and external operational environment and their competitive strategy.

Wanke (2013) applied the network-DEA centralised efficiency model established by Liang et al. (2008) and Zhu (2011) to 27 Brazilian ports for the year of 2011, in order to optimize physical infrastructure and shipment consolidation efficiency levels by focusing on shipment frequency per year as the key intermediate output. The significance of this study is that it took into consideration the number of movements as the vital intermediate output that creates the link between shorter and longer term perspectives on two relevant aspects that affect port production processes: physical infrastructure (Alderton, 2008) and shipment consolidation (Wanke et al., 2011), respectively.

The above mentioned studies have limited only to the analysis of cross-sectional data. DEA implies the benchmarking of one DMU with all other DMUs which produce during the same time and thus the role of time is ignored. However, this can be rather misleading since dynamic settings may highlight the unnecessary use of resources which are proposed to create beneficial outcomes in future periods (Cullinane & Wang, 2010).

In order to overcome the limitation of DEA cross-sectional data analysis, Itoh (2002) used DEA-CCR/BCC models to compare between the efficiency scores obtained by cross-section and panel data of eight major container ports in Japan in the period between 1990 and 1999. Cullinane et al. (2004, 2005), Al-Eraqi et al. (2008) and Cullinane and Wang (2010) also used the DEA-CCR/BCC output oriented model to panel data and window analysis to assess and benchmark the relative technical efficiency of container ports. In the same context, Alonso and Bofarull (2007) and Cullinane and Wang (2007) applied the DEA-CCR/BCC and additive models to panel data to analyse the scale efficiency of container ports.

Most of the above research reveal one important characteristic. That is the DMUs, hereby corresponded to ports, are identically treated. This is the so-called homogeneity, which is a prime criterion for DEA based efficiency assessment models. Nevertheless, in port efficiency measurement, heterogeneity of DMUs often presents due to uncontrollable elements like geographical location. Container ports in Far East, for instance, could be completely different from those in Europe, although they all run the same business with the same sets of inputs and outputs (Wu et al, 2009). Their efficiency should not be symmetrically evaluated as the two regions represent completely different economic markets. Thus, it is essential to further analyse the impact of the specific group of factors on the port efficiency.

Barros and Managi (2008) analysed efficiency drivers of a sample represents 39 Japanese seaports in the years 2003 to 2005 by applying the two-stage procedure developed by Simar and Wilson (2007). In the first stage, the technical efficiency of ports is measured using DEA-CCR, BCC and scale efficiency models. In the second stage, the Simar and Wilson (2007) procedure is applied to bootstrap the DEA estimates with a truncated bootstrapped regression to determine efficiency drivers. The adoption of this approach improved both efficiency of estimation and inference. Thus, benchmarks can be attained for enhancing the performance of inefficient ports.

As an extension to their studies in (2007 and 2008) Al- Eraqi et al. (2010) used the DEA-CCR/BCC input oriented model and window analysis to measure the super-efficiency scores of 22 seaports in the Middle East and East Africa in the period between 2000 and 2005. Bichou (2013) examined the relationship between port efficiency and the operating conditions of container ports. DEA-CCR/BCC models are applied to benchmark the efficiency of 420 container terminal for the panel data from 2004 to 2010. The study explained that a large number of terminals show IRS properties. The results also revealed that the larger ports and those investing in new infra/superstructure show DRS.

Yuen et al. (2013) used the DEA-CCR/BCC efficiency models to calculate the efficiency estimates of 21 container terminals in China and their development during the period between 2003 and 2007. Regression models were then applied to analyse the elements affecting container terminal efficiency estimates and its enhancement. Both the bootstrapping procedures with Tobit model and a regression model as explained by Simar and Wilson (2007) were applied. The results showed that there is a considerable difference between the efficiency estimates attained from the two models, which demonstrates that bootstrapping procedures are essential in order to attain consistent efficiency scores in regression models.

Tovar and Wall (2015) applied a directional technology distance function to analyse the technical efficiency and production technology of 20 port authorities in Spain for the period 1993–2012.The analysis revealed that the directional distance is a flexible and powerful technique for the purpose of this research, offering more flexibility than the traditional Shephard output-oriented and input-oriented distance functions when measuring technical inefficiency and port production technology.

Ju and Liu (2015) employed a two-stage procedure, DEA and regression analysis, to analyse the efficiency of 14 port-listed companies in China for the period between 2001 and 2011. DEA was first employed to measure the efficiency estimates of listed companies. Second, the influencing factors of efficiency were established by using a regression model. Panel data is then used to examine how these factors influence the efficiency of the sample companies. The results illustrated that a long-term equilibrium relationship exists between efficiency and its influencing elements.

On the other hand, some studies used stochastic frontiers estimate a stochastic production frontier to calculate the operational efficiency (Liu, 1995; Notteboom et al, 2000; Estache et al, 2002; Cullinane and Song, 2003, 2006; Cullinane et al., 2002, 2006; Tongzon and Heng, 2005). The functional form applied in most of the studies is Cobb–Douglas; despite that the Translog function has also been calculated (Liu, 1995; Estache et al., 2002). Merely the work of Liu (1995) encompasses technological change in the model specification. Banos-Pino et al. (1999) combined the input-oriented distance function with the cost frontier to assess the capital stock capacity. However, by using only one output, they did not utilise the potential of the distance function (Gonzalez & Trujillo, 2009).

The study of Notteboom et al. (2000) is worthy of mention as the only research that applied Bayesian techniques to stochastic frontiers in the port market. Banos-Pino et al. (1999), Coto-Millan et al. (2000), Dıaz (2003), Barros (2005) and Tongzon and Heng (2005) quantified economic efficiency using a stochastic cost frontier in which technological change is identified as a trend or as sequential effects. The first introduced a quadratic function value, which enables zeros to appear in the output vector. The other research have also selected for the measurement of a flexible functional form, which is the Translog. Gonzalez (2004) was the first to apply a multi-output distance function in the port market. Then, Rodriguez-Alvarez et al. (2007) and Trujillo and Tovar (2007) proposed a model of composite equations for a distance function and the input spending equations. Both research specified a Translog function and model the time variance through temporal effects (Gonzalez & Trujillo, 2009). Next section discusses the main features of the input and output variable that have been used to assess and benchmark the technical efficiency of seaports.

Tovar and Rodríguez-Déniz (2015) classified the Spanish port authorities by establishing a model that contains SFA, clustering and self-organized maps (SOM).Results revealed that use of a combination of cost frontier and cluster approach to define robust port typology and SOMs, together or separately, provides useful information to the port policy makers.

3.5 Variables specifications of the existing literature

All port resources and activities should be taken into consideration when port efficiency is assessed and analysed. However, in the empirical studies, the decision upon which variables to be incorporated in the efficiency analysis largely depends on the quality and availability of the data. For example, the definition of port outputs depends on the activities carried out by the port, and as such it can comprise the port throughput, the number of vehicles or the volume of transhipment traffic (Cullinane & Wang, 2007; Lu et al, 2015).

On the other hand, the input measures that have been used to analyse port efficiency can be classified into two broad categories. The first presents the inputs used to assess ports' technical and scale efficiency and the second represents inputs that are used to assess ports' allocative efficiency. The former constitutes inputs related to ports' infra and superstructure that represent the ports operational elements such as land, capital and labor. The later presents the ports financial and economic measures such as price of capital, labor cost and investment (Gonzalez & Trujillo, 2009).

As far as the assessment of allocative efficiency is concerned, Martinez-Budria et al. (1999) used some variables like labor cost, depreciation changes and other expenditures to examine ports' relative efficiency and allocative efficiency development. Barros (2003a, 2003b) used the number of employees and Book value of assets to analyse ports' allocative efficiency. Similarly, Barros (2006) utilised labor, capital invested and operational costs as an input variables for measuring port allocative efficiency. Liu (2008) used labor, funding and infra/superstructure to assess the operational and allocative efficiency of main ports in the Asia-Pacific market.

Tovar and Rodríguez-Déniz (2015) used labor and materials for assessing and clustering the efficiency of 20 port authorities in Spain. Tovar and Wall (2015) used labor and intermediate consumption expenditure. Labor is measured using the average number of port authority employees. Intermediate consumption includes costs of all productive factors apart from labor and capital, including office supplies, water and electricity. Ju and Liu (2015) used total assets, number of employees and prime operating costs as input variable for benchmarking the efficiency of 14 port-listed companies in China by using the DEA.

In the recent literature in port efficiency, it has been argued that the use of single output will cause a sort of bias in the analysis (Jara-Diaz et al, 2005). For a multi-activity port, it is not appropriate to use a single output measurement such as the number of containers (TEU) for two reasons. First, despite TEU, traditional conventional cargo is an output usually measured in Tonnage. Second, within the container handling operations there are two kinds of container: Ro/Ro, Roll On/Roll Off, container and Lo/Lo, Lift On/Lift Off, container, which need different handling equipment. As such, they need to be counted as different outputs (Gonzalez & Trujillo, 2009).

Some of the recent research have included multiple outputs. Barros (2005) used the total cargo and number of ship-calls as outputs; Rodriguez-Alvarez (2007) examined containers and general cargo as outputs; Trujillo and Tovar (2007) considered the container traffic, passengers and the rest of freight traffic as outputs; Gonzalez and Trujillo (2008) examined containers, passengers, liquid bulk and other cargoes as outputs. Chang and Tovar (2014) used container throughput, general and rolling cargo and dry bulk cargo as outputs to measure the operational efficiency by using the TFP and SFA models. Tovar and Rodríguez-Déniz (2015) used four outputs which are dry bulk cargo, liquid bulk cargo, general cargo and passengers to measure port efficiency by using the SFA. Tovar and Wall (2015) used containerised cargo, dry bulk cargo, liquids cargoes, general cargo and passengers as output variables to assess the operational efficiency of selected sample of Spanish ports by using directional technology distance function. Ju and Liu (2015) used earnings per share and prime operating revenues as output variables for benchmarking the technical and allocative efficiency.

Although most of the studies in the literature use multiple outputs, TEU is still the main measure of output in the container port market because TEU is the most suitable measure for container transport operations, including container handling and shipping. In any related research if the opportunity of including other outputs is available, they should be comprised, although these variables are considerably less descriptive than TEU measurements (Gonzalez & Trujillo, 2009).

The arrangement of inputs in the literature that used the SFA is not as unified as that of outputs. There are two categories of input specification that are not mutually exclusive. The first category of studies use as input variables: labour and capital (Liu, 1995; Coto-Millan et al, 2000; Estache et al, 2002; Cullinane and Song, 2003; Trujillo and Tovar, 2007). The second category of research identifies inputs based on the infra/superstructure, that is, berth length, terminal area, storage capacity and number of cargo handling equipment (Tongzon and Heng, 2005; Cullinane and Song, 2006; Sun et al, 2006; Yan et al., 2009; Sohn and Jung, 2009). In addition to the above mentioned inputs, Medda and Liu (2013) used maximum berth depth, crane spacing, terminal type and operation type as inputs to measure ports technical efficiency through the use of SFA. Similarly, Chang and Tovar (2014) used number of workers, net fixed assets, number of berths and number of machinery to benchmark the operational efficiency and performance of main ports in Chile and Peru.

Studies that are used labour and capital as inputs, the composition of container ports and terminals is slighted, because all the elements are aggregated into a single capital variable. In the second category the studies do not include labour data, but the specification reveals a more precise configuration of the port, and there is a primary assumption that the need for labour in the port operation is relative to the type of equipment according to a certain ratio. In this context it is very essential to be cautious; because this hypothesis is not always correct, different equipment requires different numbers of labours and different skill levels (Gonzalez & Trujillo, 2009).

In addition to inputs and outputs, other factors knowing as exogenous (uncontrolled)variables affect the efficiency of container ports. Exogenous factors are not under the control of port operators, such as legislation conditions, population and country GDP or they are under the port managers' control but they are not direct inputs such as the features of the transport network. Thus, the objectives of research in these cases are to analyse how specific exogenous elements, such as country GDP, port location and number of rivals, affect port efficiency. Other factors that have been used in the previous studies include port ownership, size, location and regulations (Gonzalez & Trujillo, 2009).

The above review on port efficiency implies that compared with traditional port efficiency evaluation, the inherent DEA models allow to assess the overall efficiency of a port and benchmark the efficiency of different ports. DEA estimates can provide a benchmark to port managers and operators, so that inefficient ports can exactly determine their weaknesses and how they might enhance their production (Song et al, 2001; Cullinane & Wang, 2007).

Wang and Cullinane (2006a) asserted that when DEA is used, the DMU should be selected with caution. All chosen DMUs should be homogenous in terms of their production functions. In other words, it would be illogic to compare a container terminal with a tanker terminal. Also, most of the literature seems to emphasize on production at the terminal level. This corresponds to the argument of Alderton (1999) that "*there is little that can be measured on a whole port basis. Most comparable data must concentrate on a terminal basis*".

Only the operational (in)efficiency of ports can usually be evaluated by DEA, rather than any allocative (in)efficiency. This is due to the variance in port pricing systems and strategies. This argument explains why most previous research focus on technical, rather than allocative efficiency. The only exception is the study of Martinez-Budria et al. (1999). Since their analysis used data from the same country (Spain), it is then likely to calculate profits and costs in a common currency and within the same economic environment. No trial has been made to measure the allocative efficiency when ports are located across various countries. Almost no identical input and output variables have been selected by different researchers to build into their DEA analysis. The selection of input and output variables is very critical for the application of DEA as it is difficult to define the input and output variables in the assessment of DMUs (Thanassoulis, 2001; Cullinane and Wang, 2007).

Wang et al. (2002) explained that under the framework of microeconomics and the features of port production, given the condition that the data are always available, which is not true in reality, the variables that include information on human resources such as the number of stevedores and management staff, infra/superstructure such as terminal area, number of cranes, number of berths, number of tugs should be used as input variables in DEA models. The output variables should comprise cargo traffic variables such as container throughput, the quality of service such as the idle time of a ship at port in contrast to the study by Tongzon (2001a) where idle time is treated as an input variable. However, in practice, it could be assumed that the choice of input and output variables is also affected by data availability

Panel data are the most appropriate to be gathered and analysed using DEA models. It would be beneficial to monitor whether a port can enhance its efficiency over various time periods, and to find the causes of such a change. The above literature demonstrates that, despite the extensive research in port efficiency, there is still no consistent methodology to assess efficiency (Ashar, 1997). Also, without factual and standard data from the different ports studied, the port (in)efficiency measured by DEA could probably be biased.

3.6 Chapter summary

Analysing container port efficiency is becoming more important because of the increasingly globalised world economy and the significant contribution that container transportation makes to this process. Contemporary studies in port efficiency can simply be divided into productivity and efficiency measurement. The former is more widely applied in practice, and mainly comprises partial productivity measures, while the latter is still in a stage of continued theoretical development. However, some trials have been made to apply DEA to the port market, container ports in particular. In the context of the significance and complexity of port efficiency, it is very essential to examine the suitability of DEA as a methodology that can be used for attaining the objectives of such studies.

The general conclusions are that port infra/superstructure and location are important factors in determining port efficiency, while capital intensity and port privatisation has no significant advantage (Liu, 1995).In addition, large ports are less efficient than smaller ones and autonomy does not make any difference (Coto Millan et al, 2000; Tongzon, 2001a). Scale economies decreased operating costs, while pure technical change contributed to increase costs. Ports denote one of the main sectors in economics where frontier models have been applied, with methods as varied as DEA to econometrics.

The above reviewed literature has shown that the analysis of efficiency in the port industry has enjoyed significant contributions in recent years. It is also characterised by a number of dominating features. On the methodological side, a few important points emerge. First, while practically most of studies recognise the multi-output nature of port activity, not all reflect it in their assessment of the performance of the port operators. Most often this is due to a lack of data which forces analysts to rely on aggregate measures which in turn influence the possible interpretation of the results. Second, due to data limitations, the DEA approach has been the technique usually applied to reflect the multi-production nature of the port industry. Third, in the stochastic approach, difficulties in obtaining reliable data to estimate a multi-output cost function, has led to the lack of this type of study (Gonzalez & Trujillo, 2009).

Recent developments in models and techniques such as distance functions and bootstrapping regression analysis have significantly increased the scope for reliance on parametric estimates accounting for the multi-output nature of the sector. This should contribute to the enhanced use of this approach when its advantages dominate the alternatives. Finally, regarding the data required, the dynamic analysis made possible by data panels should be preferred to static photographs of cross-section samples. Moreover, the information on all factors affecting port activity, such as geographical location, is also necessary in order to reach robust conclusions.

The above review on port efficiency also illustrates that researchers have addressed different aspects that affect port efficiency through the use of different methods. The researchers focused their studies on ports located in different markets such as North Europe, Far East, USA and Latin America. However, the studies that focus on the Mediterranean container ports tend to be limited in scope; they use data from one single country, compare between ports of two countries, or use only the Mediterranean European ports. This is mainly due to limitations in data availability for such a wide and diverse group of ports belonging to various countries and different continents.

In the context of the above observations, the present research is a methodological improvement in the port industry, since it measures the efficiency estimates with different DEA models and then tests statistically several hypotheses. Next chapter provides a comprehensive overview about research design and methodologies that are applied to assess port competitiveness analyse market dynamics, benchmark ports technical efficiency and examine different hypotheses that study the impact of port efficiency on port competitiveness in the defined market.

CHAPTER FOUR

RESEARCH METHODOLOGY AND DESIGN

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4.1 Introduction

Methodology is an approach that allows researchers to illustrate and examine methods demonstrating their resources and limitations, categorising their assumptions and consequences, and describing their potentialities to research advances (Miller, 1983; Saunders et al, 2007). It underlines the types of questions that can be studied and the nature of the evidence that is generated (Clark et al, 1984; Nachmias and Nachmias, 2008). As such, research methodology is essential to any type of study or research. The choice of research paradigm, type of data and its collection methods and the measurement tools has significant implications upon the research analysis and results.

This chapter illustrates the methodology and techniques that are used within this research to assess ports competitiveness and efficiency. The chapter consists of six sections. The first section explains the research design, approach and strategy as well as the theory of IO and the Structure, Conduct and Performance approach that are used to assess ports competitiveness and market dynamics. The second section illustrates the main methods that are used to assess market structure. The third section explains the method for evaluating the market conduct. The fourth section illustrates the various data envelopment analysis (DEA) models that are used to assess the market performance through the evaluation of ports efficiency as well as the model used to assess the impact of port efficiency on port competitiveness. The fifth section demonstrates the specifications of variables that are used to assess ports' competitiveness and efficiency and provide a brief explanation on data collection and software used to measure port efficiency. The conclusion of this chapter is provided in section six.

4.2 Research design, approach and strategy

Research design imparts complete guidance for the data collection and analysis of a study (Churchill 1979). The significance of research design derived from its function as an essential link between the theory, argument, analysis that informed the research and the empirical data collected (Nachmias and Nachmias, 2008). The selection of research design indicates decisions about the priority being given to a range of magnitudes of the research process (Bryman and Bell, 2007), and this will accordingly have significant impact on lower-level methodological procedures such as population sample and statistical tools. Thus, it is a blueprint that enables researchers to find answers to their research questions. Along with a clear research plan, it considers constraints, limitations and ethical issues that a research will certainly encounter (Saunders et al. 2007).

The aim of this research is to assess the impact of port efficiency on port competitiveness in the Mediterranean container market. In order to achieve this aim, the research philosophy is based on the positivist approach. The main concept of positivism is that the reality is stable and can be monitored and demonstrated from an objective viewpoint (Levin, 1988; Cohen et al, 2007) without interfering with the phenomenon under study. Positivists asserted that phenomena should be isolated and that observations should be repeatable. This entails manipulation of reality with changes in only a single independent variable so as to identify regularities to form relationships between some of the basic elements of the social world (Saunders et al. 2007).

Comte (1971) was the first to introduce this view, stated that "*All good intellects have repeated, since Bacon's time, that there can be no real knowledge but that which is based on observed facts"*. This statement comprises two assumptions; first, an ontological assumption which reveals that reality is external and objective. Second, an epistemological assumption that explains that knowledge is important, if it is related to observations of this external reality (Easterby-Smith et al, 2002).

The main reason for choosing the positivist philosophy is that it has a number of implications. Firstly, a methodological one, as all research should be quantitative, as only quantitative research can be the basis for valid generalisations and laws. Secondly, value-freedom, which means that the selection of what to study and how to study it should be identified by objective criteria rather than by human beliefs and interests. Thirdly, causality, which reveals that the main objective should be to ascertain causal relations and primary laws that explain a particular behaviour. Fourth is operationalisation, in the sense that concepts should enable facts to be measured and analysed quantitatively. Fifthly, independence, as the role of the researcher is independent of the phenomenon under study. And finally, reductionism, which means that problems are well recognized, if they are simplified to their basic elements (Bond, 1993; Hughes, 1994; Easterby-Smith et al, 1997).

Positivists assert that the data collection process should be carried out in the social environment and reflects people's reactions to it (May, 1997). Basic positivist methods entail observations, experiments and survey techniques, and often comprise complex statistical analysis that generate the findings and results and empirically test hypotheses (Schiffman and Kanuk 1997).

The aim of the positivistic researcher is to generalise the results to reflect the larger population. As such, the positivistic deductive approach is used in this research as it entails that the theory must be first determined and then examined by empirical observations. If the theory is falsified, it has to be rejected, and a new one should be formulated to replace it. The choice of the deductive explanatory approach based on its important characteristics that match the basic features of the positivist approach in terms of the existence of causal relationships between variables, developing and testing of hypothesis, operationalisation and generalisation (Easterby-Smith et al, 2002).

Following the positivistic deductive approach, the research strategy involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence. In this context, the Mediterranean container port market is used as an area of study to analyse the impact of port efficiency on port competitiveness. In order to be able to answer the research questions and study the dynamics of the Mediterranean container port market, the research model is applied to the top 22 container ports in the Mediterranean basin. The selected ports represent the large and medium size container ports in the defined market that have throughputs equal to or greater than 500,000 TEUs in the year of 2012. Moreover, the selection of these ports is based on port location as these ports share either the same or overlapped hinterland and/or foreland. The smaller container ports are intentionally ignored from the study as those ports do not have the facilities that enable them to compete in such a dynamic market.

The research uses the data related to the infra/superstructure as well as the throughput of the selected ports for the period of 15 years between 1998 and 2012. Cross-sectional data for the year of 2012 as well as a panel data for the period between 1998 and 2012 are used as a time horizon for the research. The main strength of the panel data is the capacity that it has to study development and change. Moreover, it enables researchers to exercise a measure of control over studied variables, provided that they are not influenced by the research process itself. In the panel data analysis the basic question is "Has there been any change over the study period?" (Saunders et al, 2007).

As a result of choosing the above explained paradigm, this research will test the theory of industrial organisation and SCP approach in order to assess the effect of port efficiency on port competitiveness in the Mediterranean container market. In order to achieve such aim, as shown in figure 4.1, as far as the research methodology is concerned, the research procedures are as follows: the area of study, the Mediterranean container market, and the container ports were first selected. The secondary data was then collected through the use of various issues of the *Containerisation International yearbooks* for the study period. Secondary data is used due to the unavailability and unreliability of direct data for the sample ports. Port authorities do not allow the release of detailed data related to their ports' facilities and productivity, in particular the data that could affect their competitive position within the port market. They treat such data as confidential information. The factors that are affecting the ports' competitiveness as well as the ports' efficiencies are determined and the input and output measures are then selected. The dependent and independent variables are defined accordingly.

The research follows a three-stage procedure. In the first stage, following the industrial organisation concept, the SCP approach is applied to assess market structure through the assessment of Port competitiveness in the Mediterranean container port market by using five assessment techniques. These methods are: the K-Firm concentration ratio, the Hirschman-Herfindahl Index (HHI), the Gini Coefficient, the Entropy Index and the Boston Consultant Group Matrix. The assessment of market conduct is carried out through the use of the Shift-Share analysis that measures the container ports' share effect and shift effect.

In the second stage, market performance is analysed through the benchmarking of container ports' efficiency. Five non-parametric DEA models are used to assess port efficiency. These models are: the CCR model that measures the ports' aggregate technical efficiency (AE), the BCC model that analysis the ports' pure technical efficiency (PTE), the super efficiency (A&P) model that ranks the efficient ports, the sensitivity analysis model that checks the sensitivity of ports' efficiencies through verifying whether the efficiency scores of ports under study are affected appreciably if only one input or output is eliminated from the DEA analysis and the slack variable analysis model that explains the utilisation rate of input and output variables by determining how many inputs to decrease, and/or how many outputs to increase, so as to transform the inefficient port to becoming efficient.

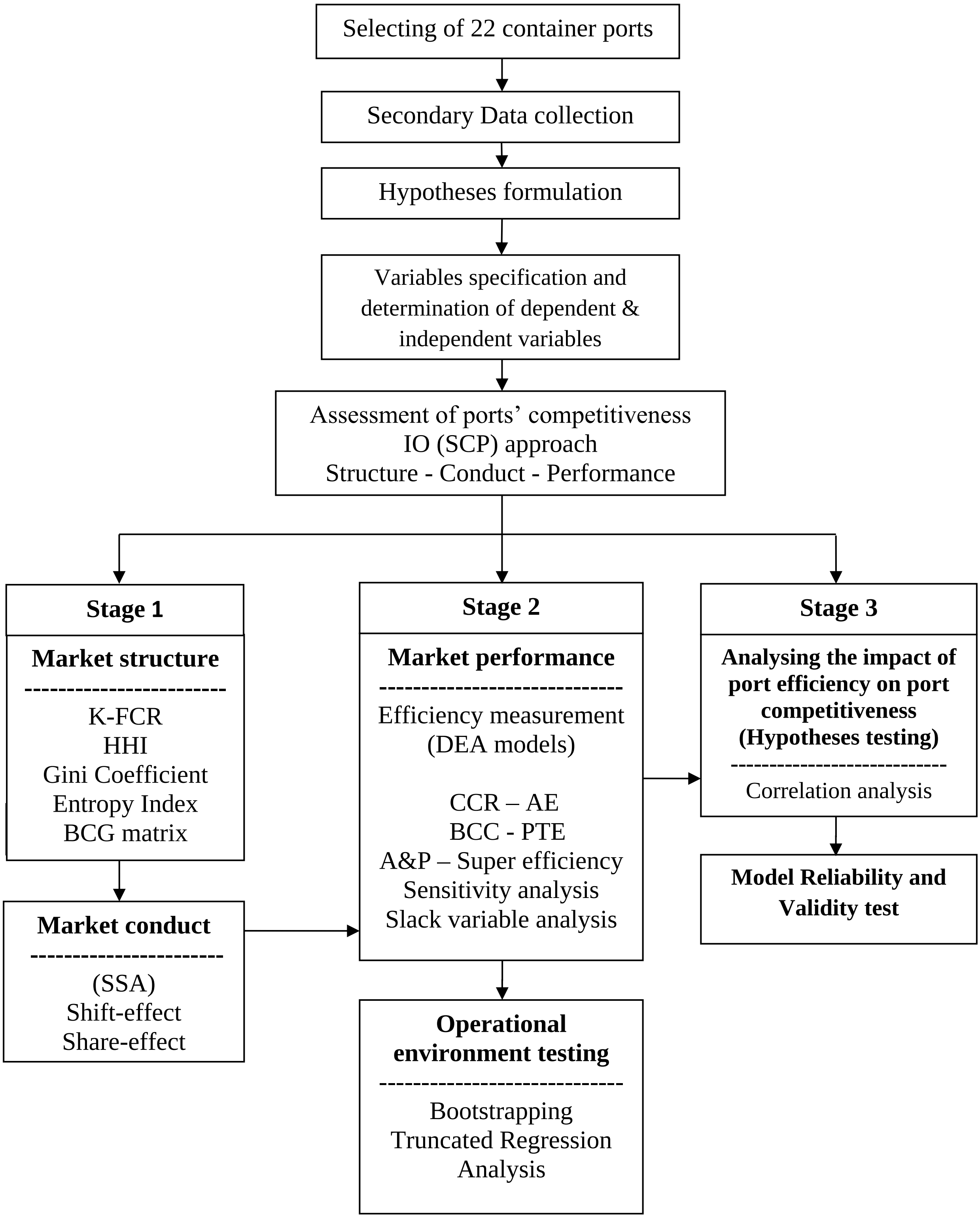

Figure 4. 1- Research methodology procedures and assessment techniques

In this way, the proposed approach uniquely addresses potential problems of small-sample bias typically met in standard parametric estimates and consistently supports management decisions of port operators regarding the internal and external operational environment and their competitive strategy.

Moreover, correlation and regression analysis is also used in this stage to analyse the impact of port efficiency on port competitiveness. The Spearman's rank order correlation coefficient is used to test a number of hypotheses that have formulated on the basis of a corpus of traditional economic theory of port efficiency. The correlation analysis has permitted the comparative assessment of the consistency of the results obtained from the different approaches and models that used to assess port competitiveness and efficiency. Thus, to a large extent, has provided an empirical validation of the approaches and techniques themselves.

Finally the research reliability and validity will be tested. Thus, different types of reliability such as equivalency, stability and internal reliability will be tested. Four types of validity that are related to the research conceptual framework, approach, design and model will be examined and verified. These types are: internal, external, construct and statistical validity. Next section illustrates different methods and techniques used here in this research to analyse the competitiveness of the Mediterranean main container ports.

4.3 Assessment of port competitiveness

4.3.1 Industrial organisation and SCP approach

Industrial economics (IE) is a unique section of economics which deals with the economic problems of firms and industries, and their relationship with society. Industrial economics concepts study the strategies of firms towards their competitors and customers and also determine firms that are competitive or less competitive in a particular market. Basically, there is no disparity between industrial economics and microeconomics. However, there is a distinction between microeconomics and industrial economics. Micro economics usually emphasises on simple market structures-competition and monopoly, while IE focuses on oligopoly market. IE is more focused on policy issues than micro (Smit, 2010).

In the USA, two schools of thought long argued the analysis of industrial economics. First is the Harvard, structure conduct performance, school in which market structure affects the firms' behaviour in the market, and the behaviour of firms verifies the various aspects of market performance. The connotation of this argument is that government should apply a relatively high level competition policy, aimed to limit strategic behaviour (Smit, 2010).

Second is the Chicago school. This school argues that anything is done by one firm can be done by any other equally efficient firm, unless some higher power interferes. As such, the main source of monopoly power is government intervention in the market place. Government, by intention or ineptness, can prevent some firms from competing, to the benefit of other firms. Apart from the prevention of naked collusion, there is little that government can do to enhance market performance; a laissez faire strategy is preferred (Edwards et al, 2006).

The SCP paradigm is applied as an analytical approach, to illustrate relations amongst market structure, market conduct and market performance. The SCP paradigm, that developed by Bain (1959), was the brain child of the Harvard school of thought and wide spread during 1940-60 with its empirical work concerning the determination of correlations between industry structure and performance. The SCP hypothesis has lead to the establishment of most anti-trust regulations.

Traditional industrial economics defines market structure as the number of competing firms and their market share. Market structure is a fundamental determinant of market conduct, the magnitude of price and non-price competition. Market conduct accordingly illustrates economic performance, particularly if firms' profits are increased through the practice of monopoly power or oligopolistic collusion.

Economists in industrial organisations have, however, deviated from asserting a strong causal relationship between concentration and competition. It is claimed that, in equilibrium, concentration and performance are collectively influenced by primary cost and demand factors. Thus, the unfavourable impacts of rising concentration are less definite. The contemporary industrial organization economics has brought strategic aspects to the fore, emphasizing the significance of barriers to entry and strategic interactions (Paha, 2013).

The modern industrial organisation categorises markets into six broad types. Three market categories are featured by high market power and mainly ineffective competition which are: monopoly, when one firm has 100 per cent, dominant firm, when one firm has from 40 to 99 per cent and tight oligopoly, when four firms have over 60 per cent. The other three market categories display effective competition which are: loose oligopoly, when four firms have less than 40 per cent, monopolistic competition, when many competitors each with a slight degree of market power; and pure competition, when the market encompasses many competitors and none of whom has market power (Beattie et al, 2003).

4.3.2 Assessment of market Structure

In the industrial organisation theory, market structure is featured by having considerable stability. This is due to two inter-related but mutually reinforcement factors, one empirical and the other theoretical. Measurement of market structure that is most widely used in United Kingdom, United States and Canada is an assessment of concentration. The most commonly used concentration tool is the percentage of output, or any other indicator of industry size, such as employment, assets or throughput comprised by a small number of the largest firms. Measures of concentration express characteristics of the firm size distribution at a point in the time. The size distribution varies slowly over time and so do the companion factors of concentration (Lam et al, 2007). Market structure will be analysed, here in this research, by using concentration indices. These allow the number and size distribution of competing ports to be explained in the form of a single-parameter index. These indices can also be defined as a direct measure of the degree of oligopoly (Scitovsky, 1955; Lam et al, 2007).

One of the most debatable issues in industrial economics is related to the proper method of measuring the size distribution of firms in an industry. The literature is full of indices that are created by their originators, Hall and Tideman (1967) and Hannah and Kay (1977). Such an imperative search for the optimal measures highlights a number of elements; there is no generally accepted model that associates structure, behaviour and performance from which, *n* index can be derived. Due to the absence of such a model, some researchers give different weights to the various dimensions of market structure (Notteboom, 2002).

Apart from the lack of consensus as to which market structure index is outstanding, there is a large agreement that the index should consider at least two aspects of the size distribution of firms; the number of firms and the firms' sizes variance. Thus, many indices are featured by that they increase if either the number of firms' falls or the degree of dissimilarity in firm size increases. Market structure indices can be classified into two broad categories which are discrete and summary indices. Both are distinguished in the set of points from the firms' size distribution that are used to derive the index (Notteboom, 2006c). The discrete measures use data on the market share of a small number of the largest firms. In this context, concentration ratio (CR) is the most commonly used method that uses the leading four (CR4) or eight (CR8) firms. In contrary, the summary measures use all the data points in the size distribution. These measures mainly vary in how they evaluate the individual firms' market shares. The Herfindahl index measures each market share by itself, while the entropy index uses the log of share as the weight (Baldwin, 1995).

Analysing the firm size distribution to make assumptions about the degree of competition in an industry is commonly practiced throughout examining the dynamics of concentration and market trend to assess changes in the intensity of competition. In this approach it must implicitly be viewed that the more dynamic the competitive process, the greater the expected change in concentration. Mergers, entry, exit, and the rise and fall of incumbents should all lead to changes in the size distribution of firms and, hence, changes in concentration (Notteboom, 1997).

Entry of smaller firms may cause a decrease in concentration. Shake-outs may also lead to an increase in concentration. These changes may occur not only because of increases in international competition due to falling transportation costs and tariff barriers, technological changes and shift in demand, but also due to oligopolistic interaction and the dynamics of market competition (Notteboom, 1997). The features, limitations and relevance of the different forms of concentration indices are demonstrated in the next section.

4.3.2.1 The K-Firm Concentration Ratio (CRk)

A concentration ratio is the percentage of the total industry output that the top firms of the industry have. The higher the ratio, the closer the market to an oligopolistic or monopolistic type of market structure. The most commonly used concentration ratio is the four-firm concentration ratio (Maunder et al, 1991).

Concentration ratios vary between 0 per cent and 100 per cent. A 0 per cent concentration ratio demonstrates an extremely competitive market. A 100 per cent concentration ratio reveals an extremely concentrated oligopoly or even monopoly if the ONE-firm concentration ratio is 100 per cent. Between these two extremes, concentration ratios can fall into low, medium, and high concentration. Low concentration means a concentration ratio of 0 to 50 per cent is usually explained as a market with low concentration. Monopolistic competition lies at the bottom of this with oligopoly emerging near the upper end. Medium concentration reveals a concentration ratio of 50 to 80 per cent is considered a market with medium concentration (Chen & Liao, 2011).

These markets are very much oligopoly. High concentration presents a market with a concentration ratio of 80 to 100 per cent is shown as highly concentrated. Government and policy makers are usually focused on markets falling into this category. This index indicates the share of any selected variable, which might be asset value, number of employees, capital employed, port throughput, etc., accounted for by the k largest firms in the industry (Maunder et al, 1991; Chen & Liao, 2011). For the purpose of this research, it can be explained as:

$$CR_k = \sum_{i=1}^{k} S_i$$

where S_i is the share of port throughput *i* on the Mediterranean market and *k* represents the number of ports over which the index will be calculated (from largest down). The main advantage of the k-firm concentration ratio lies in its simplicity. In addition, the data required can usually be found in published sources. Therefore, previously, there have been omnipresent empirical applications of this index to a wide range of different markets. However, this index does have some disadvantages. In principle, the choice of *k* is illogical. Slight support can be given on why CR4 is applied instead of CR3 or CR8, for instance, due to the recognised confidential nature of the required data that is relatively difficult to be obtained. Thus, the CR4 is more commonly used than CR8 (Maunder et al, 1991).

In reality, the k-firm concentration ratio considers only the *k* largest ports in the defined market and that the role played by the other ports is ignored. The index also focuses only on the inequality between the leading set of ports and the others outside that group and, thus, ignores the relative size differences within the leading group (Phillips, 1976; Notteboom, 1997; 2010). In general, the index reveals limited data on market concentration and may omit significant data such as the percentage of market share for each firm of the top four firms in the market. In order to avoid the above mentioned disadvantages of the four-firm concentration ratio and to provide a comprehensive analysis for port market structure, Hirschman-Herfindahl index (HHI) is used to identify how competitive the Mediterranean port market is.

4.3.2.2 Hirschman-Herfindahl Index (HHI)

Hirschman-Herfindahl Index (HHI) is a tool used to measure the size of firms in relation to the industry and an indicator of the amount of competition among them. HHI is an economic tool widely used in competition law, antitrust law and also technology management. The HHI was established by Hirschman (1964). For the purpose of this study, it is defined as the sum of the squared values of each port's market share that is attained by comparing the throughput committed by each port against the total throughput of the defined ports in the market (Zhang et al, 2001). It is explained as:

$$HHI = \sum_{i=1}^{n} S_i^2 \frac{10000}{n} \leq HHI \leq 10000$$

Where S_i is the throughput of port i on the Mediterranean market and n is the total number of the defined ports in the market. HHI considers the entire size distribution of ports on the market by assigning a weight to both the number of ports in the market and the inequality of market shares.

According to the US Department of Justice (1982), the Federal Trade Commission, state attorneys and horizontal merger guidelines (1992), the agency considers that a market in which the HHI is below1000 is un-concentrated. If the HHI is between 1000 and 1800, the market is moderately concentrated. When HHI is more than1800, the market is highly concentrated. An increase in the HHI generally indicates a decrease in competition and an increase of market power, whereas decreases indicate the opposite (Cariou, 2007a).

The HHI emphasises the importance of larger ports in the market and takes its minimum for s_i =1/*N*, and its maximum for s_i =1. The results obtained with this method cannot be compared since the lower limit of the HHI changes with the number of ports *N*.

Thus, it is better to normalise the HHI so that it takes values within the range [0, 1] regardless of the number *N*. In that case, the index will be written as:

$$HHI_n = \frac{HHI - {}^{1}/_{N}}{1 - {}^{1}/_{N}}$$

Two advantages for using Herfindahl index are that it considers all firms in an industry, and it gives extra weight to a single firm that has a particularly wide market share (Colander, 2001). However, HHI fails to measure the distribution of the firms output. In order to avoid such a limitation Gini coefficient is used to explain the degree of equality of the ports output (throughput).

4.3.2.3 The Gini Coefficient (GC)

The Gini index or Gini coefficient is one of the main inequality measures in economics. This index can be applied to measure the distribution of income, wealth, consumption or any other kind (Xu, 2004). Hence, from the statistical point of view, it is a function of the mean difference. It is attractive to many economists as it has an instinctive geometric interpretation, that is, it can be described as twice a ratio of two regions explained by the line of perfect equality, 45-degree line, and the Lorenz curve in the unit box. It is also an important element of the Sen Index of poverty intensity (Xu and Osberg, 2002).

There are two main methods for analysing theoretical results of the Gini index. One is based on discrete distributions, while the other is based on continuous distributions. Both approaches can be unified (Dorfman, 1979; Notteboom, 1997). Nevertheless, the major drawback of Gini index is that two very different distributions can have the same value of this index and, thus, it is not possible to determine which distribution is more equitable. This problem has been encountered in the literature by means of stochastic dominance (Fishburn, 1980) and inverse stochastic dominance (Muliere and Scarsini, 1989). It is worth noting that a more general study is carried out in (Nu´n˜ez, 2006), where several approaches are presented.

To avoid this problem, it is proved that the square of the coefficient of variation can be thought of as the ratio of the area that lies between the curve of equality and the Lorenz curve in the same way as can the Gini index and, thus, it can be used as an effective measure to discriminate between two distributions when their Gini indices are the same. The Gini index can be defined for any random variable with a non-zero expectation and not only for non-negative expectations (Notteboom, 2006c).

As shown in figure 4.2, a Lorenz curve (1905) can be used to explain the cumulative distribution by rank order of the market shares of ports and to determine the market concentration level. The GC was introduced by Gini (1921) as a statistical method to measure inequality in a population that is based on the Lorenz curve and is expressed as a ratio. If the area between the line of perfect equality, the 45 line, and the Lorenz curve is A, and the area under the Lorenz curve is B, then the GC is theoretically calculated as A/(A + B). The GC varies between zero, when all observations are equal, and a maximum value of one in an infinite population in which every observation except one has a market share of zero (Lam et al, 2007).

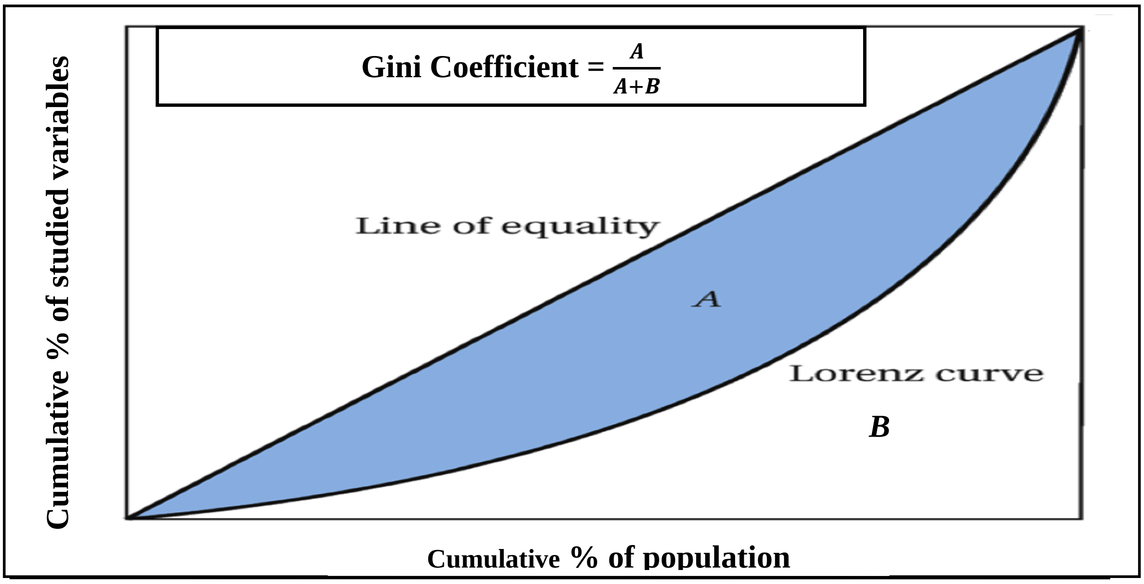

Figure 4. 2- Lorenz concentration curve.

Source: Adapted from Notteboom, T.E. (2006c) 'Traffic inequality in seaport systems revisited'. *Journal of Transport Geography*, 14 (2), 95–108.

When utilising unranked market share data, the GC is simply calculated as the relative mean difference between observations, the mean of the difference between every possible pair of individual observations, divided by the mean market share µ (Dixon et al, 1987; Damgaard and Weiner, 2000):

$$GC = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\left|y_i - y_j\right|}{2n^2\mu}$$

Where GC is the Gini coefficient, y_i represents the throughput of each port *i* on the Mediterranean market, μ is the mean throughput and *n* is the total number of ports in the Mediterranean market.

If the data are ordered by increasing market share, however, the *GC* can be calculated as follows (Dixon et al, 1988; Notteboom, 1997; 2010).

$$GC = \frac{\sum_{j=1}^{n}(2i - n - 1)y_i^{'}}{n^2\mu}$$

However, in this empirical application, the GC is calculated using the more practical and commonly used formula, referred to Brown (1994):

$$GC = \left|1 - \sum_{i=1}^{n}(x_i - x_{i-1})(y_i + y_{i-1})\right|$$

where x_i denotes the cumulated proportion of the population of ports on the Mediterranean market (with x_{0i} = 0 and x_n = 1) and y_i presents the cumulated proportion of the market share variable (with y_0= 0 and y_n= 1). Per se, the *GC* measures the cumulative percentage of output that is comprised by different percentages of the number of ports in the defined market (Lam et al, 2007).

The small sample discrepancy properties of *GC* are not known and large sample approximations to the inconsistency of *GC* are poor. Therefore, it has been illustrated that the sample *GCs* explained above need to be multiplied by *n/(n-1)* in order to attain unbiased estimators of the population coefficients (Gastwirth, 1972; Mills and

Zandvakili, 1997; Lam et al, 2007). However, the main disadvantage of the *GC* as an index of concentration is that, although it reveals the degree of inequality in the market shares of ports under study, it does not take into consideration the absolute number of ports in the market (Rosenbluth, 1955; Notteboom, 2010). An integrated method for Gini coefficient is the entropy index that is explained in the next section

4.3.2.4 The Entropy index (EI)

Entropy index is an important technique that demonstrates difference in distributions at specific moments in time (market shares) and analyses technical change over time. Entropy statistics are appropriate to decomposition analysis, which makes the index preferable to alternatives like the Herfindahl index in cases of decomposition analysis (Lam et al, 2007). There are a lot of applications of entropy in the domains of industrial organisation. Tools of entropy index are utilised in empirical research in industrial organisation, innovation's economics, regional science and economics of inequality. The entropy concept, established by Boltzmann (1877), and has been provided a probabilistic analysis in information theory by Shannon (1948). Theil (1967, 1972) and Notteboom (1997; 2010) developed several applications of information theory and Statistical Decomposition Analysis.

A common application of the entropy concept in industrial organisation is in empirical research of industrial concentration (Hildenbrand and Paschen 1964; Finkelstein and Friedberg 1967; Theil 1967; Notteboom, 1997; 2010; 2012). As far as a distribution of market shares is concerned, entropy is an inverse index of concentration varying between 0 (monopoly) to infinity (perfect competition). The index complies with the seven axioms that are commonly listed as required properties of any concentration index (Curry and George, 1983). These axioms are: a rise in the cumulative share of the *i*th. firm, for all *i*, ranking firms 1, 2, … *i* … *n* in descending order of firms' sizes, entails an increase in concentration, the notion of transfers should hold which means concentration should increase or decrease, if the market share of any firm is increased at the expense of a larger or smaller firm, the entry of new firms should reduce concentration, mergers should increase concentration, random brand switching by customers should decrease concentration, if s_j is the market share of a new firm, then as s_j becomes gradually smaller so should it affect the concentration index and random factors in the growth of firms should increase concentration (Notteboom, 2010).

Horowitz and Horowitz (1968) suggested an index of relative entropy by dividing the entropy by its maximum value log2 (n). As such, one attains a concentration index, which lies between 0 and 1. The main disadvantage of the relative entropy index is that axiom (i_v) no longer holds. Mergers not only decrease the value of H, but also reduce the value of log2 (n). Since there may be a relatively greater fall in log2 (n) than in H, concentration may be reduced after a merger.

The generalised entropy index is a general equation for calculating redundancy in data. The redundancy can be showed as inequality, non-randomness, lack of variety or segregation in the data. The main use is for income inequality (Ullah and Giles, 1998). It is the same as the concept of redundancy in information theory that is related to Shannon entropy. In information theory, entropy is an index of the uncertainty in a random variable (Ihara, 1993). The index normally denotes to the Shannon entropy, which measures the estimated value of the data included in a message (Brillouin, 2004). Shannon entropy, first introduced by Shannon (1948), is the average randomness in a random variable, which is equivalent to its data content. The entropy index calculates the data that is indicated in the form of a frequency, distribution or probability. In its simplest first order form, it is given by:

$$EI = -\sum_{i=1}^{n} s_i \text{In} s_i \quad 0 \leq EI \leq \text{In} n$$

Where s_i is the port throughput *i* and *n* is the total number of ports in the Mediterranean market. The advantage of this index is that it can be decomposed into within-set and between-set entropies if there are distinctive sub-sets of ports on the market (Jacquemin and Kumps, 1971; Curry and George, 1983; Notteboom, 2010, 2012). The value of the sub-sets contributing to the whole level of market concentration can also be demonstrated. Hart (1975) and Jafari et al. (2013) indicated that the first-order entropy depends on the number of ports (n) in the market.

Thus, it ranges between 0, when the market is concentrated into a single port (monopoly), and ln (*N*), when container traffic is distributed equally among all ports. Thus, the results obtained with this equation cannot be compared since the upper limit of the EI changes with the number of sectors *N*. As such, the Entropy Index must be also normalised according to the following formula;

$$EI_n = 1 - \frac{EI}{\mathrm{In(N)}}$$

It is also important to realise that, entropy can be considered as the opposite of concentration; the greater the measured level of entropy, the higher the index value, and then the lower the level of market concentration (Jafari et al, 2013). However, port competitiveness can also be measured through the visualisation of market dynamics that can be measured by using market share and average growth rate. In this context, Boston consultant Group matrix is applied in this study to analyse the dynamics of the Mediterranean container market.

4.3.2.5 Boston Consultant Group (BCG) matrix

The Boston Consulting Group (BCG) was developed in the early 1970's as a model for managing a portfolio of different strategic business units (SBUs). In this research, the BCG matrix is used to visualise the dynamics between the container ports in the Mediterranean market. The BCG Growth-Share Matrix is a four-cell (2 by 2) model used to present business portfolio analysis as a stage in the strategic planning process. The Matrix locates the different SBUs based on Market Growth Rate and Market Share relative to the most significant rival (Notteboom, 1997). Based on this model, business could be classified as high or low according to their market growth rate and relative market share.

Relative Market Share = SBU throughput this year / leading competitors throughput this year.

Market Growth Rate = Market's total throughput this year - Market's total throughput last year.

The analysis compel that both measures be calculated for each SBU. The feature of market strength, relative market share, will measure comparative advantage demonstrated by market dominance. The basic theory explaining this is existence of an experience curve and that market share is attained due to overall cost leadership (Armstrong & Kotler, 2005).

BCG matrix consists of four cells, the horizontal axis indicating relative market share and the vertical axis representing market growth rate. The mid-point of relative market share is placed at 1.0. If all the SBU's are in same market, the average growth rate of the market is used. While, if all the SBU's are located in various markets, then the mid-point is aligned at the economy growth rate. Resources are distributed to the business units according to their situation on the grid. The four cells of this matrix have been called as stars, cash cows, question marks and dogs. Each of these cells represents a specific type of business (Notteboom, 1997).

The BCG matrix offers a model to compare many SBUs at the same time and for allocating resources between the various SBUs. The BCG matrix distinguishes four distinct market positions. SBUs with a relative high market share and high growth rate are defined as Stars. SBUs with a relative high market share and low growth rate are defined as Cash Cows. SBUs with a relative low market share and high growth rate are classified as Question Marks. SBUs with a relative low market share in and low rate are nominated as Dogs (Armstrong & Kotler, 2005).

The BCG Matrix establishes a model for allocating resources among various business units and compares many business units at the same time. However, BCG Matrix has some limitations. First, BCG matrix categorises businesses as high and low, but generally businesses can be medium also. As such, the true nature of business may not be indicated. Second, market is not well defined in this matrix. Third, high market share does not always lead to high profits. There are high costs also tangled with high market share. Fourth, growth rate and relative market share are not the only factors of profitability. Fifth, this matrix ignores other elements of profitability. Sixth, sometimes, dogs may help other businesses in attaining competitive advantage. They can gain even more than cash cows. Seventh, for the purpose of analysis, this four-celled matrix has simple structure. Next section explains the method used to assess market conduct through the measurement of ports market share and shift effect on ports' competitiveness (Notteboom, 2012).

4.3.3 Assessment of market conduct

4.3.3.1 Shift –Share analysis

Market conduct is the real behaviours of firms in a market. It explains how the firms react to the conditions imposed by the market structure and interacts with competitors. Conduct entails the firms' strategies to compete with each other. It comprises research and development investment, advertising, pricing, merger and acquisition. Conduct also can contain collusion either explicit or tacit. Conduct is affected by market structure since firm strategies vary with competition. In contrary, conduct can affect market structure because firms can make entry cost endogenous by selecting different levels of advertising, quality and so on, thus influence the potential competitor number (Notteboom, 2010). Conduct is also related to performance. For example, advertising cost is usually higher in high profit industries, because firms with high profits can afford higher advertising expenses, and in order to maintain their profits and hinder new competitors into the profitable market, these firms would use advertising investments as endogenous sunk costs (Lam et al, 2007).

Shift-share analysis is one way to analyse market conduct and to account for the competitiveness of a region's industries and to analyse the local economic base. This technique is basically used to decompose employment changes within an economy over a specific period of time into mutually exclusive elements. It illustrates how well the region's current industries are acting by analysing the national, local, and industrial components of employment change. A shift-share analysis offers a dynamic account of total regional employment growth that is related to growth of the national economy and the competitive nature of the local industries (Wilson et al, 2005).

The shift-share regionally developed in the framework of regional economics, but it is also applied to the maritime sector to get more insight into the dynamics of port traffic (Marti, 1988; De Lombaerde and Verbeke, 1989; Notteboom, 1997). Although shift-share analysis cannot express changing conditions in the current competitive environment, it enables dividing the growth or decline of a variable ‘shift’ effect and the ‘share’ effect. The ‘share’ effect represents the estimated increase of container traffic in a port as if it would simply retain its market share and, as a result, would develop in the same way as the total port market (Notteboom, 1997).

The total shift represents the aggregate number of containers (TEUs) a port has actually lost to or won from competing ports in the same market, with the estimated container traffic (share effect) as a reference. The shift effect allows for a better evaluation of a port’s competitiveness as it excludes the growth of the overall container sector, only the net volume of TEU-shift between ports remains (Notteboom, 1997, 2010). The total sum of the shift-effects of all studied ports equals zero. Mathematically these constituents can be calculated as:

$$ABSGR_i = TEU_{it_1} - TEU_{it_o} = SHARE_i + SHIFT_i$$

$$SHARE_\iota = \left(\frac{\sum_{\iota=1}^{N} TEU_{it_1}}{\sum_{\iota=1}^{N} TEU_{it_o}} - 1\right).TEU_{it_o}$$

$$SHFT_\iota = TEU_{it_1} - \frac{\sum_{\iota=1}^{N} TEU_{it_1}}{\sum_{\iota=1}^{N} TEU_{it_o}}.TEU_{it_o}$$

Where *ABSGR*, is the absolute growth of container traffic in port *i* for the period $t_o - t_1$explained in TEU. *SHARE,* is the share-effect of port *i* for the period $t_n - t_1$explained in TEU. *TEU* is the container traffic of port *i* expressed in TEU, and *N* is the number of ports in the Mediterranean container port market.

However, Shift-share is a simple analytical tool that does not consider many factors. For instance, it reduces the effect of issues such as business cycles, recognition of actual comparative advantages and differences caused by levels of industrial detail. Program outputs should be explained with caution, given limitations of the methodology, and applied in conjunction with other regional analysis methods to get a more complete representation of market dynamics. Moreover, the shift-share technique does not analyse changes in earnings, income, or value-added, which are alternative inputs of an industry's size and strength (Notteboom, 1997). Next section illustrates the various models that are used to assess market performance by benchmarking the technical efficiency of the Mediterranean container ports.

4.3.4 Assessment of market performance and ports efficiency

The SCP approach indicates that performance should be determined by the conduct of firms. This conduct is then measured by the features of market structures. The relationships between structure, conduct and performance will then reveal the models of monopoly, oligopoly and perfect competition (Jones & Sufrin, 2010).

In order to keep pace with trade oriented economic development, port authorities have been under pressure to enhance port efficiency by ensuring that ports are provided on an internationally competitive basis. The methods for measuring productive efficiency appear once the empirical work illustrates that firms do not always succeed in achieving their objectives of economic optimisation, even when they try. As such, the importance of comparing between what firms produce and what they could have produced arises, in other words, quantifying its inefficiency. This task is handled by assessing the distance that splits the production of each firm from the production attained by the best firms observed if they utilised the same type of inputs as the firm analysed. This option is faced by establishing a new analytical model that, starting from the realisation of the optimising performance of the producers, recognises that these are not always successful (Gonzalez & Trujillo, 2009).

The new evaluation techniques must capture the possibility of different levels of success or failure among firms, or even of considering the reasons for this failure. The use of frontier approaches has increased significantly in recent years through its application to various production sectors. Bauer (1990) and Wang et al. (2005) highlighted that several reasons justify the use of such model. They explained that the frontier model is consistent with the economic theory of the firms' optimising behaviour; deviations from the frontier can be explained as an evaluation of the efficiency through which firms attain their objectives; and the information they provide in terms of the relative efficiency of firms has important policy implications and is of great value to decision makers. As such, in this study, the DEA technique is used to assess the technical efficiency of container ports in the Mediterranean market (Gonzalez & Trujillo, 2009).

4.3.4.1 Fundamental concept of Data Envelopment Analysis (DEA)

Data envelopment analysis can be defined as a linear programming technique based on mathematical programming theory. DEA calculations are nonparametric tools of evaluating the efficiency of a firm, decision making unit (DMU), with various inputs and/or outputs (Poitras et al, 1996). This can be done by creating a single virtual output to a single virtual input without pre-defining a product function. DEA does not need knowledge or measurement of a priori weights for the inputs or outputs. As such, these characteristics make DEA a more flexible technique as compared to other traditional efficiency methods derived from stochastic production frontier or economic value added (EVA), which are based on production function estimation concerning many inputs but only one output (Cullinane & Wang, 2007).

DEA as a benchmarking and efficiency measuring technique is widely used in various fields such as education, health care, banks and maritime transport (A Data Envelopment Analysis…, 1996). Some studies have included efficiency evaluation of firms with features similar to ports, such as courts (Lewin et al, 1982), post offices (Deprins et al, 1984), air force maintenance units (Charnes et al, 1985), hospitals (Banker et al, 1986) and schools (Ray 1991). Moreover, DEA permits unconventional measures such as the number of graduates, number of patients served, even journal ranking (Burton and Phimister, 1995) to be utilised for efficiency estimation. DEA has also been used in the transportation sector to airlines (Banker and Johnston 1994, Charnes et al, 1997) and railways (Oum and Yu, 1994).

DEA provides a substitute to classical statistics in extracting data from sample observations. on the contrary to parametric techniques such as regression analysis which match the data through a single regression plane, DEA optimises each individual observation with the objective of calculating a discrete piece-wise frontier determined by the set of Pareto efficient DMUs. The central point of DEA is on individual observations as opposed to single optimisation statistical models which emphasize on averages of elements. In this study, DEA refers to each port as a DMU, in the sense that each is responsible for converting inputs into outputs. DEA model can include multiple inputs and multiple outputs in its efficiency assessment (Kamble et al, 2010).

The DEA has two basic models. Following Farrell (1957), the first model is known as CCR (Charnes, Cooper and Rhodes, 1978) model that had an input orientation and presumed constant returns-to-scale (CRS). The second model is the BCC that is first established by (Banker, Charnes, Cooper, 1984) which had an assumption of variable return-to-scale (VRS) (Wang & Cullinane, 2006b). There are another four DEA models which are: the additive model, the multiplicative model, the Cone-Ratio DEA model and the Assurance-Region DEA model. The latter two models comprise priori information such as experts' opinions, opportunity cost or rate of substitution, in order to limit the results to the best DMU as in the Assurance-Region DEA model or to connect DEA with the multi-criteria analysis as in Cone-Ratio DEA model (Barros & Athanassiou, 2004).

As an extension of the DEA model there are also other models such as the DEA-Malmquist model which untangles total productivity change into technical efficiency change and the DEA-allocative model, which unravels technical and allocative efficiency. Moreover, there have been a number of extensions and development to the DEA model. For instance, Charnes et al. (1985) established window analysis to handle panel data sets that includes cross section and time series observations (Barros, 2006).

The DEA approach is based on the idea that the efficiency of a DMU is measured by its ability to transform inputs into required outputs. This approach was adopted from engineering which defines the efficiency of a machine/process as Output/Input. In this approach, efficiency estimate is always less than or equal to unity as some energy loss will always occur during the transformation process. DEA generalises this single output/input technical efficiency estimate to multiple outputs/inputs by creating a relative efficiency estimate based on a single "virtual" output and a single "virtual" input. The efficient frontier is then measured by selecting DMUs which are most efficient in producing the virtual output from the virtual input. Because DMUs on the efficient frontier have efficiency score equal to one, inefficient DMUs are determined relative to the efficient DMUs. The efficiency ranking is relative to other DMUs. It is difficult to determine if DMUs judged to be efficient are optimising the use of inputs to produce outputs (Ramanathan, 2003).

The term relative efficiency is used in DEA because the efficiency of each DMU is measured in relation to all the other DMUs in the selected sample. For multiple inputs and/or outputs, the envelopment surface will be multidimensional. All those DMUs that are located on the frontier have an efficiency estimate of one and are considered DEA efficient, while those below will be categorised as DEA inefficient and have efficiency estimates of less than one (Tongzon, 2001b).

Infante and Gutiérrez (2013) explained that the use of the DEA approach has been emphasised on the arena of production for the efficiency evaluation. In this research DEA models are used to assess the technical efficiency of container ports. Although this is not the traditional application of this type of analysis, the meaning of efficiency applied in the model is developed by (Mercado et al, 1997):

Efficiency = Total outputs / Total inputs

Overall, efficiency can be described as:

$E = \frac{Outputs}{Inputs}$ Or formally; $E = \frac{\sum_{i=0}^{N} v_i y_i}{\sum_{i=0}^{N} u_i x_i}$

Where E represents efficiency, x_i and y_i are inputs and outputs respectively, whereas u_i and v_i signify factors that explain the relative significance of every one of the factors. If the relative significance of each one of the inputs and outputs were known a priori, the focal problem of efficiency evaluation would be ended; however, this data is usually unknown. Assessment of Efficiency usually includes multiple inputs and outputs; As such, they must be chosen in relation to the nature of the problem under study. Methodologically, the research layout of DEA models, in which these aspects and factors are observed, leads not only to efficiency analysis based on the DEA models but also to a different proposal to enhance efficiency (Infante & Gutiérrez, 2013).

The above mentioned explanation to the DEA technique provides an overview about its main features. Appendix 4.1 illustrates the pros and cons of the DEA models and how can the DEA features affect the efficiency analysis of a set of firms under study.

4.4 Efficiency analysis procedures and DEA models

Based on the literature, it is clear why research which has focused on the port efficiency of emerging, advanced, and international markets has relied mainly on the DEA-CCR and DEA-BCC models, regardless the fact that information technologies in emerging markets are not as advanced as those of developed countries (Emrouznejad et al, 2008). Hence, this research applies these models as its base. Wang et al. (2003) explained that, in the context of model orientation, input-oriented models are more related to operational and managerial aspects, while output-oriented models are closely related to planning and strategy formulation. With the fast expansion of globalisation and international trade, many container ports are obliged to evaluate regularly their capacity to ensure that they can provide adequate service to port users and maintain their competitive position (Wu & Goh, 2010). From that perspective, this research applied the output-oriented CCR and BCC models to evaluate the technical efficiency of container ports in the Mediterranean region.

There are two main reasons that justify this selection. First, since the main concern of this research lies with informing policy-decisions at local, national or regional levels, an output-oriented model is more convenient. Second, all available alternative models cater for the case where there is a single output. Hence, the choice of an output-oriented model greatly simplifies the direct comparison of all alternative models on a one-to-one basis. Another attractive reason lies with the greater analytical tractability and easier data collection that is inherent in using just a single output variable as the basis upon which the analysis is undertaken (Wu & Goh, 2010). The research procedure of the present study is summarised in figure 4.3. The DMUs for the study were first selected. The selection of the DMUs, 22 container ports in the Mediterranean, is based on their location and the container traffic served.

The availability of data for input and output variables was a significant consideration in selecting ports. Then, by applying correlation analysis of the input and output variables, it was possible to determine appropriate combinations of input and output variables. To provide a comprehensive overview about the Mediterranean container ports, an examination of the efficiency of the present and potential hub ports in the Mediterranean container market are included in the second phase of the present study. This was attained by revising the combination of input and output variables to allow for the data that were available from the studied ports. The third phase constitutes an overview about the fundamental concepts of efficiency measurement and DEA models that are used in this research. The fourth phase provides a comprehensive explanation about the DEA models. Five DEA models are used in the context of this research.

The DEA-CCR and BCC models are used to conduct an efficiency value analysis. As explained in Charnes et al. (1978) the CCR model presumes that the production process produces constant returns to scale. When the returns to scale vary, production combinations will be scaled accordingly.

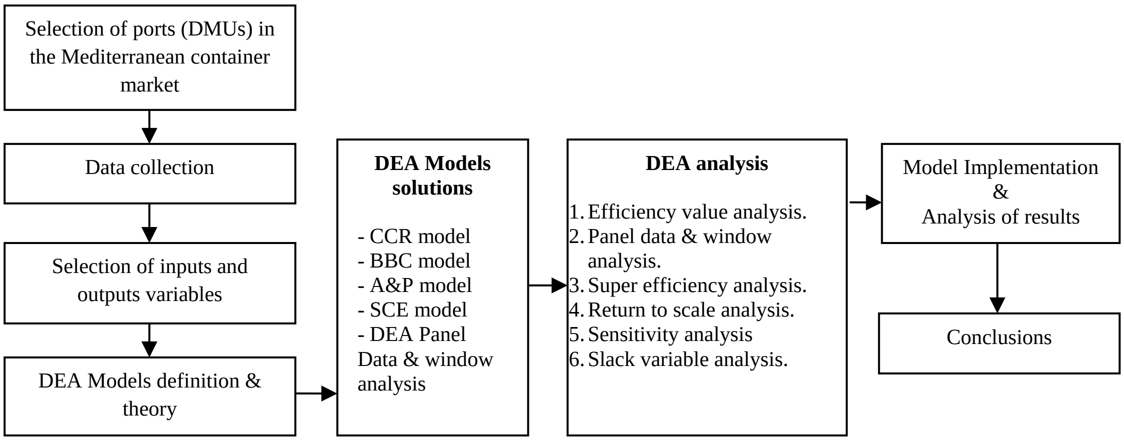

Figure 4. 3- Benchmarking and efficiency measurement procedure using DEA models.

Thus, inefficiencies can be related to operations with different returns to scale. Banker et al. (1984) then developed on the constant returns to scale model by establishing a variable returns to scale BCC model.

When the CCR and BCC models give a value of one to the efficiency of DMUs, it is difficult to rank the efficiency and distinguish the relative strengths and weaknesses of already efficient container ports anywhere. To solve this problem, the super efficiency model, A&P (Anderson and Petersen, 1993) model, is used to underline the discriminatory power of the CCR and BBC models in ranking the relative efficiency of container ports in a particular market (Wu et al, 2010). As shown in figure 4.4, with respect to the efficiency value analysis, when technical efficiency score of some of the selected DMUs is less than 1, that means that those DMUs are technically inefficient, this means that the efficiency of the inputs and outputs being used is not appropriate, and that it is essential to reduce input or increase output. However, when the scale efficiency of the selected DMUs is less than 1, that is scale inefficient, it means that the operational scale is not attaining an optimal value, and that the operational scale should be expanded or decreased. Moreover, it is viable to compare the technical efficiency score with the scale efficiency score, with the lesser of the two demonstrating the main cause of inefficiency (Lin & Tseng, 2007).

When the DMU efficiency score is less than 1, the causes for the inefficiency have to be determined by applying the pure technical efficiency and scale efficiency model. After identifying the causes of inefficiency, the slack variable analysis model can be used for the enhancement of inefficient DMUs. Then by using return to scale analysis, it is likely to examine the u_0 value from the BCC model, and thus assign the return to scale for each DMU as constant, increasing, or decreasing (Lin & Tseng, 2007).

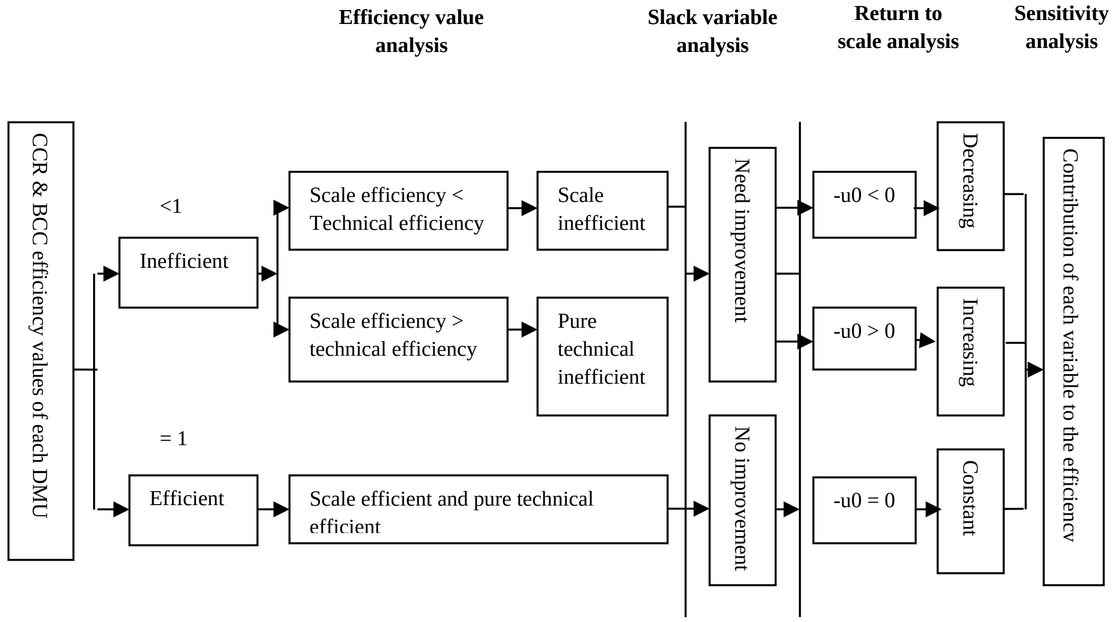

Figure 4. 4- Flow process of DEA efficiency evaluation and analysis

Source: Lin, L.C., Tseng, C.C. (2007) 'Operational performance evaluation of major container ports in the Asia-Pasific region'. *Maritime Policy and Management*. 34 (6), pp. 538.

The sensitivity analysis is then used to remove the input and output variables one by one, and then re-calculate the aggregate efficiency. This enables determination of which input and output variables are more responsible for the variation in a DMU's operational efficiency. This provides a comprehensive understanding of which input or output variables are more significant for efficiency enhancement.

Finally, the slack variable analysis model is applied to address the exploitation rate of input and output variables. This is done by evaluating how to enhance the operational efficiency of DMUs by demonstrating how many inputs to reduce, and/or how many outputs to increase, so as to make the inefficient DMUs efficient. The analysis of variable weights, the greater the weights of input and output variables, the more the variables contribute to a DMU’s efficiency score. As such, if managers look forward to enhance the operational efficiency rapidly, they should first emphasise on the input or output variables with greater weights.

If limited only to the analysis of cross-sectional data, DEA comprises the benchmark of one DMU with all other DMUs which operate during the same period of time and the role of time is neglected. However, this can be rather misleading since dynamic settings may underline the excessive use of resources which are projected to produce beneficial results in the future (Wang et al, 2005). In this study, the DEA panel data and window analysis applications are used not only to benchmark the efficiency of DMUs but also to identify the changes of the DMUs' efficiency over a specific time period between the year of 1998 and 2012. Finally, DEA models implementation and empirical results analysis are conducted in phase 5.

Appendix 4.2 illustrates the basic formulae of the DEA models that are used in the context of this research. These models are: the CCR, the BBC, the scale efficiency, the A&P, the sensitivity analysis and the slack variable analysis models. Appendix 4.3 explains the different types of panel data that are applied in this study which are; the contemporaneous, the Inter-temporal and window analysis.

4.5 Bootstrapping truncated regression model

Nonparametric efficiency models, such as DEA, normally rely on linear programming techniques for the calculations of scores and are often considered as deterministic (as opposed to econometric or statistical), as if to propose that the models lack any statistical underpinnings (Simar & Wilson, 2004). Although the DEA technique has many advantages, the results are sensitive to sample constitution. If there is sampling difference around the observed frontier, a regulatory rule relying on DEA to distinguish efficient comparators could be weakened by this uncertainty (Barros & Managi, 2008).

The bootstrap can be a very effective tool in statistics and it is easily applied using computer-based software. Bootstrap is a nonparametric technique which allows calculating confidence intervals, estimated standard errors and hypothesis testing. In general, the bootstrap follows the next 3 stages. First, resample a given data set a specific number of times. Second, calculate a certain statistic from each sample. Third, calculate the standard deviation of the distribution of that statistic (Hawdon, 2003). Simar and Wilson (1998) stated that "*The bootstrap has been advocated as a way of analysing the sensitivity of measured efficiency scores to the sampling variation*".

Bootstrapping, established by Efron (1982) and Efron and Tibshirani (1993) is derived from the idea that when there is no enough information about data generating process for a sample of observations, the d.f. can be calculated by using the given sample to create a set of bootstrap samples from which factors of interest can be estimated. The process uses the values of original sample to create an empirical distribution of the variable of interest by repeated the sampling of the original data series, application of the estimation process to the sampled data and then computing relevant statistics, e.g. means and standard deviations from these results. It has been applied effectively to decrease the sample bias in a wide range of econometric research (Hall, 1992; Hawdon, 2003; Al-Eraqi et al, 2008).

Following the DEA-based performance measurement of each container port (second stage), the present study aims at assessing the effect of several determinants (explanatory variables) of technical efficiency (third stage). The use of the Super-Efficiency DEA estimates facilitates the identification of the role of its determinants (environmental factors) at the latter stage. This is because it allows disentangling their influence on the most efficient ports which may take values beyond unity, as in the case of Mediterranean container ports, and it circumvents the problem of imposing upper-bound (unity) constraints, compared to the case of adopting the standard DEA results (Bichou, 2013). Furthermore, the DEA-CCR Super-Efficiency scores θ^{super} are used as the dependent variable at this stage of analysis, since they express the total technical efficiency (both the pure technical efficiency and scale effects) of container ports j = 1,…, n. By using some regression model, the effect of each determinant k = 1,…, K on θ^{super} score is identified. In a generalised form (omitting the constant term), this model can be formulated as follows:

$$\theta_j^{\text{super}} = \sum_{k=1}^{k} \beta_k x_{kj} + \varepsilon_{j,} \qquad (1)$$

Where β_k denotes the coefficient corresponding to the *kth* determinant and ε_j is an independent and equally distributed random error term. Since the efficiency scores θ^{super} are constrained to the minimum value of zero, the Tobit regression technique (Tabernacle, 1995) is typically implemented to solve Eq. (1), in order to address the censorship bias which may result from the use of Ordinary Least-Squares (OLS) method. The Tobit model signifies the potential value of the dependent variable θ^{super} as a latent variable $\widehat{\theta}^{\text{super}}$ which can only be partially observed within the feasible range of efficiency scores (≥0), as follows:

$$\widehat{\theta}_j^{\text{super}} = \sum_{k=1}^{k} \beta_k x_{kj} + \varepsilon_j$$

$$\theta_j^{\text{super}} = \begin{cases} 0, & \text{if } \widehat{\theta}_j^{\text{super}} \leq 0 \\ \widehat{\theta}_j^{\text{super}}, & \text{if } \widehat{\theta}_j^{\text{super}} > 0 \end{cases} \qquad (2)$$

The Tobit Regression was adapted in the study of Turner et al. (2004) in order to estimate the effect of several factors on the efficiency of the North American ports.

However, model (2) relies on (censoring) assumptions which are not consistent with the true data generation process, yielding inaccurate estimates of the standard error of parameters. This is because efficiency scores constitute point estimates without statistical distribution, as it is required by Tobit (or other parametric regression) techniques and they may be correlated with explanatory variables.

In order to improve the accuracy of results, Simar and Wilson (2007) suggested the use of truncated regression with parametric bootstrapping, which can produce more consistent and efficient model coefficients. Specifically, the distribution of the error term $\varepsilon_j \sim N(0, \sigma_c^2)$ is assumed to be uniformly truncated with zero mean (before truncation) and unknown variance σ_c^2 so that ensure the negative-value constraint of the dependent variable. Both the Tobit and truncated regression models are solved here by using the maximum likelihood method and iterative parametric bootstrap simulation techniques (Niavis & Tsekeris, 2012).

4.6 Definition of variables and data

4.6.1 Ports output and inputs measures

Several research have benchmarked ports using selected efficiency and performance measures. In DEA analysis, being efficient means combining available inputs to accomplish a higher level of outputs than comparable DMUs. However, the main objective of using the DEA is to find the most efficient DMUs which accordingly belong to the production frontiers and the least efficient which need proper adjustments to the inputs and outputs in order to enhance the efficiency. In addition, the DEA permits a quantitative measurement for the relative efficiency of DMUs and planning of targets in different aspects in order to enhance efficiency in every DMU (Rios & Macada, 2006).

Cullinane et al. (2006) explained that the input and output variables should precisely represent actual objectives and the process of container port operation. In the context of the former, the observed efficiency of a port might be closely related to its objectives.

For example, a port could use state-of-the-art, expensive equipment to enhance its efficiency if it simply aims to maximise cargo throughput. Similarly, a port may be aimed to use cheaper equipment if its objective is to maximise profits. The objectives of a port are important to the selection of variables for efficiency analysis. For example, if the objective of a port is to maximise its profits, then any information on labour should be considered as an input variable. Number of labour and the labour salaries significantly affect port economic efficiency. The former represents one of the port physical resources while the latter is counted as part of the port operating costs and thus affects port's allocative efficiency. However, if one objective of a port is to increase national or regional employment then, regardless of the fact that it may appear to be somewhat counter-intuitive, labour should be considered as an output variable.

A significant part of the judgment of variable definition in port benchmarking research lies in the recognition of the relationship between controllable and uncontrollable factors. Only variables based on controllable factors should be included in the comparison analysis. However, the extent to which uncontrollable factors affect port efficiency should also be considered. It is important to realise this aspect in the context of benchmarking port efficiency because as one goes down the decision-making hierarchy, the port operator is allocated a certain input and output package under his control (Bichou, 2013).

The aims of a port are closely related to what is so called the economic function of a port. As such ports mainly aim to increase throughput, maximise profit, minimise operating costs and generate added value (Suykens & Van de Voorde, 1998; Notteboom, et al, 2000; Cullinane & Wang, 2010). For the purpose of this analysis, the main objective of a port is set to be the minimisation of the use of inputs and maximisation of the output. Ports are the relevant DMUs. The selection of the DEA inputs or outputs is closely related to the DMUs market condition. For instance, in competitive markets, DMUs are output criteria, presuming that inputs are under DMU control, which aim to increase its output.

In contrast, in monopolistic markets, the DMUs are input criteria, exogenous, while the outputs are considered as endogenous. As shown in figures 4.5 and 4.6, for the purpose of analysing the competitiveness of main container ports in the Mediterranean market, the research uses two main variables which are the ports, throughput and market share. As far as port efficiency evaluation and benchmarking is concerned, this study uses six endogenous/controlled variables. The research uses one output measure which is the container port annual throughput, the total number of containers loaded and unloaded, which is unquestionably the most important and widely accepted indicator of port or terminal output. As shown in chapter 3, most of previous research regarded it as an output variable, because it directly relates to the need for cargo-related facilities and services and is the main basis upon which container ports are benchmarked, particularly in evaluating their relative size, amount of investment or service levels. Another concern is that container throughput is the most relevant and analytically tractable index of a port operational efficiency (Wang et al, 2005).

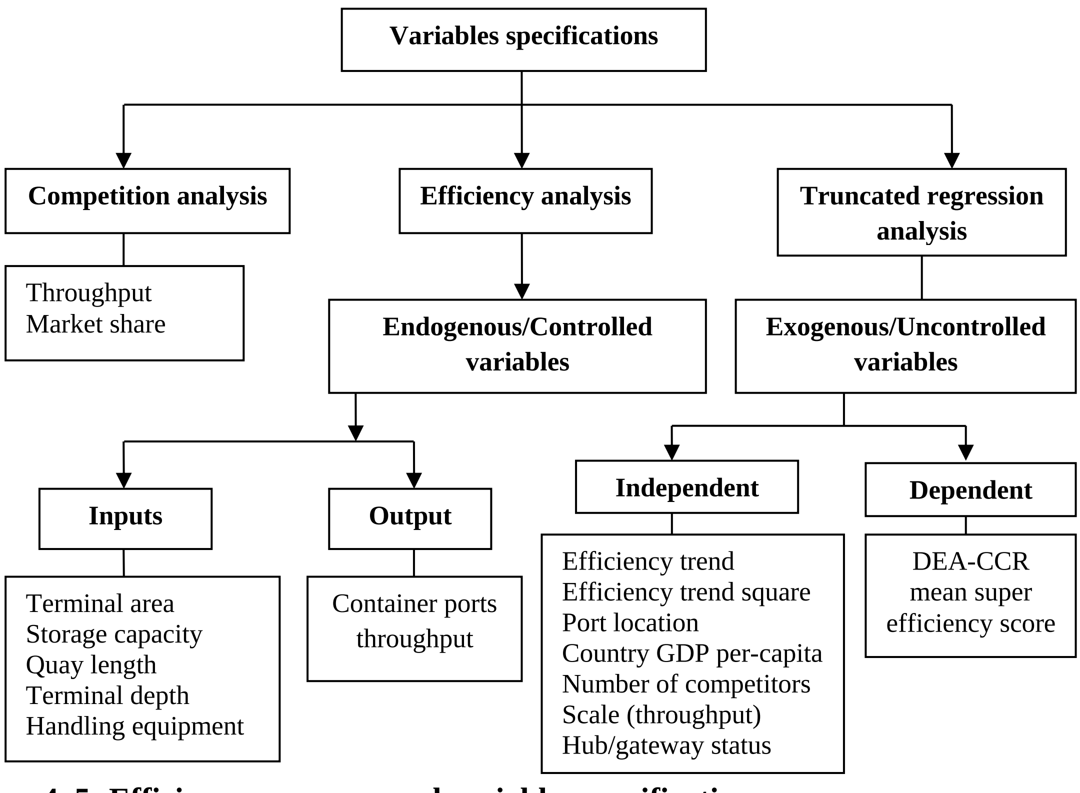

Figure 4. 5- Efficiency measures and variables specifications.

However, as in most of research examining the efficiency of container ports, cargo throughput has been chosen as the most suitable output variable for the DEA. The issue of transhipment traffic then arises as a possible problem in the calculation of total container traffic. However, according to (Wang and Cullinane, 2006a; Demirel et al, 2012), in most of cases this issue is largely diminished because the amount of work related to the handling of a transhipment container within that equate, to a large extent, to that associated with an import or export container. Moreover, the truncated regression analysis which is used within this study on the outputs from the DEA explicitly highlights the impact of transhipment on container port efficiency estimates (Demirel et al, 2012).

Chang (1978), Wang et al. (2005) and Infante and Gutiérrez (2013) argued that the inputs of a port should contain the actual value of the port’s net assets, the number of employees and the average number of employees per month each year, and considering technological development. Under the orthodox microeconomic framework, capital and labour costs should necessarily be incorporated in the model. Capital includes the investment made in various port services (Cullinane et al, 2005).

Dowd and Leschine (1990) explained that container port production depends crucially on the efficient use of labour, land and capital. Therefore, this research incorporates five measures of port efficiency into the model as input variables that represent the ports’ infra/superstructure for the period between 1998 and 2012. These inputs are: container terminal area, storage capacity, terminal length, maximum depth and container handling equipment.

The first and second inputs are the terminal area (land) and the storage capacity which act together as a buffer between sea and inland transportation or transhipment. The capacity of a ship is often thousands of times the capacity of the land vehicles that carry the cargo to and from the port leading to a storage requirement. The third variable is the total quay length. This variable represents the major capital inputs in port operations and directly reflects the number of ships that can be berthed at a time. Quay length has been used in various research that applied DEA to measure port efficiency. For instance, Notteboom et al. (2000), Tongzon (2001a) and Cullinane et al. (2002) used the number of berths as an input variable.

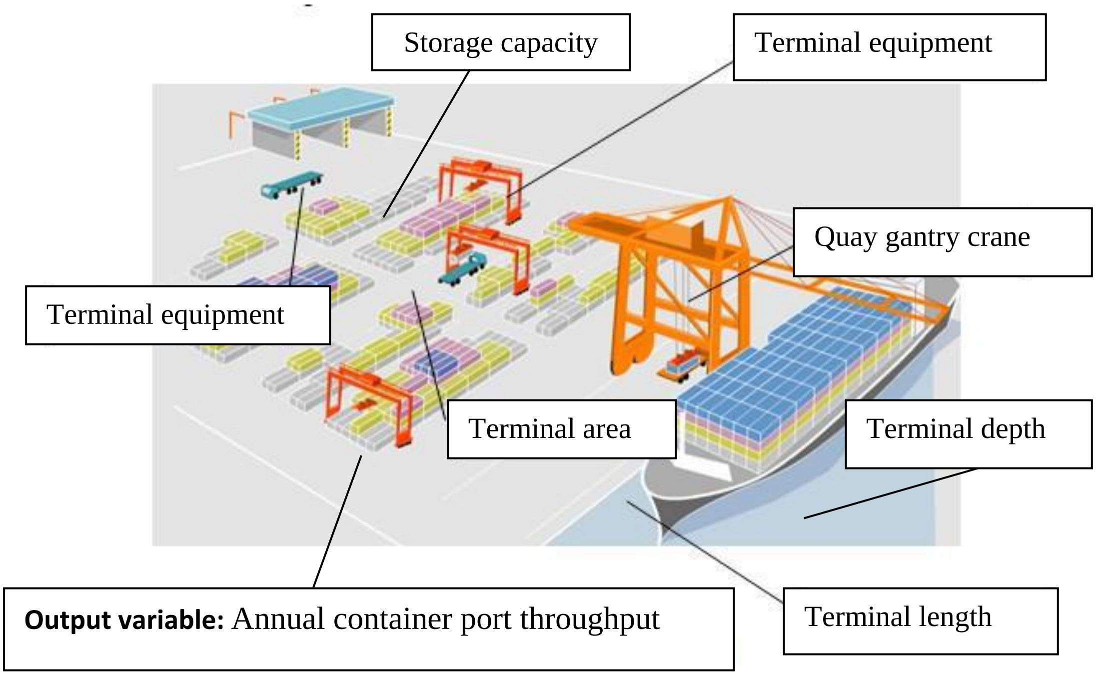

Figure 4. 6- Inputs and output variables for efficiency measurement.

However, equitable comparability is a significant criterion for performance and efficiency measurement (Vancil, 1973, Wang et al, 2005). From this perspective, it may not be appropriate to count the number of berths rather than to count the total length of all berths. This is because the number of berths can be varied easily according to port requirements by reconfiguring the quays within a port or terminal and, therefore, is quite an artificial metric. Another drawback in counting the number of berths is that this bears no underlying relationship to capacity. For example, the length of one berth in GioiaTauro is 3011 m compared with 1325 m for two berths in Izmir.

As such, focusing solely on the number of berths will naturally lead to the conclusion that the single container terminal in GioiaTauro is more efficient than its counterparts in Izmir. The fourth is the terminal depth which represents the ability of ports to accommodate different ship sizes and capacities. The fifth is the handling equipment that includes the quay-side gantry cranes, which is a vital piece of equipment in the production process that decides the efficiency of a port and the number of terminal equipment units that represent the quality and quantity of support infra/superstructure provided that is directly affecting the number of containers handled in the port.

Inequitable treatment that has introduced bias into the estimates of production efficiency in previous research also exists in the way that terminal equipment has been incorporated into models. The number of gantry cranes in terminals is normally considered as an input variable (Notteboom et al, 2000). This may be tricky because quayside gantry cranes and yard cranes should be classified according to their different functional usage.

On the other hand, the gantry crane is not the only equipment that plays a part in container terminal operations. For instance, straddle carriers, mobile cranes, front-end loaders, reach stackers, top lifters and forklifts are also utilised in certain container terminals. One direct solution is to count the aggregate number of all types of equipment present within a container terminal or port. However, problems immediately arise concerning comparability and equitable treatment. For example, the capacity of just one yard crane is much more than straddle carriers. Thus, a container terminal with more yard cranes will have a higher level of estimated efficiency, even though this high efficiency does not reflect its real input levels (Wang et al, 2005).

The solution applied in this study has been focused solely on the most important container handling equipment. Yard gantry cranes, including rubber-tyred gantry cranes (RTGs) and rail-mounted gantry cranes (RMGs), as well as straddle carriers handle most of containers in a container yard. Cullinane et al. (2005b) explained that it is logic to treat the absolute number of these separate equipment that are operated within a container yard as input variables and to neglect the other items of equipment that may be deployed within a container yard. An exception is made in the case of some mobile cranes. During the data collection process, some mobile cranes were found to have quite large capacities (over 80 tonnes). As such, these mobile cranes have been considered as equivalent to yard gantry cranes because they are able to handle a similar volume of containers. The study uses the number of handling equipment instead of the total handling capacity for two main reasons. First, the number of equipment implicitly implies the number of labour in a container port. Second, the total handling capacity does not reflect the actual ability of a port to handle a certain amount of containers per annum. A container port could have a small amount of handling equipment with high capacity that cannot handle the targeted number of containers per year or have a large number of handling equipment with lower capacity but has the ability to achieve the targeted throughput.

Quite apart from terminal facilities (capital), according to the orthodox production theory espoused in mainstream elementary economics, labour should also be included in any model of an industry's production function. Previous literature has used two main approaches to attain this. The easiest approach is to directly determine the number of employees and stevedores that work in the terminals (Tongzon, 2001b; Cullinane and Song, 2003). The drawback of this method is that it is difficult to attain data and the potential for measurement error. Valentine and Gray (2001) explained the inaccuracy of labour data and clearly stated that information was particularly difficult to obtain from ports that were joint ventures between public and private sector companies.

An alternative solution is to include labour data into the model implicitly. For example, Notteboom et al. (2000) highlighted that expert analysis has revealed that a there is a close relationship between the number of handling equipment and the number of labour in a container terminal, commercial and administrative staff excluded. Thus, labour data can be described as a mathematical function of the facilities of a port. Although the ideal situation would be to incorporate information on port labour directly into the model, this data is both difficult to obtain and often unreliable, either from secondary or even primary sources (Cullinane et al, 2005b).

In the third stage, the research uses the regression model to examine the relationship between container ports competitiveness and their operational efficiency. The dependent variable is the CCR-DEA mean super efficiency score attained from DEA in the second stage. Seven independent, explanatory, variables are used as follows. The first variable refers to the efficiency trend of the defined ports over the period of study. The second variable is the efficiency trend square. The third variable refers to the economic status of the territory in which the port is located, as expressed by the measure of per-capita Gross Domestic Product (GDP).

The fourth variable refers to port location represented by the distance of each port from the main liner trade route in the Mediterranean basin, which denotes the relative importance of geographical position in the region. The geographic location of a port in relation to the main trade routes is a very important consideration that may favour one port over another (Lu & Marlow, 1999, Bichou, 2013). The carrier's main objectives are to provide the most comprehensive door to door coverage with minimum transit time and cost. Therefore, the closer the port is to the main trade route, the higher its competitive advantage is in the market (Guy & Urli, 2006). As such, port location is used as an exogenous factor that could affect port efficiency. The port location is represented by the deviation distance from the main East-West trade route.

The distance is measured through the use of transit time/distance calculator (www.searates.com/reference/..., 2012). The fifth variable is the number of competitors of each port with the defined market. The sixth variable is the hub status of container ports, a dummy variable identifying a port as "hub" or "gateway," depending on a fairly subjective threshold value of 50 per cent for the calculated transhipment ratio. The last variable is the container ports scale of production represented by the ports mean throughput over the period of study (Demirel et al, 2012).

The Banxia Frontier Analyst software is used to solve the two DEA models that explain the return to scale of the ports production function, the CCR model (CRS) and BCC model (VRS).The software provides detailed analysis on how DMUs, container ports, are performing and how their efficiency can be enhanced. Moreover, because the measurement is based on peer-group comparisons, the improvement targets are realistic. One of the best features of Frontier Analyst is the diversity of outputs it produces. It supports all standard output information provided by DEA in addition to some excellent graphic demonstration of the relationships among DMUs.

The software has the following key characteristic, which make it effective data envelopment analysis programme. The software includes weighting facility to ensure that important elements are always included. It is able to benchmark the efficiency of 75 to unlimited DMUs. It has flexible import functions from both file and spread sheet using a distinctive "wizard". Input data filtering and individual unit inclusion/exclusion functions offer flexible input data management. Filtering supports date fields, text and numbers. The Input and output variables selection is so powerful and "what-if" assessments are easy to perform. The software also allows for tabular scores report with a different sorting methods and graphical summary.

4.7 Chapter summary

This chapter provided a comprehensive illustration of the research design, approach, strategy and time horizon. The research design reveals the significance of the methodology that is used, in this study, to assess port competitiveness and efficiency. The research applies the theory of industrial organisation and constructed a model that uses the SCP approach to examine the impact of port efficiency on port competitiveness in the Mediterranean container market. From the literature reviewed in the previous chapter, it can be concluded that none of the previous researchers have examined the relation between port competition and port efficiency by using such an approach.

As illustrated above, the model constitutes four phases. The first phase includes the determination of the area of study, data collection and variables specifications. The second phase constitutes the application of SCP approach that includes assessment of market structure and dynamics, measuring the market conduct and evaluation of market performance. The third phase assesses and benchmarks the relative efficiency of the main container ports in the Mediterranean. The fourth phase examines the impact of port efficiency on port competitiveness. Next chapter applies the SCP approach in order to analyse the competitiveness level of the main container ports in the Mediterranean market through the assessment of the Mediterranean container market structure and conduct.

CHAPTER FIVE

ASSESSING THE COMPETITIVENESS OF THE MEDITERRANEAN MAIN CONTAINER PORTS

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5.1 Introduction

Container ports have not only encountered competition from the large load centers in the same port range but also from the medium and small load centers having the same hinterland and, to some extent, from load centers in other port ranges. The hub-and-spoke system that has emerged in liner shipping operation patterns has increased pressure on the supply chain network around load centers. Thus, the concept of containerisation has enlarged the geographical coverage of seaports to the extent that the concept of a captive market is no longer valid (Ng, 2006a).

In this context, the current developments in the Mediterranean ports have given rise to some inferences that may be producing a northern expansion of the hinterlands of Mediterranean ports. The increasing competitiveness of these ports along with new services that connect them with world markets enable to offer possibilities for them to compete in some markets of central EU, ports such as Le Havre, Rotterdam, Antwerp and Hamburg (Gouvernal et al, 2005).

As mentioned in chapter four, following the deductive method of Industrial Organization (IO) and the Structuralists (Harvard school) methodology (Cariou, 2007b), the main objective of this chapter is to assess the competitiveness level of the main container ports in the Mediterranean. SCP approach is applied to analyse the competitiveness of 22 container ports in the Mediterranean basin for the period between 1998 and 2012. In doing so, this chapter constitutes five sections and is organised as follows; section one provides an overview about the main features of the study area and the dynamic characteristics of the Mediterranean container port market. Section two encompasses a thorough analysis of structural changes and development of the Mediterranean container port market demand. Section three analyses the Mediterranean container port market structure through the use of five methods. These methods are; the K-Firm concentration ratio, the Hirschman-Herfindahl index, Gini coefficient, Entropy index and BCG matrix. Section four constitutes a comprehensive analysis for the

Mediterranean container port market conducted through the use of the shift-share analysis. Finally, section five draws a conclusion for this chapter.

5.2 Mediterranean container port market characteristics

5.2.1 Structural changes and development of market demand

The developing container shipping networks and changing status of the Mediterranean ports have drawn the scholars' attention (Valleri & Van de Voorde, 1992; Sutcliffe & Ratcliffe, 1995; Twerdy et al, 1998; Zohil & Prijon, 1999; Ridolfi, 1999; Fageda, 2000; Genco & Pitto, 2002; Gouliemos & Pardali, 2002) and practitioners (Drewry Shipping Consultants, 2000). Over the last decade this market has experienced major development and restructuring (Gouvernal et al, 2005). For much of the containerisation era, the Mediterranean basin remained a minor market in the global transportation system (Genco & Pitto, 2002). In spite of the fact that its northern coasts included some of the most advanced economies in the world, and, despite the fact that one of the most vital trade routes, Asia–Europe, passed through the basin, container traffic presumed a local and regional feature. Most main trade routes services passed through the Mediterranean without stopping (Gouliemos & Pardali, 2002) and all the markets of central EU and a significant market share of south EU passed through the ports of north-west Europe (Valleri & Van de Voorde, 1992).

Geographically, the Mediterranean region is considered to be not only a link between East and West markets but also an intersection point with Asia, Europe and Africa. This enables such regions to become transhipment and logistics bases between markets in Europe, the Far East and India. Moreover, these regions are now growing markets that can offer and absorb containers and cargoes due to the economic growth in North Africa and the Middle East (Francesetti & Danila, 2001).

The Mediterranean container market has been characterised by strong long term growth rates. The pace of growth in this market has been truly dynamic. In 2000, the total container throughput of the top 20 container ports in the Mediterranean was about 16.3 million TEUs. It increased to 26.2 million TEUs in 2005 and 47 million TEUs in 2012 with an average annual growth rate of about 10% (Degerlund, 2013b). The driving forces of such growth are, for example, the increased penetration of containerized cargo, the increasing focus on port efficiency and effectiveness in port management, the growing trend towards privatisation, the new investment in high quality equipment and container terminal facilities, the increasing trend in consolidation (merger and acquisition activities), the change in the operational strategies of shipping lines and the use of transhipment to achieve savings in time (Francesetti, 2004).

Meanwhile, the increase in cargo volume on routes from China and Southeast Asia to the regions and the booming of consumers' buying power also has its impact on the market growth (Woodbridge, 2006a). The Mediterranean port market cannot be deemed as a harmonised set of ports. It includes large ports as well as a number of medium-sized to smaller ports each with specific features in terms of location characteristics, cargoes handled and hinterland markets served,. This distinctive combination of various port sizes and types combined with a massive economic hinterland forms port market structure and competition features (Notteboom, 2010).

As far as port competition is concerned the Mediterranean container ports can be segmented into two main types with different commercial and operational requirements: the origin/destination (hinterland) and transhipment market. For the former, such as Valencia, Barcelona in Spain, Genoa and La Spezia in Italy, Mersin and Izmir in Turkey and Alexandria in Egypt, containers are transported directly onto/from a deep sea container vessel to the hinterland via barges, trucks or rails. This type of ports should be located at the centre of population and industry and offers deep water and equipment to handle large container vessels. The latter, such as GioiaTauro in Italy, Piraeus in Greece, Port Said in Egypt, Algeciras in Spain, Marsaxlokk in Malta and Tangier in Morocco are transhipment ports (hubs) that should be close to the main shipping routes and should also offer deep water and facilities to accommodate and handle large vessels (Francesetti, 2004).

Hub-ports can further be divided into two types, feeder traffic (hub and spoke) such as Damietta in Egypt, Marseilles in France, Livorno, Taranto, Cagliari and Naples in Italy, where containers move from deep sea vessels to short sea vessels (feeder) and relay traffic where containers move from deep sea vessels to deep sea vessels. Differentiation between transhipment traffic from hinterland traffic is a key element to consider when assessing the level of competition between ports (Drewry Shipping Consultant, 2000). Mediterranean container ports involved in ever-changing economic and logistics activities and were threatened with changing port management structure. Hence, the present Mediterranean container ports' market looks completely different when compared to the port market structure in the 1990s. Such changes have taken place due to a multitude of reasons.

First of all, the economic centres in the Mediterranean have enhanced their position in relation to the traditional economic centers in Europe. The increased involvement of this region on the European economy allowed the creation of new ports and inland transport networks. Second, during the second half of the 1990s, the Europe-Far East trade route became one of the main international trade route. The significant growth of China economy had its full influence on liner shipping and redirected the attention of many container ports towards the East. This entailed a shift from the Atlantic route to the Suez route, thus paving the way for the Mediterranean to attract international traffic (Notteboom, 2012).

Third, the use of large post-Panamax container ships only started in 1996 with the deployment of the Regina Maersk (official capacity of 6500 TEUs, but anticipated at 8000 TEUs) followed by the super post-Panamax container vessel with 13,500 TEUs, Emma Maersk, that entered into service in 2006 and operated on the Europe Far East route. Recently, the 18,000 TEUs container ship is also deployed and took place in the East-West trade route. Such an increase in vessels sizes have increased burdens on nautical accessibility and port turnaround times. That should theoretically give a competitive advantage to seaports and reduce the number of port calls per liner service (Parola et al, 2013).

Fourth, shipping lines, terminal operators and logistics service providers have gone through an exceptional trend towards consolidations. This has led to effective global terminal networks, carrier alliances and logistics service providers (Notteboom, 2010). This development was further improved by vertical integration policies of many market players contributing to the development of mega carriers. As such, Mediterranean ports have to deal with large port clients who possess a strong bargaining power vis-à-vis terminal operations and inland transport operations (Notteboom and Winkelmans, 2001a; Olivier and Slack, 2006). The loyalty of a port customer cannot be taken for granted. The bargaining power of the large market players, reinforced by strategic alliances between them, is used to play off one port or group of ports against another (Notteboom, 2010).

Fifth, since the mid-1990s, global terminal operators such as APM Terminals from Denmark (AP Moller group), DP World from Dubai, PSA from Singapore and Hutchison Port Holdings from Hong Kong have entered the Mediterranean container port market. Presently, these companies each operate between 5 and 10 container terminals spread out over the Mediterranean as well as the main European regions (Notteboom, 2006a; Drewry Shipping Consultants, 2007). The Mediterranean entry of large terminal clusters has been encouraged by lower entry barriers following the effective procedures implemented by port authorities in relation to the donation of port sites to private terminals operators (Pallis et al, 2008; Notteboom, 2010).

The above changes in the Mediterranean port market have to a large extent affected the competitiveness of container ports, but meanwhile they have also allowed new comers to enter the port market, potentially influencing the Mediterranean port hierarchy. Thus, it is interesting and relevant to analyse, in the next section, how the interaction of the above changes in the Mediterranean port market has affected the recent functional and the competitive position of container ports in the Mediterranean container market.

5.3 Assessment of ports' competitiveness

5.3.1 Mediterranean container port market structure

As shown in figure 5.1, this research is limited to 22 container ports in the Mediterranean market. These ports are classified into two main categories. The first category presents the existing hub ports such as GioiaTauro, Algeciras, Marsaxlokk, Piraeus, Tangier-Med and Port Said. The second category is the gateway and potential ports that represent the potential hubs such as, Valencia, Barcelona, Ambarli, Genoa, Haifa, La Spezia, Mersin, Izmir, Taranto, Constantza, Livorno, Naples, Alexandria, Cagliari, and Marseilles. The selection of the ports under study is based on their location and the container traffic served, since these ports share the same foreland. Moreover, these ports represent the large and medium size container ports in the defined market with container throughput greater than 500,000 TEUs within the period of study.

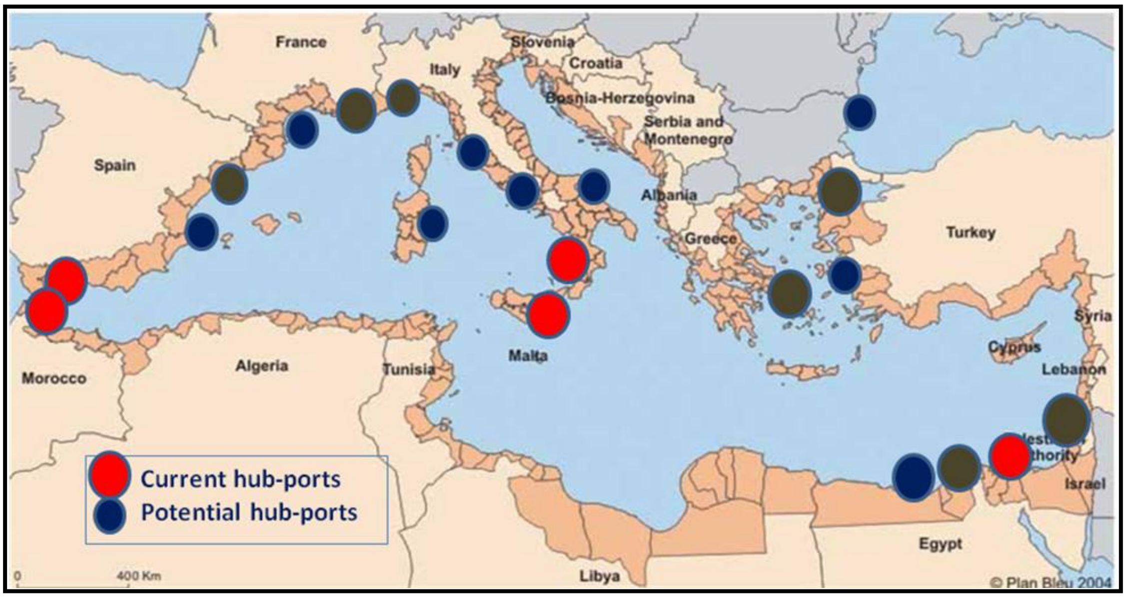

Figure 5. 1- Mediterranean main container ports

Source: Adapted from Adamo, K., and Garonna, P. (2009) 'Euro-Mediterranean integration and cooperation: prospects and challenges. UNECE Annual Report Economic Essays.

Drewry Shipping Consultant (2000) explained that the annual growth rate of ports was 12.9% between 1990 and 1998. This growth was mainly in the western Mediterranean basin, derived in particular by the performance of Spanish and Italian ports. The recent data of the main ports in the Mediterranean confirm that the growth has continued to the present day, with a tripling of business between 1998 and 2012 (UNCTAD, 2013a). The Mediterranean container ports recorded an average growth rate of 11.2 % between 1998 and 2012. The majority of that growth has been related to transhipment traffic. Since 1990 transhipments grew at an annual rate of 19.6%, thus outperforming the whole regional average growth rate by a substantial margin. It has led to the establishment of a number of hub ports in the southern basin whose main function is that of transhipment, and two of these ports, Algeciras and GioiaTauro, are today the largest container ports in the Mediterranean (Rodrigue et al, 2013).

Figure 5.2 illustrates that the total average growth rate of ports of GioiaTauro in the last fifteen years, the study period, between 1998 and 2012 is 1.8% while the total average growth rate of Algeciras is 6.0% in the same period. Appendix 5.3 shows that GioiaTauro annual average growth rate of container throughput was about 6.0% in 1999 and reached to 18.1% in 2012 while Algeciras had an average growth rate of 0.4% in 1999 and achieved a growth rate of 14.2% in 2012.

In the same context, port of Marsaxlokk in Malta recorded a total average growth rate of 6.4% at the same period. The port's average growth rate was -2.5% in 1999 raised to 7.6% in 2012. Meanwhile, Port Said in Egypt has achieved an average growth rate of 20.6% within the period of study. The main reason of that growth is the inauguration of Suez Canal Container Terminal (SCCT) in 2004. The port recorded an average growth rate of 19.3% in the year of 2000 raised to 48.3% in 2004, 86.3% in 2005 and 66.3 in 2006. However, the port's average growth rate has dramatically declined to 13.0% in 2008 due the effect of the world economic and financial crisis.

Port Said had encountered a further reduction in its average growth rate to almost 10.0% in 2012 due to the political issues that took place in Egypt in such period. In the meantime, since its inauguration in 2003, port of Tangier in Morocco has attained a remarkable total average growth rate of 65.3% in the study period. Tangier achieved an average growth rate of 13.1% in 2004. In 2009, the port recorded a four digits increase, 1804.1%, in its average growth rate due to its unique position on the strait of Gibraltar at the west entrance of the Mediterranean basin that attracts APM terminal to invest in the port with a long term concession (30 years) started in 2007.

On the other hand, many of the established gateway ports, such as Valencia and Barcelona in Spain have also developed transhipment activity. As such, as shown in figure 5.2, Valencia and Barcelona recorded a total average growth rate of 11.6% and 3.4% respectively. Moreover, Genoa, La Spezia and Naples in Italy attained almost the same total average growth rate of 3.6%, 3.9% and 3.9% respectively. Similarly, Livorno and Taranto attained almost the same total average growth rate of 7.6% and 7.2% respectively. In the same context, Gateway ports in Turkey such as Mersin and Izmir achieved a total average growth rate of 12.5% and 4.1% respectively. Constantza in Romania, Damietta and Alexandria in Egypt achieved a total average growth rate of 22.1%, 6.6% and 8.2% respectively in the same time period.

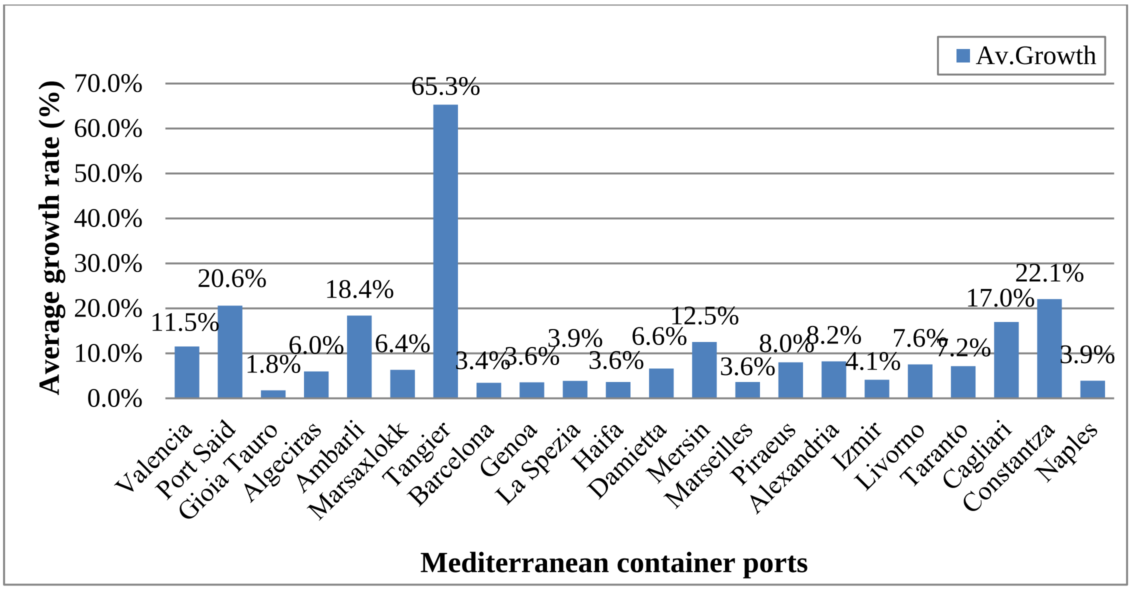

Figure 5. 2- Mediterranean container ports average growth rates (1998 – 2012)

That might lead one to conclude that this exceptional rate of traffic growth in the Mediterranean ports should reveal changes in hinterland penetration. However, Transhipment activity entails a double counting. This significantly magnifies port totals and growth rates. Cazzaniga and Foschi (2002) indicated that it is footloose and not directly tied market capacity. In order to attain a more practical picture of traffic, the transhipment traffic must be excluded from traffic totals. The complexity is deriving a reliable approximation of transhipment totals. Ridolfi (1999), for instance, indicated that 80% of GioiaTauro container traffic in 1998 was transhipment. On the other hand, Cazzaniga and Foschi (2002) indicated that in 1999 it was 97%. Moreover, the proportions of transhipment traffic differ noticeably over time. For instance, Mediterranean Shipping Company (MSC) has selected Valencia as its western Mediterranean hub in 2002, increasing its transhipment proportion from 13.7% in 1999 to 36% in 2003 (Gouvernal et al, 2005).

Many factors have been helped for the growth in container traffic in the Mediterranean. A significant element has been the enhanced efficiency of some of the ports. All the major ports in the Mediterranean, with the exception of Marseilles and Naples, have experienced a growing trend towards privatisation and labour reform (Gouvernal et al, 2005). This is well clear in the transhipment ports, but the success of Genoa and other gateway ports is attributed to the involvement of private terminal operators (Valleri

&Van De Voorde, 1992; Notteboom, 2010). The enhanced efficiency probably makes these ports more competitive in inland markets.

Another explanation for the growth of Mediterranean ports is the development of the local economies (Musso & Ferrari, 2001). Most of the countries bordering the basin have experienced significant economic development over the last decade. This has donated to an expansion of trade. Gouliemos and Pardali (2002) and Notteboom (2010) asserted that, previously, many shipping services passed through the Mediterranean without making a call, even if some of the container traffic were eventually destined for markets adjacent to or within the basin. Unfortunately, there has been little research of this aspect, clearly because of a lack of data. Documentation of some ports identifies the countries of origin or destination of containers but does not explain the routing and services employed (Gouvernal et al, 2005).

Since the mid-1990s the major container shipping lines have been developed their fleets, with the purchase of ever larger new ships. The addition of significant additional capacity made up of post-Panamax vessels and the Ultra large Container Ships (ULCS) that are being used on the most traffic concentrated routes (Asia–west coast North America, and Asia–north-west Europe), has made it essential to redeploy the smaller vessels once used on these east–west trade routes. These vessels are now being deployed in the Mediterranean, and an up-scaling is taking place in almost all trades. In the intra-Mediterranean routes, ships of less than 100 TEUs were typical in 1994 and the median size was 464 TEUs. In 2004 the median size grew to 693 TEUs. The largest proportionate increase has been in the direct Asia services, where the median size of ships has grown from 2334 TEUs in 1994 to 4833 TEUs in 2004. The general increase in median size is matched by the growth in the capacity of the largest ships used in each trade, with the exception of Mediterranean– North America, while post-Panamax and Ultra Large Container ships are deployed in many trade routes passing the Mediterranean (Gouvernal et al, 2005).

Moreover, the increase in ships capacity has given rise to a totally enlarged trade for the gateway ports. In 1994 their connections with Asia were limited, with a few direct services, and an inadequate number of calls by ships on east–west routes. The gateway ports have seen their capacities increase by a factor of four, although in the case of

Valencia some of this growth is due to its selection as a hub port by Mediterranean Shipping Company (MSC). Increasing container ships capacities has given opportunity to an increase in the number of direct Asia–Mediterranean services at the gateway ports with the exception of La Spezia. For instance, the number of direct calls to Asia from Barcelona has doubled. At all the gateway ports the direct Asia service capacities now exceed those of the pendulum services. The reverse is true for the transhipment ports that are massively involved in the pendulum services. This demonstrates that the shipping lines are re-deploying ships to make direct calls at many gateway ports as such service loops have become economically feasible (Gouvernal et al, 2005).

The increased service frequencies and larger ships' capacity imply that the ports offer shippers more choices. The direct services between the gateway ports and Asia, as well as services with North America, have opened up new markets. More direct access to these markets improves the ports' attractiveness. The gateway ports may also gain from the development of the transhipment hubs, since trade that once passed through the Mediterranean is being offloaded at a Mediterranean hub and is being distributed to the main gateway ports and others by feeder services. As such, today, the Mediterranean gateway ports are more integrated with global markets than before. At the same time the use of larger ships generates economies of scale that create a reduction in unit costs (Cullinane & Khanna, 2000). Together with the efficiencies gained in most ports because of privatisation it may be assumed that these ports have become more attractive (Gouvernal et al, 2005).

As such, the Mediterranean container ports under study have witnessed a remarkable increase in their annual throughput. The total Mediterranean container port throughput amounted to 13.8 million TEUs in 1998, 27.4 million TEUs in 2005 and 42.4 million TEUs in 2012 (Appendix 5.1). The analysis on the dynamics of container throughput is based on container throughput figures in TEU for the period 1998-2012. With a total maritime container throughput of about 95.2 million TEUs in 2012, the Mediterranean container port market ranks among the busiest container port markets in the world. Development has been specifically strong in the period before the start of the world economic crisis with an average annual growth rate of 10.0% in the period 2000-2007, compared to 7.5% in 1999. The financial crisis that had its full influence in late 2008 has affected the growth curve. The market share of the Mediterranean ports grew considerably between the late 1990s and the late 2000s at the expense of the ports in the Le Havre-Hamburg range. The substantial increase of the market share of the Mediterranean is essentially due to the insertion of transhipment hubs in the region since the mid-1990s (Notteboom, 2010, 2013).

Figure 5.3 shows the selected Mediterranean container ports' throughput between 1998 and 2012. Port Said is the market leader in 2012 with a throughput of 4.8 million TEUs followed by Valencia that achieved a throughput of 4.5 million TEUs. Meanwhile, GioiaTauro is one of the main hub ports in the region with a throughput of almost 2.1 million TEUs in 1998 and 2.7 million TEUs in 2012 which has declined from a peak of 3.5 million TEUs in 2008. In the period between 2009 and 2012, the port has experienced significant decline in traffic due to the growing competitiveness of other Mediterranean ports such as Algeciras, Tangier, Port Said, Valencia and Marsaxlokk (Musso et al, 2013).

However, the main reason for such a drop is the emergence of new competition from Port Said, particularly, the Suez Canal Container Terminal (SCCT), which is operated by APM Maersk who as a key customer to GioiaTauro, has switched a large amount of its transhipment services to the Eastern Mediterranean and Black Sea with eight main lines calling weekly at Port Said, SCCT, (Woodbridge, 2006b). Another hub with a massive feeder connection to the Mediterranean is Malta free port (Marsaxlokk). The terminal achieved an annual throughput of 1.1 million TEUs in 1998. In 2012 the terminal handled around 2.5 million TEUs whilst the privatisation of the terminal has enhanced its productivity by almost 65%.

Although the number of container handled in the main Italian ports grew between 2000 and 2007, in the following three years there was a significant decline in container movements by sea. This trend was due in part to the economic crisis affecting European and international trade during the 2008–2009 period. By contrast, the period of 2009–2010 marked an average 11.9% increase in overall traffic excluding Taranto, which saw significant declines (Musso et al, 2013). The port attained a throughput of 0.3 million TEUs in 2000 reached to 0.9 million TEUs in 2006. The ports' throughput declined to 0.56 million TEUs in 2012. However, these declines were compensated by the significant increases of the total tonnage handled over that same period at the Italian ports, mainly due to a decline in traffic at the port of GioiaTauro.

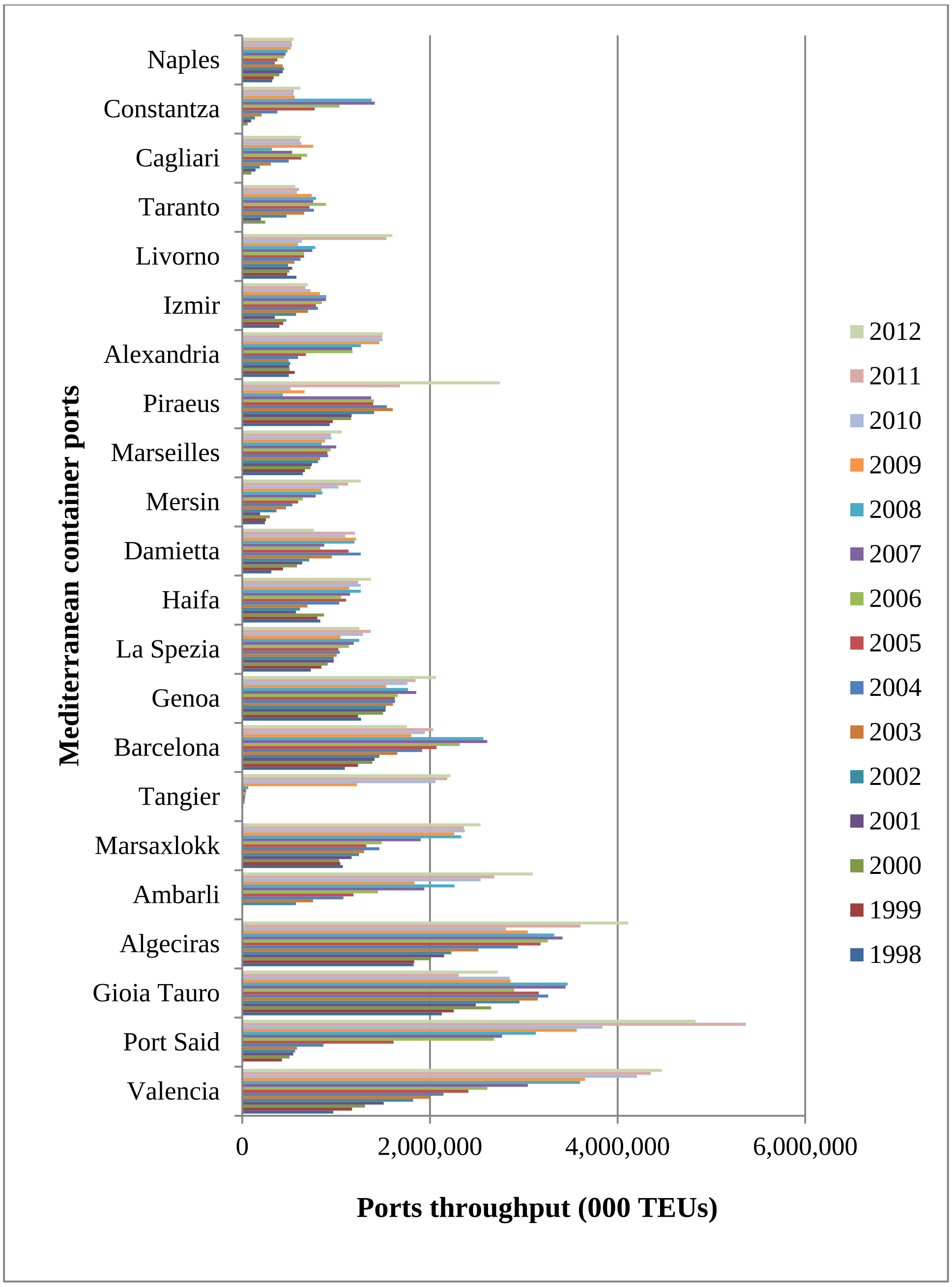

Figure 5. 3- Mediterranean container ports throughput (1998 – 2012)

The port of Genoa is also one of the most vital multi-traffic and transit link for international sea traffic. Its catchment area also involves some essential markets of Central Europe (Basel, Munich) and countries bordering the Mediterranean Sea, up to the Black Sea and the Far East (Musso et al, 2013). The port achieves a throughput of

1.3 million TEUs in 1998 peaked to 2.1 million TEUs in 2012. Meanwhile, the port of Naples is also a central transit node for Mediterranean Sea traffic (with North Africa). Recently, and with particular reference to the Motorways of the Sea, the port has experienced growth in cabotage traffic, an area where the shipping lines for Sicily, mainly links with the ports of Palermo and Catania (Musso et al, 2013). However, the port recorded the lowest throughput within the ports of study. Naples had a throughput of 0.32 million TEUs in 1998 and 0.55 million TEUs in 2012. The main reason for such a low productivity is the inefficiency of port technical operations.

The port of Taranto, located in Southern Italy, is the second Italian transhipment port after GioiaTauro. The port attained a throughput of 0.25 million TEUs in 2000 peaked to 0.9 million TEUs in 2006. Besides its significant role in intra-Mediterranean and transoceanic traffics, the port manages feeder routes gravitating in the Aegean sea (Gemlik, Izmir, Limassol) up to the Black Sea and to the African Mediterranean ports (Tunis, Misurata, Alexandria). Shipping lines passing through the Suez Canal can save about seven sailing days by calling at Taranto instead of the ports of Rotterdam or Hamburg (Musso et al, 2013). However, the port throughput is declined to 0.56 million TEUs in 2012 due to the fierce competition from its rivals such as GioiaTauro, Piraeus and Izmir.

Among the rivals, Algeciras is also a strong competitor in the Mediterranean due to its strategic location at the tip of straits of Gibraltar. The port attained a throughput of 1.8 million TEUs in 1998, 3.4 million TEUs in 2007. The port throughput decreased to 2.8 million TEUs in 2010 owing to fierce competition from the Ports of Barcelona and Tangier. Algeciras has returned to its competitive position when it achieved a throughput of 3.6 million TEUs and 4.1 million TEUs in 2011 and 2012 respectively. Meanwhile, Barcelona has the potential to be a major hub in the Mediterranean due to its significant infra/superstructure and its strategic location close to distribution centres in Spain and southern Europe. The port achieved a throughput of 1.1 and 2.6 million TEUs in 1998 and 2007 respectively. The port throughput declined to 2.7 million TEUs in 2012 due to the fierce competition from ports of Valencia and Algeciras.

In the West-Med, port of Marseilles in France has missed opportunities for growth with regards to container traffic. Although Marseilles has seen a certain growth with respect to container volumes handled, they are clearly below those of competitor and neighbouring ports. The port handled about 0.6 million TEUs in 1998 reaching1.1 million TEUs in 2012. The ports of Valencia and Algeciras have now four times more container throughput than Marseilles, as compared to less than 2 times more in 1998. Other ports in the Western Mediterranean which have now double the volumes of Marseilles are Genoa and Barcelona. These competitors have more deep sea and short sea connections, could in some cases be considered global hubs and are more efficient. Although Marseilles has for a long time been shielded from competition due to its quasi-monopolistic position, it is now subject to fierce competition from Le Havre and Antwerp for what it once considered its natural hinterland as well as Barcelona and Valencia from the fore landside (Merk & Comtois, 2012).

In the East-Med, Piraeus has witnessed pronounced variations in it container throughput during the last decade. In 1998 the port handled about 0.93 million TEUs and 1.6 million TEUs in 2006. However, such amount has dropped to 1.4 million TEUs in 2007. In 2008 another decline to 0.43 million TEUs was incurred due to the problems of continuous strikes and berth congestion as well as the international economic crisis that took place in 2008 affecting the port industry worldwide. Nevertheless, the terminal returned to grow at the end of 2012 and attained an annual throughput of 2.8 million TEUs following improvements in terminal productivity and the noticeable reduction in ships' waiting time. In Egypt, Port of Damietta recorded a throughput of 0.3 million TEUs in 1998 and reached to its peak of productivity in 2004 with an annual throughput of 1.3 million TEUs. However, the port encountered a noticeable decline in its throughput, 0.76 million TEUs, in 2012 due to the strong competition of Alexandria and Port Said (SCCT). Alexandria port has achieved a significant increase in its throughput within the study period. The port handled about 0.5 million TEUs in 1998 peaked to 1.5 million TEUs in 2012. The main reasons of such growth are related to the strong intra-port competition between container terminal operators and the consistent investment in port's infra/superstructure.

In Turkey, due to the country's growing economy, strategic location and an increased number of larger container ships calling Turkish ports, the ports have witnessed considerable growth during the last decade. Among these growths are large foreign investments in port development, the privatisation of state-owned ports and more joint ventures between private Turkish ports and foreign port operators from Europe and Asia. As such, port of Ambarli, the largest container port in Turkey, had a throughput of 0.6 million TEUs in 2002 increased to 3.1 million TEUs in 2012.

Moreover, Mersin is the second largest container port in Turkey. The port achieved a consistent increase of container throughput. In 1998, the port throughput was about 0.24 million TEUs raised to 1.3 million TEUs in 2012. Izmir is also considered as a strong competitor for ports of Ambarli, Mersin and Haifa. The port had handled about 0.4 million TERUs in 1998 reached to 0.9 million TEUs in 2008. Nevertheless, the port's throughput has declined to 0.7 million TEUs due to the strong competition of its rivals in East Mediterranean.

The volume of containers handled at the port of Constantza has increased by more than 12 fold from 1998 to 2006. The port handled about 0.05 million TEUs in 1998 raised to its peak with a throughput of 1.4 million TEUs in 2007. Constantza container throughput declined to 0.62 million TEUs in 2012. The reasons of such drop are: the competition from Adria ports for traffic from and to Central Europe. Ports such as Triest (Italy), Koper (Slovenia) and Rijeka (Croatia) have close ties to Austria and Hungary for geographic and historic reasons, the growth in container transport at these ports reduced container volumes at Constantza (Notteboom, 2012). In addition, ocean freight rates to and from Constantza were higher at the beginning of 2006 for market reasons versus Hamburg and Rotterdam, regardless of the shorter distance by sea, this would prevent the development in Constantza. Inefficiencies in the area of customs: a slower and deficient implementation of EU standards could have a negative impact.

The above analysis for the growth of the Mediterranean container port market reveals that there is a potential for some ports to enhance their competitive position and thus changes the market structure. Next section analyses the impact of such growth on the degree of market concentration and the features of the inter-port competition in the defined market.

5.3.2 Mediterranean container port market concentration
5.3.2.1 K-Firm concentration ratio (K-CR) analysis

The strategic location of the Mediterranean Sea in the route between the Far East and Europe has not been capitalized upon in the past by ports located in this area. North European port, such as Rotterdam, Antwerp and Hamburg, are at the extremes of a complex transport and communications infrastructure network which crosses different regions and countries along the great human and industrial concentration axis of the Ruhr and Rhine, which gives these ports a strategic advantage. Mediterranean ports have suffered from labour conflicts, low productivity, the poor condition of railways and customs and control services, and consequently high costs and poor reliability. Excessive state involvement in these ports has also limited their commercial viability and management capability (Notteboom, 2010). Shipping lines have therefore preferred not to use most of the Mediterranean ports and seek better services in the northern European ports.

In the past two decades, Mediterranean ports have secured independence from state organizations, which has allowed for more efficient management and a more aggressive commercial policy. For instance, SCCT in Port Said in cooperation with Maersk line has invested in a dedicated terminal that is managed and operated by Maersk in BOT bases. Moreover, terminal operators have invested in ports' infra/superstructure in order to keep pace with the shipping lines requirements and enhance their competitive positions. That in turn has reformed the market structure and intensified competition between container ports in the Mediterranean.

In this context, in order to test the first hypothesis, as mentioned in chapter one, a number of concentration ratios and indexes, explained in chapter four, are used to measure the Mediterranean container port market concentration within the period of study. Four indexes are used to test the first hypothesis **(H1)** that presumes that "*the Mediterranean container port market moves towards deconcentration and pure and perfect competition*". These indexes are the K-CR, HHI, GC and EI. The numbers derived from that ratios and indices assist in measuring the competitive or monopolistic environment in a given port market

One of the most well-known concentration ratios is the four-firm and ten-firm concentration ratios. This ratios measure the percentage of market share of the top four or ten largest firms in the market divided by the total market output. The larger the ratio, the less competition there is in the market; the smaller the ratio, the more competitive the market is. More specifically, a ratio of less than 40% is considered competitive; a ratio of more than 40% is considered an oligopoly (Baye, 2010). The four-firm concentration ratio is commonly used to indicate the degree to which the market control is held by the four largest firms in the industry.

Using the K-Firm concentration ratio (K-CR), Table 5.1 explains the degree of the Mediterranean container port market concentration between 1998 and 2012. The market share of the top four ports decreased from 45.61% in 1998 to 41.40 in 2003, 39.47 in 2008 and 39.21% in 2012 which reveals a tendency towards deconcentration and increased competition between ports in the market. The market share of the top ten ports also decreased from 83.1% in 1998 to 73.9% in 2003, 73.3% in 2008 and 72.0% in 2012. However, there have been significant shifts in the ranking of ports within the period of study. Port of GioiaTauro, Algeciras, Genoa and Barcelona have ranked as the top four ports in 1998. Ports of Marsaxlokk, Valencia, Piraeus, Haifa, La Spezia and Marseilles have secured the next six positions in the study ports hierarchy, from the fifth to the tenth position respectively.

In 2003, ports of GioiaTauro, Algeciras and Barcelona have secured their competitive positions in the first, second and fourth places in the market, while Valencia has succeeded to enhance its competitive position from being in the sixth place in 1998 to be in the third place in 2003. Port of Genoa lost its competitive position from being in third place in 1998 to be in the fifth place in 2003 followed by the ports of Piraeus, Marsaxlokk, La Spezia, Damietta and Marseilles that took the ranks from the sixth to the tenth position respectively.

In 2008, Valencia has taken the lead and enhanced its competitive position from the third place in 2003 to the first place in 2008 followed by ports of GioiaTauro and Algeciras which lost one rank in the hierarchy to be in the second and third place respectively.

Table 5. 1- Measurement of Mediterranean container port market structure using K-firm concentration ratio (K-CR)

Port	Throughput (1998)	Market share	Port	Throughput (2003)	Market share	Port	Throughput (2008)	Market share	Port	Throughput (2012)	Market share
GioiaTauro	2,125,640	15.4%	**GioiaTauro**	3,148,662	14.0%	**Valencia**	3,602,112	10.5%	**Port Said**	4,831,165	11.4%
Algeciras	1,825,614	13.2%	**Algeciras**	2,515,908	11.2%	**GioiaTauro**	3,467,772	10.1%	**Valencia**	4,469,754	10.5%
Genoa	1,265,593	9.1%	**Valencia**	1,992,903	8.9%	**Algeciras**	3,324,310	9.7%	**Algeciras**	4,114,231	9.7%
Barcelona	1,092,920	7.9%	**Barcelona**	1,652,366	7.3%	**Port Said**	3,128,776	9.1%	**Ambarli**	3,097,464	7.3%
CR4		**45.61%**	**CR4**		**41.40%**	**CR4**		**39.47%**	**CR4**		**38.92%**
Marsaxlokk	1,071,669	7.7%	**Genoa**	1,605,946	7.1%	**Barcelona**	2,569,550	7.5%	**Piraeus**	2,745,012	6.5%
Valencia	970,758	7.0%	**Piraeus**	1,605,135	7.1%	**Marsaxlokk**	2,334,182	6.8%	**GioiaTauro**	2,721,104	6.4%
Piraeus	933,096	6.7%	**Marsaxlokk**	1,300,000	5.8%	**Ambarli**	2,262,086	6.6%	**Marsaxlokk**	2,540,000	6.0%
Haifa	832,377	6.0%	**La Spezia**	1,006,641	4.5%	**Genoa**	1,766,605	5.2%	**Tangier**	2,220,000	5.2%
La Spezia	731,882	5.3%	**Damietta**	955,045	4.2%	**Constantza**	1,380,935	4.0%	**Genoa**	2,064,806	4.9%
Marseilles	644,000	4.7%	**Marseilles**	831,000	3.7%	**Alexandria**	1,264,455	3.7%	**Barcelona**	1,756,429	4.1%
CR10		**83.08%**	**CR10**		**73.88%**	**CR10**		**73.26%**	**CR10**		**72.04%**
Livorno	576,680	4.2%	**Ambarli**	754,873	3.4%	**Haifa**	1,262,000	3.7%	**Livorno**	1,600,000	3.8%
Alexandria	495,777	3.6%	**Izmir**	700,795	3.1%	**La Spezia**	1,246,139	3.6%	**Alexandria**	1,500,000	3.5%
Izmir	396,619	2.9%	**Haifa**	694,000	3.1%	**Damietta**	1,195,630	3.5%	**Haifa**	1,372,209	3.2%
Naples	319,577	2.3%	**Taranto**	658,426	2.9%	**Izmir**	895,000	2.6%	**Mersin**	1,263,495	3.0%
Damietta	309,671	2.2%	**Port Said**	583,930	2.6%	**Mersin**	854,500	2.5%	**La Spezia**	1,247,218	2.9%
Mersin	241,865	1.7%	**Livorno**	554,405	2.5%	**Marseilles**	847,651	2.5%	**Marseilles**	1,061,000	2.5%
Port Said	0	0.0%	**Alexandria**	495,186	2.2%	**Taranto**	786,655	2.3%	**Damietta**	760,000	1.8%
Ambarli	0	0.0%	**Mersin**	467,111	2.1%	**Livorno**	778,864	2.3%	**Izmir**	700,000	1.7%
Tangier	0	0.0%	**Naples**	430,000	1.9%	**Naples**	481,521	1.4%	**Cagliari**	627,609	1.5%
Taranto	0	0.0%	**Cagliari**	303,537	1.3%	**Piraeus**	433,582	1.3%	**Constantza**	620,000	1.5%
Cagliari	0	0.0%	**Constantza**	206,449	0.9%	**Cagliari**	317,325	0.9%	**Taranto**	563,461	1.3%
Constantza	0	0.0%	**Tangier**	24,113	0.1%	**Tangier**	64,178	0.2%	**Naples**	546,818	1.3%
Total	13,833,738	100%	**Total**	22,486,431	100%	**Total**	34,263,828	100%	**Total**	42,421,775	100%

Port Said has significantly enhanced its competitive position from being ranked as the fifteenth in 2003 to be the fourth in 2008 due to the inauguration of the SCCT. Meanwhile, ports of Alexandria, Constantza and Alexandria have achieved a significant growth and enhanced their competitive position in the study ports hierarchy to be in the seventh, ninth and tenth places instead of being in the eleventh, twenty-first and seventeenth places respectively in 2003.

The situation has also changed in 2012; while Port Said continued its success to become in the first place, Valencia lost one position to be in the second place and Algeciras secured its competitive position in the third place. However, port of Ambarli achieved a remarkable enhancement in its competitive position from being in the seventh place in 2008 to be in the fourth place in 2012. While port of GioiaTauro, Barcelona and Constantza lost their competitive positions from being in the second, fifth and ninth places in 2003 to be in the sixth, tenth and twentieth places in 2012, ports of Piraeus and Tangier succeeded to enhance their competitive position from being in the twentieth and twenty-second places in 2008 to be in the fifth and eighth positions in 2012.

The above analysis reveals the intense competition among study ports in the Mediterranean container market. In the next section, the Hirshman-Herfindahl Index (HHI) is used to provide further elaboration of the changes in the ports' market shares in relation to the total market throughput.

5.3.2.2 Hirschman-Herfindahl index (HHI) analysis

Hirshman-Herfindahl Index (HHI) is a measure of the size of firms in relation to the industry as a whole. It is also an indicator of the degree of competition between firms in the market. The HHI is used to provide further elaboration of the changes in the ports' market shares in relation to the total market throughput. The assumption behind the HHI is that a low level of concentration is expected to be accompanied by a high level of competition and vice versa. This assumption is particularly true for inter-port competition in the container port market. Figure 5.4 and Table 5.2 show that the overall level of competition in the Mediterranean container port market as measured by HHI reveals increasing trend overtime, decreasing value of the HHI over time indicates that the level of competition is intensifying. Figure 5.4 and Table 5.2 shows that in 1998 the HHI was about (848.83) which indicated that the market was low-concentrated. By 2012 the HHI had decreased to (649.81) indicating an increase in competition between the market players which reveals that the inter-port competition between ports under study is intensified.

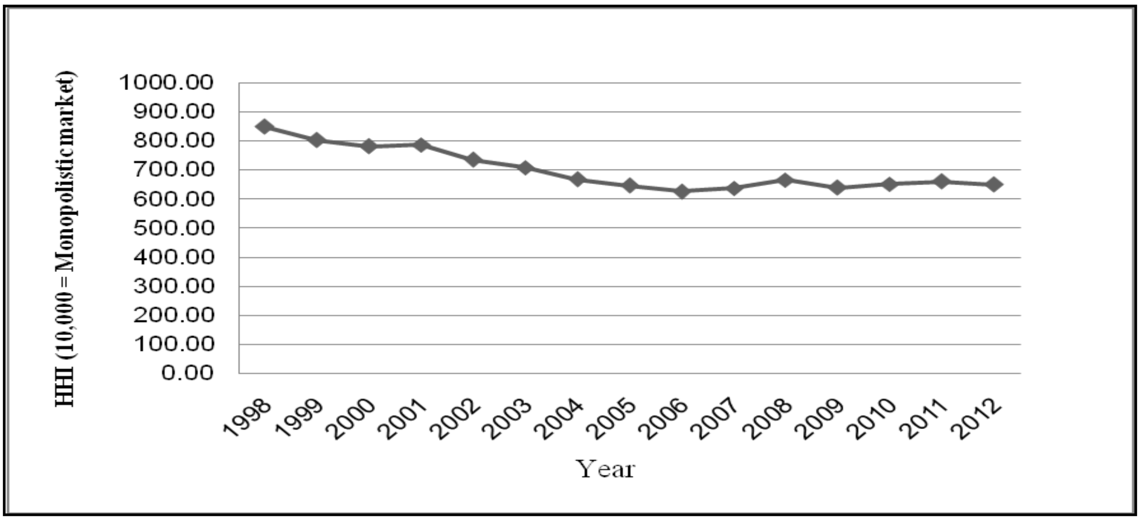

Figure 5. 4- Mediterranean container port market concentration (1998 – 2012).

This result accords with the widely accepted view of the general trend in the container port market over recent years, as reviewed in the important literature of inter-port competition that have included among others, Notteboom and Winkelmans (2001b), Heaver et al. (2001); Cullinane et al. (2004) and Notteboom (2010, 2012).

Table 5. 2- Hirshman-Herfindahl Index for Mediterranean container ports (1998 &2012)

Port	Throughput (1998)	Market share (1998)	HHI (1998)	Throughput (2012)	Market share (2012)	HHI (2012)	Av. Growth rate
	(1000) TEU	%		(1000) TEU	%		
Valencia	970,758	7.0%	49.24	4,469,754	10.5%	111.02	11.5%
Port Said	0	0.0%	0.00	4,831,165	11.4%	129.70	20.6%
GioiaTauro	2,125,640	15.4%	236.10	2,721,104	6.4%	41.14	1.8%
Algeciras	1,825,614	13.2%	174.16	4,114,231	9.7%	94.06	6.0%
Ambarli	0.00	0.0%	0.00	3,097,464	7.3%	53.31	18.4%
Marsaxlokk	1,071,669	7.7%	60.01	2,540,000	6.0%	35.85	6.4%
Tangier	0	0.0%	0.00	2,220,000	5.2%	27.39	65.3%
Barcelona	1,092,920	7.9%	62.42	1,756,429	4.1%	17.14	3.4%
Genoa	1,265,593	9.1%	83.70	2,064,806	4.9%	23.69	3.6%
La Spezia	731,882	5.3%	27.99	1,247,218	2.9%	8.64	3.9%
Haifa	832,377	6.0%	36.20	1,372,209	3.2%	10.46	3.6%
Damietta	309,671	2.2%	5.01	760,000	1.8%	3.21	6.6%
Mercin	241,865	1.7%	3.06	1,263,495	3.0%	8.87	12.5%
Marseilles	644,000	4.7%	21.67	1,061,000	2.5%	6.26	3.6%
Piraeus	933,096	6.7%	45.50	2,745,012	6.5%	41.87	8.0%
Alexandria	495,777	3.6%	12.84	1,500,000	3.5%	12.50	8.2%
Izmir	396,619	2.9%	8.22	700,000	1.7%	2.72	4.1%
Livorno	576,680	4.2%	17.38	1,600,000	3.8%	14.23	7.6%
Taranto	0	0.0%	0.00	563,461	1.3%	1.76	0.6%
Cagliari	0	0.0%	0.00	627,609	1.5%	2.19	17.0%
Constantza	0	0.0%	0.00	620,000	1.5%	2.14	22.1%
Naples	319,577	2.3%	5.34	546,818	1.3%	1.66	3.9%
Total	13,833,738	100.0%	**848.83**	42,121,775	100.0%	**649.81**	8.3%

5.3.2.3 Gini Coefficient and Entropy index analysis

Many studies see Notteboom (1997), McCalla (1999) and Lago et al (2001), have applied the Gini coefficient (GC) as an index to evaluate spatial concentration or inequality in port markets. As explained in chapter four, the GC has its advantages, but it considered as a descriptive technique, not an illustrative one. Thus the GC demonstrates only little information on the dynamics lying behind the studied deconcentration or concentration trends. In most of the cases such an illustration can only be comprehensively explained by a thorough analysis of qualitative factors and conditions in the port market under study (Notteboom, 2006c).

The previous studies on port competition and port selection provide more understandings into the elements of cargo shifts between ports (Huybrechts et al, 2002). The literature on liner shipping networks and ship operating considerations, including increases in ship capacity, provides understanding of additional elements affecting port market concentration levels (Cullinane et al., 1999; Notteboom, 2002; 2012; 2013). However, the question persists whether the GC itself can be applied as a tool for a analysing the port market dynamics. In this section, the overall GC for the Mediterranean port market is being illustrated in more details.

A new trend of steadily decreasing Gini ratios began in the early 1990s, following a first deconcentration period in the late 1970s which was limited in relation to a concentration tendency in the early 1980s (Notteboom, 2006c). Due to the unavailability of data, this research started the Mediterranean observation period only in 1998. In contrast to the dependency of the Hirschman-Herfindahl Index (HHI) on the number of ports, the GC enables comparison of the concentration level for a different number of ports on an equal basis. Nevertheless, Scherer (1980) explained that the GC can create misleading results when applied to a market with a small number of evenly matched firms (Fageda, 2000).

Table 5.3 shows the Gini coefficient for the Mediterranean container port market. The value of GC (0.32389) indicates a deconcentration trend in 1998 followed by a period of increasing equality in 2012 as the coefficient value decreased to (0.31746). Between 2004 and 2007, new ports were built such as SCCT in Port Said and Tangier whereas meanwhile medium-sized ports strengthen their position versus the larger ones. The hub battle in the Mediterranean basin altered activities from distant ports, in terms of deviation distance to the main trade route; to close by ports and changed the current hierarchy in the Mediterranean ports.

While new port plans are still being established along the main trade route at Cagliari, for example, many other hubs along the same lane such as Tangier and SCCT are in the process of developing their facilities to catch more traffic. Figures 5.5 and 5.6 show the Mediterranean container port market trend towards deconcentration as the curves of inequality are moving towards the diagonal line which represents the total equality of the population. The Gini ratios in figures 5.5 and 5.6 point to a continued but rather weak deconcentration trend between 1998 and 2012. The Lorenz curve demonstrates the cumulative percentage of output accounted for by different percentages of the number of ports, and thus explains the inequality rather than the concentration of the ports' market shares. Figure 5.5 explains the size inequality of the main container ports in the Mediterranean market in 1998, and shows that almost 50% of the ports account for roughly 27% of the total throughput. However, in 2012, as shown in figure 5.6, the Lorenz curve shows that about 60% of the ports account for almost 30% of the total throughput.

Inequality in the Mediterranean container port market slightly increased in the last decade. This has recently become an interest to some researchers who are interested in political and economic issues. Traffic concentration at the level of a certain container port market is evidently different than cargo traffic concentration at the level of individual shipping lines of the liner networks (Cullinane & Khanna, 1999; Notteboom, 2006c). From a shipping line's point of view, the scale economies in all ports would favour a few number of load centres in a specific market.

The advantages of cargo concentration in a small number of ports of call would be more effective at the shipping line level than at the port level, basically because not all shipping lines select the same ports in their liner service operation patterns (Notteboom, 2002, 2006).

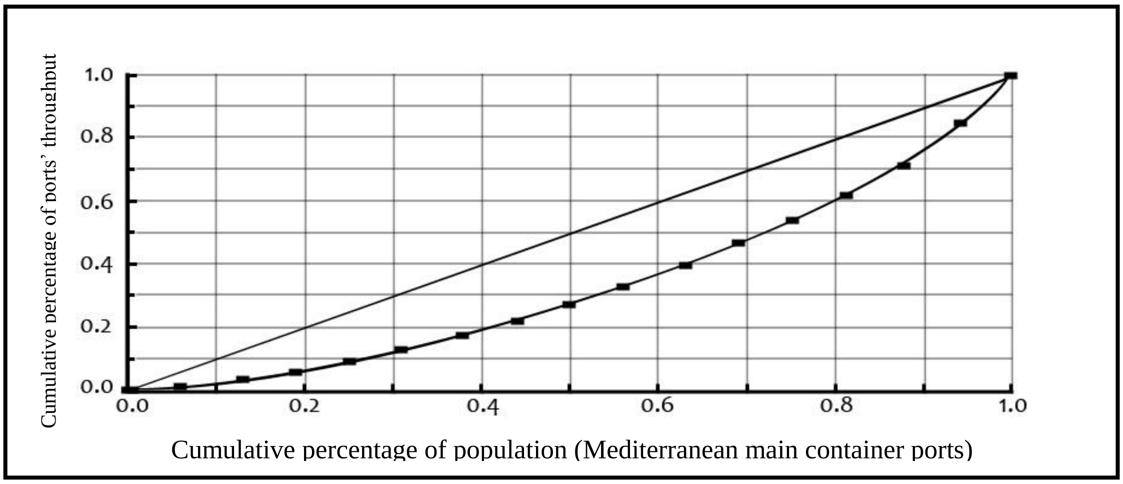

Figure 5. 5- Lorenz Concentration curve for Mediterranean container port market (1998)

Source: Wessa, P. (2012) 'Free Statistics Software, Office for Research Development and Education'. version 1.1.23-r7, URL http://www.wessa.net/

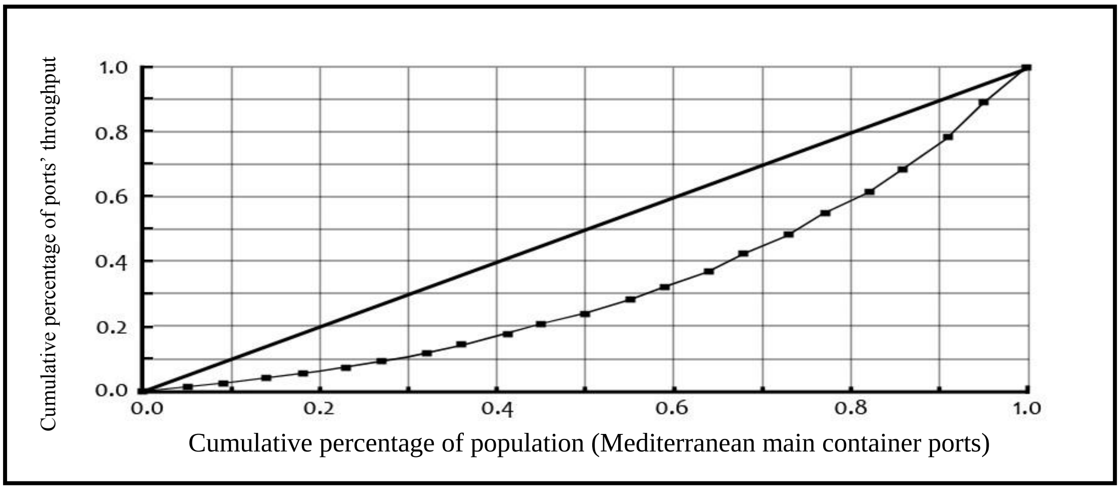

Figure 5. 6- Lorenz Concentration curve for Mediterranean container port market (2012)

Source: Wessa, P. (2012) 'Free Statistics Software, Office for Research Development and Education'. version 1.1.23-r7, URL http://www.wessa.net/

Another simply constructed concentration measure is the Entropy Index (EI). As mentioned in chapter four, it was frequently applied to assess the industrial firms' strategy. The construction principle is the same as for the HHI; the weights attached to market shares are only different: HHI assigns higher weights to higher shares whereas the EI assigns to higher shares lower weights. Thus, both indexes are subject to weight bias. Nevertheless, they are not exempt from some weaknesses. Rhoades (1995) highlighted that two of them are very sensitive about the number of firms, which increase rapidly with the increment in number of firms.

The cumulative curve plots the ports' cumulative market share against their ranks in the market. The height of the curve above any point on the horizontal axis illustrates the percentage of the market's total size accounted for by the largest ports in the market. The curve is continuously rising from left to right, but rising at a continuously diminishing rate. It reaches its maximum height of 100% at appoint on the horizontal axis corresponding to the total number of ports in the market. Figure 5.7 shows the concentration curve for the study ports in the Mediterranean container market. It explains the fact that the largest ten container ports, in terms of market share hold about 70% of the total market throughput in 1998.

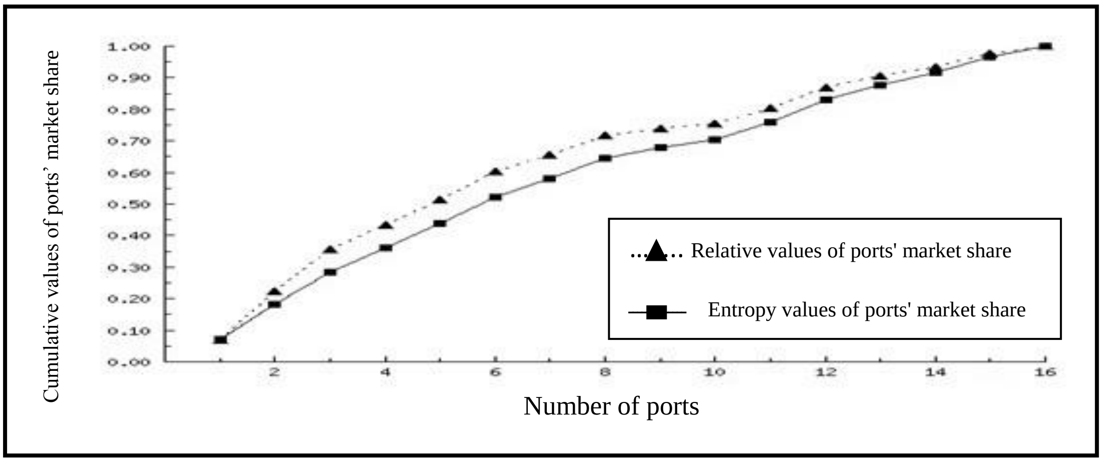

Figure 5. 7- Cumulative Entropy index for the Mediterranean container ports (1998).

Source: Wessa, P. (2012)'Free Statistics Software, Office for Research Development and Education'. version 1.1.23-r7, URL http://www.wessa.net/

In 2012, as shown in figure 5.8, the cumulative Entropy curve for the study ports in the Mediterranean container market shows that the largest ten container ports, in terms of market share hold about 60% of the total market throughput. That in turn reveals the market tendency towards deconcentration as the market share of the top ten ports decreased and distributed among the whole ports in the defined market.

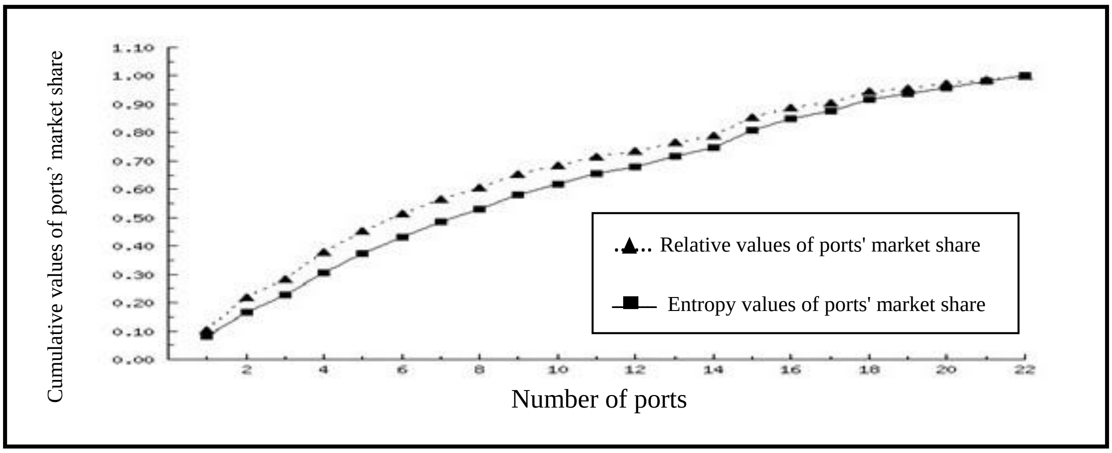

Figure 5. 8- Cumulative Entropy index for the Mediterranean container ports (2012).

Source: Wessa, P. (2012) 'Free Statistics Software, Office for Research Development and Education'. version 1.1.23-r7, URL http://www.wessa.net/

The cumulative concentration curve and Lorenz curve differ in two aspects. First, the cumulative concentration curve calculates the cumulative number of ports along the x-axis, whereas the Lorenz curve explains the cumulative percentages of ports. Second, the cumulative concentration curve ranks the ports starting with the largest; on the contrary, the Lorenz curve ranks the ports starting with the smallest port in the market. Both curves will be influenced by a change in ports market shares.

Nevertheless, a concentration measure must not be affected by the number of entities existing in the market, only the share they own should determine the market concentration. This could easily be corrected by the normalization of the HHI and EI, as they take values between zero and one regardless of the number of firms on the market. However, the weight bias that characterises these concentration measures will always be present.

The normalised Entropy index (EI) confirms the same market trend towards deconcentration, as shown in Figure 5.9, 5.10 and Table 5.3 respectively. In 1998 the EI was (2.604007) and it increased to (2.888778). In this context, it should be highlighted that the Entropy index is a negative indicator of concentration, the higher its value, the lower the level of concentration.

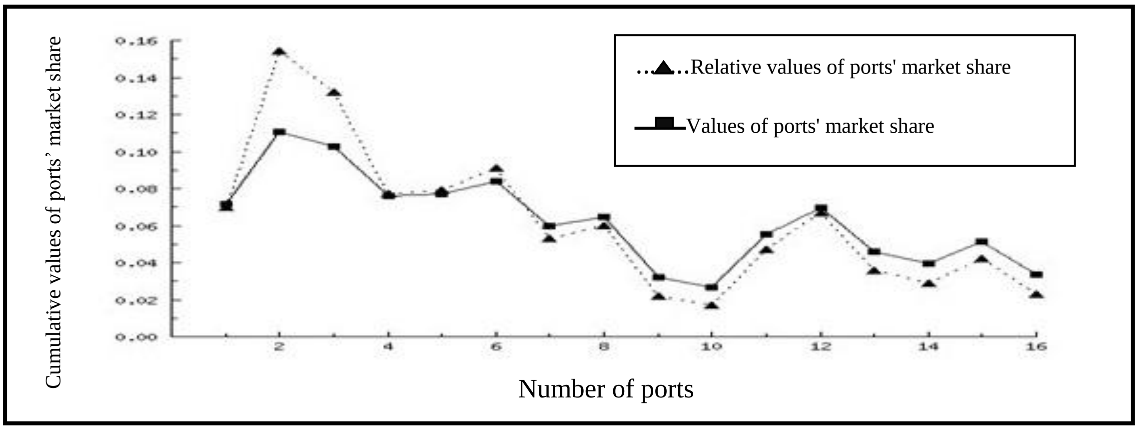

Figure 5. 9- Relative Entropy index for the Mediterranean container port market (1998).

Source: Wessa, P. (2012) 'Free Statistics Software, Office for Research Development and Education'. version 1.1.23-r7, URL http://www.wessa.net/

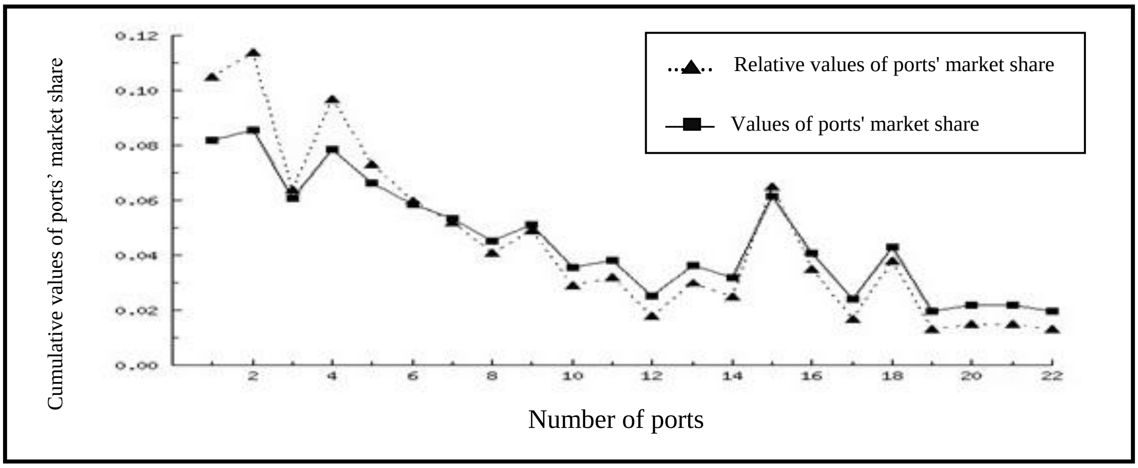

Figure 5. 10- Relative Entropy index for the Mediterranean container port market (2012).

Source: Wessa, P. (2012) 'Free Statistics Software, Office for Research Development and Education'. version 1.1.23-r7, URL http://www.wessa.net/

The above analysis reveals that the Mediterranean container market moves towards deconcentration in the period between 1998 and 2012. Table 5.3 summarises the value of different indexes that are used to measure the market concentration and accordingly the level of inter port competition in the Mediterranean container port market. The K-CR decreased from 45.61 in 1998 to 39.21 in 2012. The HHI decreased from 848.83 to 649.81 in the same period. While the Gini coefficient decreased from 0.323 to 0.317, the EI increased from 2.604 to 2.888. In this context, it should also be noticed that the number of firms (container ports) have also increased within this period from 16 ports in 1998 to 22 ports in 2012. The increase in the number of ports is related to the inauguration of some container port within this period such as Taranto, Cagliari and Constantza which are operated in 2000, SCCT in Port Said that is operated in 2005, Ambarli which is operated in 2002 and Tangier in 2003.

However, as explained by Lapteacru (2012), a concentration measure must not be influenced by the number of entities existing in the market, only the share they own should determine the market concentration. This could easily be corrected by the normalisation of the HHI and EI, as they take values between zero and one regardless of the number of firms on the market. Table 5.3 also demonstrates that the value of the normalised HHI is almost 0.02 and the values of the normalised EI vary between 0.94 in 1998 and 0.93 in 2012. That reveals the deconcentration and competitive Features of

Table 5. 3- Summary of the Mediterranean container market concentration indexes

Index	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
K-CR (CR4)	45.61%	43.82%	43.87%	44.31%	42.53%	41.40%	40.01%	39.54%	37.98%	37.99%	39.47%	39.74%	38.43%	39.73%	39.21%
K-CR (CR10)	83.08%	80.52%	78.78%	79.52%	75.46%	73.88%	71.25%	69.76%	69.44%	71.24%	73.26%	70.37%	72.56%	70.54%	72.56%
HHI	848.83	801.85	780.81	786.99	734.60	708.32	668.30	646.41	625.84	636.98	666.18	639.64	651.05	661.25	649.81
Normalised HHI	0.024	0.023	0.030	0.030	0.027	0.027	0.022	0.020	0.018	0.019	0.022	0.019	0.021	0.022	0.020
Gini Coefficient	0.32	0.32	0.40	0.41	0.39	0.40	0.37	0.34	0.33	0.35	0.38	0.34	0.36	0.35	0.36
Entropy Index	2.60	2.67	2.73	2.72	2.80	2.83	2.87	2.89	2.90	2.89	2.86	2.91	2.89	2.89	2.89
Normalised Entropy Index	0.94	0.94	0.91	0.91	0.92	0.92	0.93	0.93	0.94	0.93	0.92	0.94	0.93	0.93	0.93
Number of ports	16	17	20	20	21	22	22	22	22	22	22	22	22	22	22

the Mediterranean container port market which in turn reveals the intensified competition between container ports in the Mediterranean basin and restructured the market in terms of the competitive position of the ports under study. As such the first hypothesis is confirmed as the market moves towards deconcentration and pure and perfect competition.

Next section analysis the Mediterranean container port market structure and the changes in the competitive position of the ports under study. The Boston Consulting Group (BCG) matrix is used to provide an overview about such changes in term of the change of ports' market shares and average growth rate.

5.3.2.4 Mediterranean container ports BCG matrix 1998-2012

Most ports consider their rates of growth and proportion of market shares as the main determinants for assessing competitive position (De Lombaerde and Verbeke, 1989).In this context, the BCG Matrix is used to analyse the dynamics of the Mediterranean container port market and test the second hypothesis mentioned in chapter one. The second hypothesis **(H2)** assumes that "*the competitive positions of the Mediterranean container ports under study are changed over the period of study*".

The BCG matrix identifies four market positions: first is the question mark which reveals that the future potential of the ports is uncertain, ports have high rates of growth but their market share is not significant. Second are the Stars that present ports with high future potential, high growth rates and market share. Third is cash cows which are ports in decline with a high market share but low increase rates. Fourth are dogs that present ports with a little or zero development perspective: growth rates and market share are reduced.

As illustrated in figure 5.11, different ports are placed in the matrix according to total throughput in 1998. The vertical axis of the matrix presents the annual average rate of growth while the average market share is presented by the horizontal axis. As such, an analogous decision matrix is made in which every port position is described in terms of annual average rate and average market share. Figure 5.11 shows that GioiaTauro, Valencia, and Barcelona are stars. Those are ports with an annual rate of growth higher than the average growth rate of the Mediterranean container port market and a significant market share. These ports may create cash but because of the fast growing market, stars need huge investments to retain their lead. Ports positioned in this cell were attractive as they are situated in a robust market. These ports are very competitive in the market. If successful, a star will become a cash cow when the market matures.

However, Damietta, Alexandria, La Spezia and Izmir are question marks, that is, ports with a significant annual growth rate but with low market share. These ports require a huge amount of investment to maintain or gain market share. Question mark ports try to enhance their quality of service to attract more customers. If these ports do not invest in their infra/superstructure as well as their quality of service, they may become dogs, while if huge investment is made, then they have potential of becoming stars. Five of the study ports are considered as cash cows with low average growth rate and high market share. These ports are; Algeciras, Marsaxlokk, Piraeus, Genoa and Haifa. Cash cow ports require little investment and generate cash that can be utilized for investment and service improvement. These ports have potential to become stars. However, if these ports lost their market share due to the fierce competition, they might fall into dogs.

Ports of Naples, Mercin, Marseilles and Livorno display the worst results and appear as dogs, since they have low annual growth rates and no significant market share. They neither create revenue nor need a huge investment. Because of low market share, these ports encounter cost disadvantages. Usually economising policies are implemented because these ports can increase market share only at the expense of rival ports. They had weak market share because of high operating costs, poor service quality and ineffective marketing. These ports would be turned to question marks, if they succeed in adopting strategies that increase their average growth rate. They could also be cash cows if they increased their market share by attracting more traffic and being more customers oriented in their services provision.

However, as shown in figure 5.12, in 2012, the competitive positions of the ports under study are dramatically changed. The main reasons of such change are: the Mediterranean container port market tendency towards deconcentration, the increased number of market players; container ports, new investment that took place in ports infra/superstructure, restructuring of ports management and ownership and the involvement of the private sector in port operation and management, the improvement of port efficiency and the success of ports to attract more vessels and shipping lines.

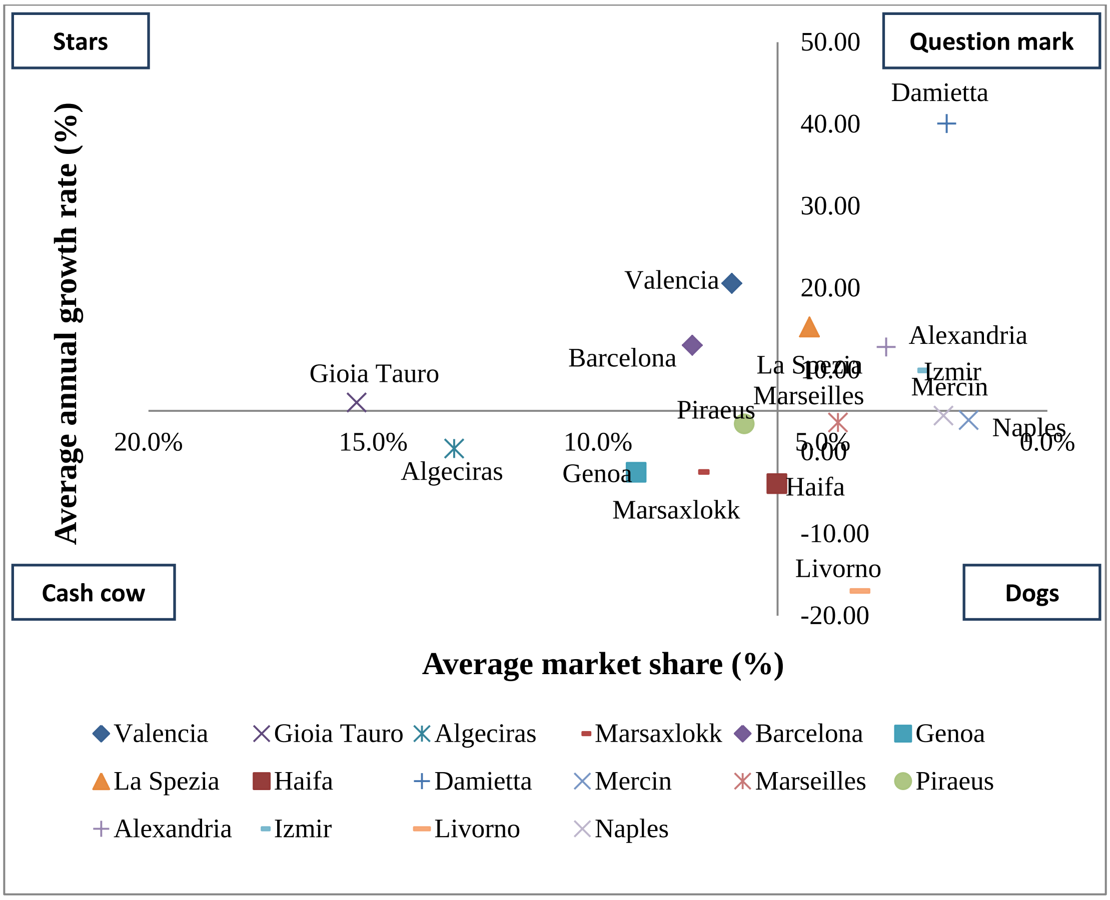

Figure 5. 11- Mediterranean container ports BCG matrix 1998

As shows in figure 5.12, Ports of Piraeus, GioiaTauro, Ambarli and Algeciras have become stars in the BCG matrix. These ports succeeded to enhance the average annual growth rate and increase their market shares. Some ports like Constantza, Mercin, Genoa, Haifa and Marseilles have succeeded to become question marks in the matrix. Although port of Genoa's market share has decreased in the period between 1998 and 2012, the ports improved its annual growth rate. As such the port's competitive position have enhanced from being cash cow to be a question mark in the BCG matrix.

Similarly, the average growth rate of the ports of Mercin and Marseilles has also increased in the same period and accordingly the competitive positions of the ports are enhanced from being dogs to be question marks. Ports of Valencia, Marsaxlokk, Tangier and Port Said became cash cows in 2012. The competitive position of Valencia has dropped from being stars in 1998 to cash cow in 2012 due to the reduction in its average growth rate. The unique location of Port Said and Tangier has its major effect in attracting shipping lines and accordingly enhancing the competitive position of these ports. Those ports have an opportunity to improve their competitiveness to be stars if, they succeeded to increase their annual growth rate through the increase of their annual throughput.

Meanwhile, ports of Damietta, Barcelona, La Spezia, Taranto, Cagliari, Naples and Alexandria and Livorno are dogs in the BCG matrix. The ports have small market shares and low annual average growth rate. The ports have an opportunity to be either Cash Cow, if they succeeded to increase their market share or question marks, if they increased their annual average growth rate. Figure 5.12 also illustrates that the star ports such as Piraeus, GioiaTauro and Algeciras are the existing hub ports in the Mediterranean container market.

However, there is a potential for some Cash Cow ports such as Tangier, Valencia and Port Said to be future hubs, if they succeeded to increase their average growth rate. Similarly, there is an opportunity for some ports in the question mark block such as Genoa, Haifa, Mercin and Constantza to be future hubs, if they increased their market share. Nevertheless the increase of one port's market share means a reduction in other competing port or ports' market share. That in turn, will change and affect the competitive position of some ports in the market.

The above analysis of BCG matrix for the years of 1998 and 2012 reveals that the competitive positions of the Mediterranean container ports under study have changed over the period of study due to the significant change of their market share and average growth rates. As such, the second hypothesis is confirmed.

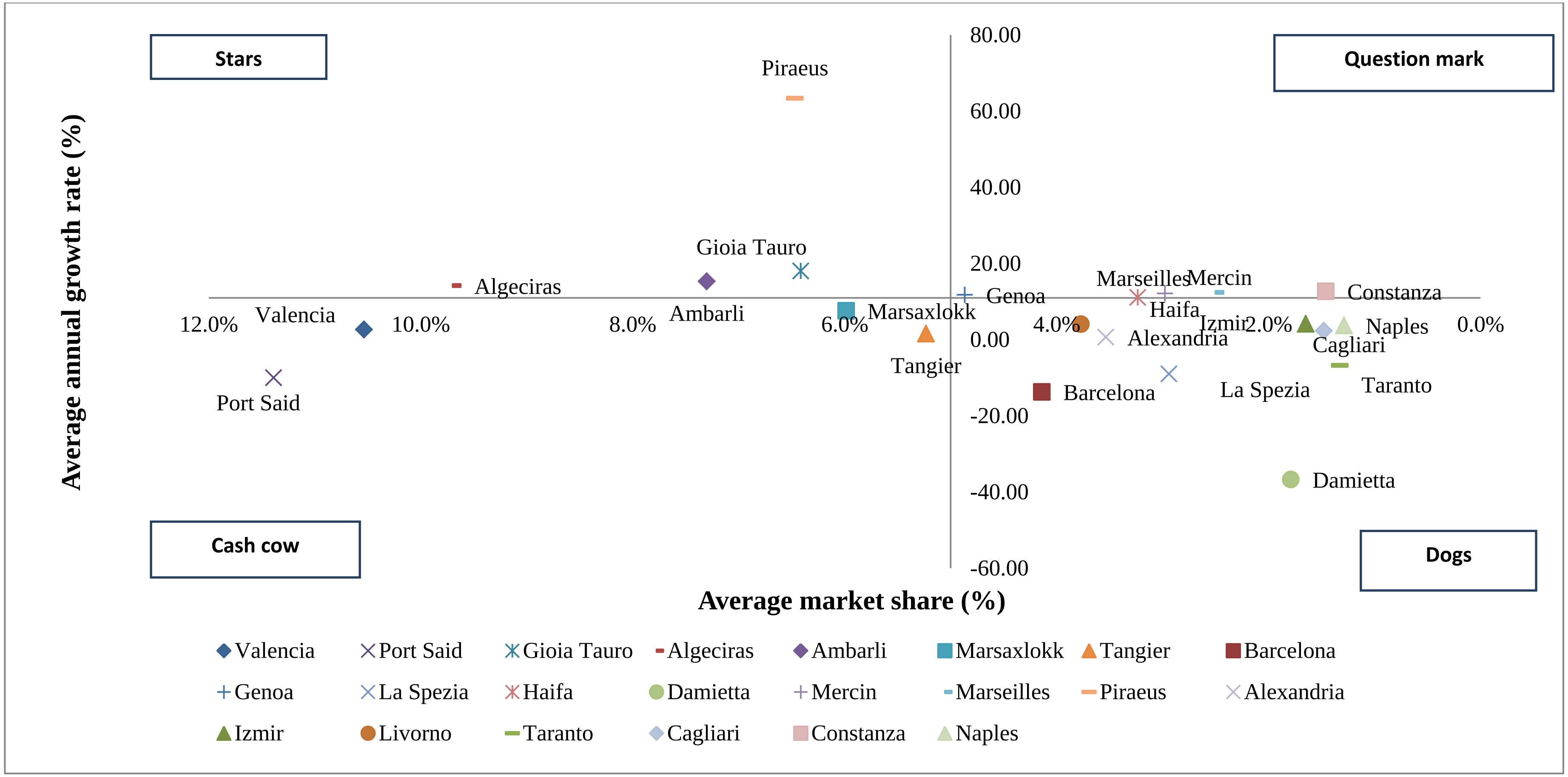

Figure 5. 12- Mediterranean container ports BCG matrix 2012.

In order to transpose some of the former conclusions into the Mediterranean container market, it is beneficial to analyse the amount of container shifts among ports and port categories (medium-sized and large ports). Therefore, a customised form of the shift-share analysis will be used in the next section to analyse the Mediterranean container market conduct.

5.3.3 Mediterranean container port market conduct

5.3.3.1 Shift-Share analysis

As illustrated in chapter four, in the context of this research, market conduct is the actual behaviours of ports in the defined market. It explains how the Mediterranean container ports respond to the conditions imposed by the market structure and interacts with competitors. The shift-share analysis is applied in order to analyse the behaviour of study ports in the defined market. The shift-share analysis was originally established in the framework of regional economics, it is appropriate to get more insight into the issue of the growth of ports throughput (Notteboom, 1997).

Although shift-share analysis unable to describe the market dynamics in the immediate competitive environment, it enables dividing the growth or decline of ports into related sections-the ‘share’ effect and the ‘shift’ effect. The ‘share’ effect indicates the estimated growth of container traffic in a port as if it would simply preserve its market share. The total shift reveals the total number of containers (TEUs) ports have actually won from or lost to competing ports in the same market, with the estimated container traffic (share effect) as a reference. The ‘shift’ effect enables a better evaluation of a port’s competitiveness as it eliminates the growth of the overall container sector. This means that only the net amount of TEU-shifts between ports remains. The sum of the shift-effects of all study ports equals zero (Notteboom, 1997).

It is beneficial to analyse the amount of container shifts among study ports in order to get a thorough understanding of throughput dynamics. The net shift analysis offers a good method for assessing container shifts. It is a modified form of the shift-share analysis, which was first used in Notteboom (1997). As explained in chapter four, a net shift of zero would mean that the port would have the same growth rate as the total port market. The average annual net shift figures for the study ports demonstrate a gain (positive sign) or a loss (negative sign) of potential container traffic i.e. compared to the situation under which the study ports would have grown at the same average growth rate as the total Mediterranean container market.

Figure 5.13 and appendix 5.5shows the results of a market-based total shift analysis applied to the Mediterranean container port market. For purposes of comparability, the study period, from 1998 to 2012 were used as years of reference in the simplified shift-share analysis. Notwithstanding the fact that the total net volume of shift effects within the Mediterranean container port market increased from 776,441 TEUs in 1999 to 2,220,669 TEU in 2012. The percentages of TEUs shift within the Mediterranean market amounts to around 6% of total throughput in 1999 and about 5% in 2012. The decrease in percentages might explain that dynamics, in terms of TEU-shifts. The total volume of containers shifted between the respective ports reached an exceptionally high level in the study period.

In that time span, among the major winners and losers in terms of total shifts are a large number of Mediterranean ports. In 1999, Port Said, Valencia and Damietta were the main winners and showed the best performances. The total TEUs gained by these ports as a percentage of the total shift was 54%, 16% and 13% respectively. While the ports of Livorno, Algeciras, Genoa and Marsaxlokk showed the worst performance. The percentages of losses of these ports were 19%, 18%, 17% and 15% respectively.

In 2005, the ports of Port Said and Constantza represent the major winners. The former, due to the inauguration of SCCT with its strategic location with zero deviation from the main container trade East-West trade route, gained about 47% of the total TEU shift, while the later gained around 25% of the total shift. However, compared to the total TEU shifts, the ports of GioiaTauro, Piraeus, Marsaxlokk and Damietta lost about 22%, 17%, 16% and 15% respectively. Similarly, in 2009, due to the increased transhipment traffic in the Mediterranean basin, the ports of Tangier, Port Said and Cagliari gained around 38%, 18% and 15% of the total shift. The remarkable gain of Tangier port is related to the new investment in the ports’ infra/superstructure that took place in that period and the unique location of that port at the west entrance of the Mediterranean basin , while ports of Constantza, Barcelona and GioiaTauro were the main losers. The losses of these ports were 25%, 22% and 16% respectively.

In 2012, port of Piraeus was the main winner. The port gained about 44% of the total TEUs shifts followed by the ports of Algeciras, GioiaTauro and Ambarli that respectively gained 14%, 13% and 12% of the total TEUs traffic shift in the Mediterranean market. Meanwhile, ports of Port Said, Damietta and Barcelona were the main losers at that period of time. The ports losses from the total TEUs traffic were about 37%, 23% and 17% respectively. Thus, although the Mediterranean ports involved themselves in large-scale container traffic, shifts between ports are remarkably increased and demonstrating considerable dynamics within the container ports under study. Two elements are the main reasons for the dynamics of container traffic in the Mediterranean basin.

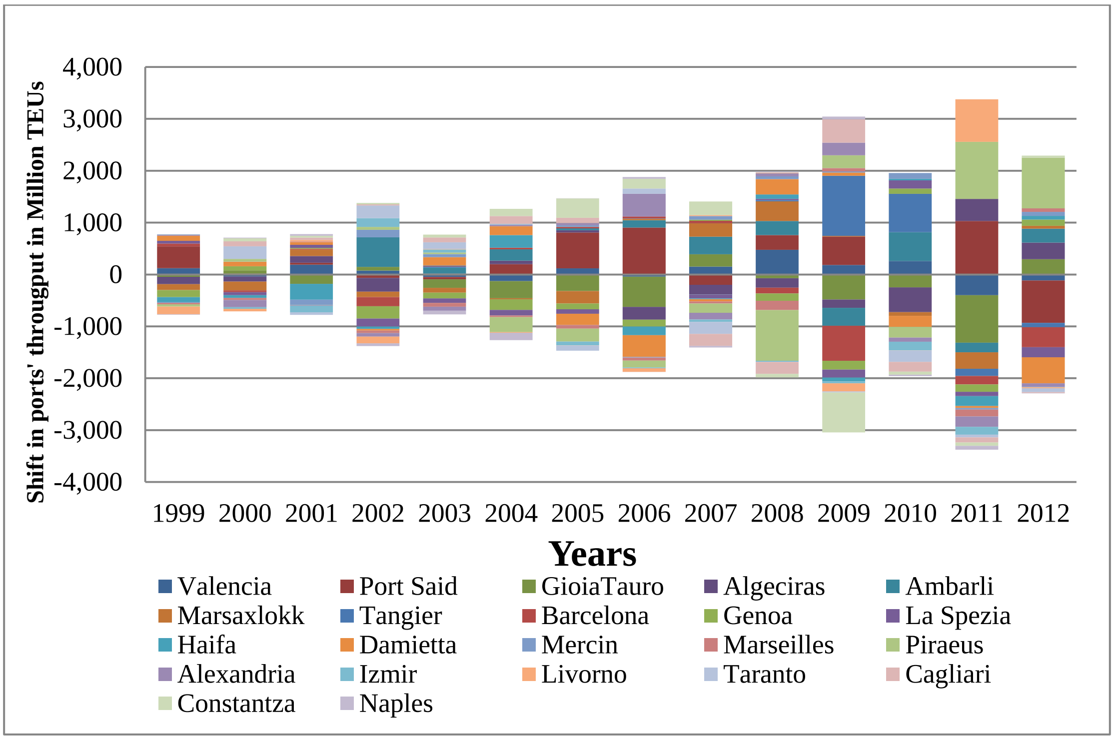

Figure 5. 13- Shift in Mediterranean container port's throughput (1998-2012).

First of all, locational elements, nearness to main Round-the-World (RTW) trade route, seem to be the main reason for the emergence of new ports, not congestion or the lack of space in the existing ports. Indeed new ports, such as SCCT in Port Said and Tangier, are located along the RTW track route, maritime track connecting the Suez Canal to the Strait of Gibraltar. Secondly, the fact that the recent emergence of new ports did not coincide with a deconcentration trend in the Mediterranean range, but resulted merely in a stagnation of the Gini coefficient.

According to the total shift analysis, this stagnation derived from the strengthening of the position of the small and medium-sized ports at the expense of the larger ones (Marseilles, in particular). The hub battle moved activities from remote ports, in terms of deviation distance from main RTW route, to nearby ports. Among the latter ports, Algeciras, Tangier and Port Said are distinctive in that it gives the possibility of a north-south and east-west interline.

The total shift analysis also showed that the current hub ports in the Mediterranean are already losing ground to the benefits of some potential hubs such as Tangier and Ambarli and some gateways such as Piraeus. In the future, the land side and in particular corridor development will undoubtedly prove to be essential to maintain a competitive edge for the Mediterranean ports. In this context, the load centres in the Mediterranean container market can be considered as the dominant players.

As far as the share analysis is concerned, the market share of each port is calculated as a percentage of the total throughput of the 22 selected ports. Figure 5.14 and appendices 5.2 and 5.4 illustrate that, in 1998, ports of GioiaTauro and Algeciras were the market leaders with market shares of 15.4% % and 13.2% respectively. Ports of Genoa, Barcelona, Marsaxlokk and Valencia had approximately equal market shares of 9.1%, 7.9%, 7.7% and 7.0% respectively while ports of Damietta and Mercin had the lowest market shares of 2.2% and 1.7% respectively.

In 2005, the ports of Algeciras and GioiaTauro succeeded to maintain their competitive position as market leaders in the Western Mediterranean market that includes ports of Barcelona, Valencia, Cagliari, Marseilles, Marsaxlokk and Genoa. The ports achieved market shares of 11.6% and 11.5% respectively. The remarkable drop in the port of GioiaTauro market share is related to the emergence of new competition from Port Said after the inauguration of SCCT. During such a period, Port Said attained a market share of 5.9%. Moreover, the operation of SCCT by APM affected Piraeus market share, which declined from an average market share of 7.0% in the period between 1998 and 2004 to about 5.1% in 2005.

Figure 5.14 and appendix 5.2 and 5.4 also show that among the major winners just before the world financial crisis in 2008 and 2009 were the Spanish Mediterranean ports. In 2007, the ports of Valencia and Algeciras achieved market shares of 9.1% and 10.3% respectively. However, Barcelona was hit hard by the crisis as its market share dropped from 7.9% in 2007 to 5.5% in 2009. Container transhipment activities, sea to sea in particular, did not recover after 2009 and the Catalan port closed 2012 at market share of 4.4%. At the other extreme, Valencia recorded a spectacular and consistent growth between 2007 and 2010. The port had a market share of 9.1% in 2007 raised to 11.8% in 2010. MSC's choice to use the port as a hub for the region boosted transhipment volumes and enhanced the port's competitive position in the Mediterranean port rank.

Among the major winners after the crisis were Port Said and Valencia. The ports achieved market shares of 11.4% and 10.5% respectively in 2012. However, the market share of the ports of Algeciras and GioiaTauro dropped to 9.7% and 6.4% respectively in the same year. The reduction in Algeciras market share is directly related to the increase of Tangier market share that increased to 5.2%, while the reduction in GioiaTauro market share is due to the increase of Port Said market share and Piraeus market share that increased to 6.5%. The main losers in this period are the ports of Taranto and Naples with market of 1.3% and ports of Cagliari and Constantza with a market share of 1.5%.

As such, the net result of the above growths has been as light decline in the market share of the West Mediterranean hubs, except Tangier, in the last fifteen years after a significant emergence in the second half of the 1990s. Thus, West-Mediterranean ports far away from the main shipping routes (such as Marseilles, Genoa and Livorno) succeeded for the first time ever in attaining market share in the past three years, from 2010 to 2012, vis-à-vis other Mediterranean ports closer to the shipping route. The transhipment traffic remains a highly 'footloose' business. This has led some transhipment hubs such as GioiaTauro and Algeciras to develop rail services to capture and serve the economic centres in the distant hinterlands directly, while at the same time trying to attract logistics sites to the ports (Notteboom, 2012).

The significant improvement of the Mediterranean container ports under study was mainly due to the inclusion of transhipment hubs in the market since the mid-1990s (GioiaTauro, Marsaxlokk, Cagliari, Algeciras, Port Said and Taranto). The market share of transhipment hubs in total Mediterranean container throughput peaked since 2005. The main reasons for such increase are that some shipping lines rely on the hub-and-spoke operation pattern in the Mediterranean, others preferred to add new line-bundling services calling at main land ports directly (Notteboom, 2010). In response, mainly Italian transhipment hubs are changing their focus, now serving central and East Mediterranean market. Algeciras, strong hold of APM Terminals, relies a lot on east-west and north-south interlining and is facing competition from the port of Tangier.

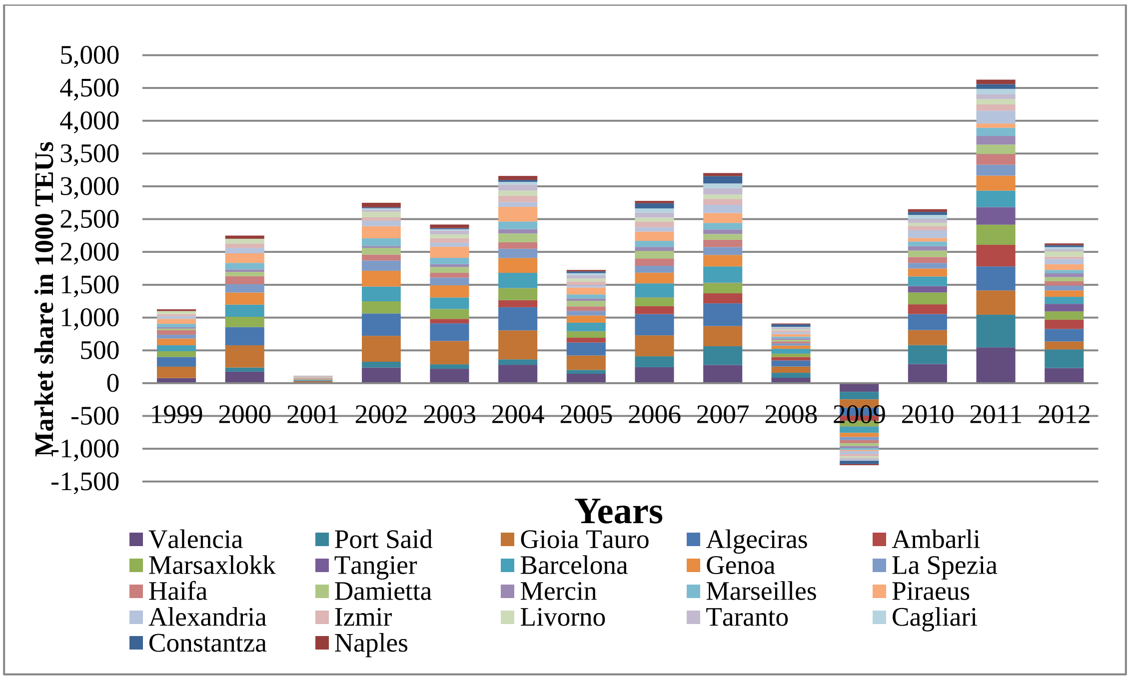

Figure 5. 14- Share in Mediterranean container port's throughput (1998-2012)

5.4 Discussion and conclusion

Over the last two decades the ports of the Mediterranean market have experienced significant growth in container traffic as well as a remarkable expansion and restructuring of the port market. The evolving container shipping network and changing status of container ports in the Mediterranean have attracted the interest of scholars and practitioners to explore the dynamics of changes in market concentration and the impact of such changes on the competitive positioning of ports.

The aim of this chapter was to examine and analyse the port competitive level and the recent dynamics in the Mediterranean container port market for the period from 1998 to

2012 in terms of market concentration and deconcentration tendencies, and the impact of such tendencies on the container ports' competitiveness. As indicated in chapter four, the research followed the concept of the Industrial Organisation (IO) and the Structuralists (Harvard school) methodology to assess the market structure and to measure market concentration that demonstrates the market dynamics and port competitiveness. In doing so, the Structure-Conduct-Performance (SCP) approach is used. For the purpose of this chapter, the research focused on analysing market structure and conduct, while market performance will be measured and analysed in the next chapter.

Market structure is analysed through the measurement of market concentration and inequality. A number of measurement techniques are used. Market concentration is measured and analysed by using the K-CR and HHI. The market inequality is measured through the use of Gini coefficient and Entropy index. The ports competitive positions at the beginning and the end of the study period, in which the market dynamics is explained, are presented by using the BCG matrix. Market conduct is explained through the use of shift-share analysis technique.

The research provided a thorough analysis of the concentration, deconcentration and inequality levels of the Mediterranean container port market. The scope of the research mainly concerns the assessment criteria and techniques perceived, not an in-depth analysis of the reasons causing the observed results. The research findings demonstrate that the recent deconcentration tendency of the Mediterranean container port market is due to the increased number of market players and the distribution of container traffic among the ports under study. This can clearly be noticed from the analysis of the K-CR and HHI. The K-CR analysis revealed that the market shares of the top four and top ten container ports in the defined market have decreased within the study period. Similarly, the value of the HHI is also decreased in the same period. Thus the first hypothesis can be accepted as the market moves toward deconcentration and pure and perfect competition.

As far as the inequality analysis is concerned, the chapter assessed inequality at the level of the Mediterranean container ports under study. At first sight, the reduction in the value of Gini coefficients as well as the increase in Entropy indices for the

Mediterranean container port market demonstrated a remarkable deconcentration trend within the period of study. The recent hub battle undoubtedly influences the present hierarchy in the Mediterranean port market. Hence, new ports are built to accommodate (RTW) services with the best technology and location such as Algeciras in Spain, Marsaxlokk in Malta, Port Said (SCCT) in Egypt and GioiaTauro in southern Italy, while medium-sized ports are reinforcing their position vis-a-vis larger ones. Using the Gini coefficient and Entropy indices as analytical techniques enables observations that could be made in relation to the net contribution of the inequality between individual ports to overall traffic concentration in the defined port market. By doing so, the research is able to get an overview on spatial dynamics in the Mediterranean container port market than provided solely by the Gini coefficient. This comprises a valuable and distinct contribution to the literature of port geography.

The research also concluded that the dynamic characteristics of the Mediterranean container market have a significant impact on determining not only the degree of market concentration but also the competitiveness level of container ports in such a market. In this context, the BCG matrix is used to test the second hypothesis that presumes that the competitiveness level of the ports under study is changed over the period of study. The results indicated by the BCG matrix confirm such hypothesis as ports of GioiaTauro, Valencia and Barcelona were the market leaders in 1998, while ports of Algeciras, GioiaTauro, Piraeus and Ambarli took the lead in 2012. Meanwhile, there is a potential for some ports such as Port Said and Tangier to enhance their competitive position and become market leaders as hub ports in the Mediterranean basin. The former has a potential to increase its average growth rate, while the later has a good opportunity to increase its market share through the transhipment traffic.

In the context of the analysis of market conduct, the shift-share analyses explain that the level of port market concentration in the Mediterranean container port market stagnated in the period of study. The stagnation in the concentration level was a result of container shifts to medium-sized (new) ports such as Tangier and SCCT which provide a more favourable location to receive RTW services. The recent hub battle in the Mediterranean certainly increases inter-port competition within the Mediterranean market, which will most probably lead to a further traffic distribution between east-west and north-south. The volume of this traffic will highly depend upon the productivity gains in the Mediterranean ports and the improvements in land container services, roads and rails operating on multimodal transport networks, and feeder services between container ports in the Mediterranean basin and their hinterlands (Notteboom, 1997). Port authorities in the Mediterranean market could use these results as a component to analyse whether the studied spatial growth of the respective container port market is corresponding to their policy objectives. The results also provide a good basis for evaluating the impacts of recent developments in liner service itinerary, market structure and hinterland services on the spatial distribution of container handling activities.

According to the above mentioned analysis of the Mediterranean container port market structure and conduct, in terms of port hierarchy the market can be segmented into two main categories, the present hub-ports and the potential hubs. The former such as GioiaTauro, Marsaxlokk, Algeciras and Port Said (SCCT) have a competitive advantage in their strategic location near to the main liner trade routes, while the later such as Valencia, Barcelona, Genoa and Ambarli are trying to utilize their resources in terms of terminals infra/superstructure in order to enhance their competitive position and increase their market share.

Nevertheless, the ability of port to compete in such a dynamic market not only depends on the availability of ports infra/superstructure, location and throughput but is also affected by the optimum utilisation of such facilities in terms of port efficiency. The severe competition characterises the container port industry in the Mediterranean market has inspired a blatant concern in the efficiency with which it exploits its resources. The study of the container ports efficiency is very important for the endurance and competitiveness of the market players. As such, next chapter assesses the technical efficiency of the study ports in the Mediterranean container market. In doing so, a number of DEA models are used not only to measure the relative technical efficiency of the defined ports and offer an effective management tool for port operators, but also represent a significant input for enlightening regional and national port development to planning and operations.

CHAPTER SIX

BENCHMARKING THE TECHNICAL EFFICIENCY OF THE MAIN CONTAINER PORTS IN THE MEDITERRANEAN

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6.1 Introduction

Port efficiency is a significant factor that stimulates port competition and enhances regional development. With growing international maritime traffic and changing technology in the maritime transport industry (containerisation, integrated logistic services, etc.), ports are coping with mounting pressures to promote and offer cutting-edge technology (Merk & Dang, 2012). As such, Mediterranean container ports are being forced to enhance port efficiency to provide comparative advantages that will attract more sea traffic.

In this context, the aim of this chapter is to explore the use of efficiency measures as a proxy to assess market performance through benchmarking the relative efficiency of the main container ports in the Mediterranean, as a second stage on using the SCP paradigm. The research analyses the technical efficiency of 22 container ports in the Mediterranean market using a cross-sectional, panel data and window analysis application of the output oriented models of data envelopment analysis (DEA) for the period between 1998 and 2012. In doing so, this chapter analyses the results of the efficiency analysis of Mediterranean main container ports. As a first stage, in order to acquire a variety of complementary efficiency analyses for major ports in the defined market, the results of five DEA models are analysed to benchmark the efficiency of container ports under study.

This chapter is organized as follows; section two encompasses sample description and data statistical analysis. In section three, DEA-CCR/BCC models are applied to benchmark the relative aggregate technical efficiency under (CRS) and pure technical efficiency under VRS of ports under study. In section four, return to scale analysis is utilised to find out the status of return to scale of each port and super-efficiency A&P analysis is conducted to rank the efficient ports. A sensitivity analysis is used in section five to distinguish between variables that have larger weights in terms of efficiency and slack variable analysis is used to determine potential areas of enhancement for inefficient ports. Finally the conclusion is presented in section six.

6.2 Sample description and data statistical analysis

In this chapter, sets of both cross-sectional and panel data are analysed to allow the evaluation of container port efficiency under a number of various assumptions and model specifications. Table 6.1 demonstrates the descriptive statistics of cross-sectional data inputs and output variables for the year of 2012 and comprises the data of the main container ports in the Mediterranean basin. The selection of the DMUs, 22 container ports in the Mediterranean, is based on their location and the container traffic served, since these ports share the same foreland represented by the Mediterranean. Moreover, these ports represent the large and medium size container ports in the defined market with container throughput greater than 500, 000 TEUs in 2012. These ports are Valencia, Barcelona and Algeciras in Spain; GioiaTauro, Genoa, La Spezia, Livorno, Taranto, Cagliari and Naples in Italy; Ambarli, Izmir, Mersin in Turkey; Marsaxlokk in Malta; Tangier in Morocco; Haifa in Israel; Marseilles in France; Piraeus in Greece, Constantza in Romania and Port Said, Damietta and Alexandria in Egypt.

To avoid having too many DMUs with efficiency estimates being equal to one, which would lower the discriminatory power of DEA, Norman and Stoker (1991) proposed that the number of studied DMUs should be at least twice the sum of input and output variables. Therefore, this research uses twenty-two ports, and hence the sum of input and output measures could not be greater than eleven.

The required secondary data are mostly taken from different issues of the *Containerisation International Yearbook.* As the publishers of this source contact the ports under study every year, and the data are collected based on their surveys, the data analysed within this study is considered as the most reliable and comprehensive available. To assess the efficiency of the ports under study, data for the years from 1998 to 2012 are used. The primary data is not used here in this research as it was difficult to be collected from the study ports. Port operators and authorities do not release such type of data as they consider it as confidential and affects their competitive position in the market.

Based on the argument that container terminals are more suitable for one-to-one comparison than whole container ports (Cullinane et al, 2005b), this research initially intended to benchmark the efficiency of all individual container terminals. However, data sources often report the required data, container throughput in particular, collectively for the whole port, rather than on the basis of the individual container terminals at each of those ports within the sample. Therefore, the input and output of a port were defined as the aggregation of the input and output of all individual terminals within the port.

Table 6.1 shows that, in terms of the output variable represented by ports annual throughput, there is a wide range across the data. The data set also shows a high dispersion at which the standard deviation is 1,310,474. The kurtosis parameter for this variable is 0.02, close to zero, which means that the data set is normally distributed. In the context of the input variables, Table 6.1 also shows that there is a wide range across the terminals areas and storage capacity data sets. The kurtosis parameters of the ports throughput and terminals areas are 0.02 and 0.43 respectively, near to zero, which means that the data is almost normally distributed. In terms of the quay length, maximum depth and handling equipment, the kurtosis parameters are 0.94, -0.31 and 0.48 respectively, near to zero, which means that the data is almost normally distributed.

Table 6. 1- Descriptive statistics of cross-sectional data inputs and output variables for the year (2012).

Variables	Inputs					Output
	Terminal area (Ha)	Storage Capacity (ha)	Quay length (m)	Maximum depth (m)	Handling equipment (unit)	Throughput (TEUs)
Min.	13.50	2,500.00	550.00	12.00	8.00	263,461.00
Max.	181.49	112,471.00	4,793.00	18.00	290.00	4,831,165.00
Range	167.99	109,971.00	4,243.00	6.00	282.00	4,567,704.00
Mean	85.24	35,756.23	2,392.05	15.07	106.73	1,914,316.23
Std. Dev.	40.94	28,593.16	1,211.13	1.46	72.00	1,310,474.48
Skewness	0.60	1.08	0.67	-0.37	0.89	0.91
Kurtosis	0.02	0.43	0.94	-0.31	0.48	0.02
Number of DMUs	22	22	22	22	22	22

Table 6.2 illustrates the descriptive statistics of the panel data inputs, outputs and explanatory variables. This sample serves as the basis for the panel data analysis and also encompasses the main container ports in the Mediterranean. The sample of window analysis comprises a total of 314 observations. Table 6.2 reveals that there is a wide range across the throughput and terminal area data sets.

There is also a high dispersion of the data from the mean, in which the standard deviation is very high. The Skewness coefficients of port throughput and terminal area are (1.34) and (0.94) which means that the distribution of data is skewed to the right and the data is not normally distributed. The kurtosis parameters of the ports throughput and terminals areas are 1.70 and 1.21 respectively which indicates that the data is not normally distributed.

Similarly, there is a wide range across the data sets of the storage capacity, quay length and maximum depth. The Skewness coefficients of the storage capacity, quay length and maximum depth are 1.34, 1.25 and 0.94 means that the distribution of data is skewed to the right and the data is not normally distributed. The kurtosis parameters for the same variables are 2.53, 1.29 and 13.86 respectively.

Table 6. 2- Descriptive statistics of the panel data inputs and outputs variables

Variables	Inputs					Output
	Terminal area (Ha)	Storage Capacity (ha)	Quay length (m)	Maximum depth (m)	Handling equipment (unit)	Throughput (TEUs)
Min.	6.00	700.00	481.00	9.00	20.00	24,113.00
Max.	213.49	112,471.00	7,268.00	30.00	305.00	5,366,968.00
Range	207.49	111,771.00	6,787.00	21.00	285.00	5,342,855.00
Mean	73.52	24,876.39	2,191.71	14.46	82.71	1,298,551.09
Std. Dev.	40.95	19,384.16	1,396.04	1.91	54.62	965,442.60
Skewness	0.94	1.34	1.25	0.94	1.37	1.34
Kurtosis	1.21	2.53	1.29	13.86	2.52	1.70
Number of DMUs	314	314	314	314	314	314

There is also a wide range across the yard equipment data set. There is a high data far from the mean and the Skewness coefficient is 1.37,which means that the distribution of data is skewed to the right.

In order to confirm that the selected input and output variables could evaluate the efficiency of the ports properly, correlation analysis was carried out to verify that they demonstrated isotonicity. Table 6.3 shows the correlation coefficient of the cross-sectional data of the inputs and output measures for the year of 2012. Table 6.3 shows that all variable are positively correlated.

The correlation coefficients of five input variables against one output variable are all greater than 0.20. The lowest correlation coefficient 0.20 is between the quay length and the maximum depth, while the highest correlation coefficient of 0.84 is between the quay length and handling equipment. Table 6.3 also shows that there is a strong positive correlation between the terminals' area and the storage capacity, quay length and handling equipment with correlation coefficients of 0.688, 0.673 and 0.693 respectively. Thus, it demonstrates that they were all positively correlated, and that all six variables complied with the isotonicity.

Table 6. 3- Correlation coefficients of the cross-sectional data input and output measures for the year 2012

Variables	Output	Inputs				
	Throughput (TEU)	Terminals Area (ha)	Storage capacity (TEU)	Quay length (m)	Max. depth (m)	Handling equipment (unit)
Throughput (TEU)	1.000					
Terminals Area (ha)	0.491	1.000				
Storage capacity (TEU)	0.510	0.688	1.000			
Quay length (m)	0.591	0.673	0.516	1.000		
Maximum depth (m)	0.444	0.319	0.248	0.201	1.000	
Handling equipment (unit)	0.515	0.693	0.505	0.838	0.223	1.000

Note: Correlation is significant at the 0.01 level (2-tailed).

Similarly, Table 6.4 shows the correlation coefficients of the panel data input and output measures. Table 6.4 illustrates that all variables are positively correlated with each others. The lowest correlation coefficient of 0.386 is between the handling equipment and the maximum depth, while the strongest correlation coefficient of 0.762 is between the quay length and the handling equipment. There is also a good positive correlation between the output variable and the five input variables which varies between 0.480 and 0.602. As such, all variables of the panel data prove isotonicity.

Table 6. 4- Correlation coefficients of the panel data input and output measures

Variables	Output	Inputs				
	Throughput (TEU)	Terminals Area (ha)	Storage capacity (TEU)	Quay length (m)	Max. depth (m)	Handling equipment (unit)
Throughput (TEU)	1.000					
Terminals Area (ha)	0.550	1.000				
Storage capacity (TEU)	0.561	0.566	1.000			
Quay length (m)	0.502	0.679	0.491	1.000		
Maximum depth (m)	0.480	0.382	0.303	0.437	1.000	
Handling equipment (unit)	0.602	0.738	0.472	0.762	0.386	1.000

Note: Correlation is significant at the 0.01 level (2-tailed).

The next section assesses the Mediterranean container market performance through benchmarking and analysing the aggregate and pure technical efficiency of the Mediterranean main container ports. The DEA-CCR model is used to assess the aggregate technical efficiency under constant return to scale (CRS), the DEA-BCC model is applied to assess the pure technical efficiency under variable return to scale (VRS) and the scale efficiency model is used to analyse the study ports' return to scale in terms of increasing, decreasing or constant return to scale.

6.3 Assessment of market performance-DEA models analysis

Sufficient infrastructure, along with factors like know- how, expertise, organisational reform and the efficient use of port infrastructure (Chlomoudis & Pallis, 1998) assist to attract cargo traffic when competition is intensified. The cargo generating capability of a port remains a powerful factor but other elements like electronic data interchange linking port authorities, stevedores, shippers and ship owners should also be considered. In their absence, ports cannot meet the demand for cargo traffic to be delivered or transhipped quickly and reliably (Kallstrom &Warnecke, 1998).

Whether a port will manage to enhance these elements is largely dependent on the ports ability to enhance its efficiency and optimise the available resources.

Infrastructure might not be the main influential element of port competitiveness especially when ports are well equipped in that respect (MST et al, 1996). Over the period of the 1990s problems have arisen owing to infrastructure congestion. Moreover, regardless of capacity requirements, even the most successful ports need further infrastructure modernisation though for various reasons: large ports to integrate into logistics chains, small and medium ports to surmount less efficient and less specialised facilities and to counteract their weaknesses regarding economies of scale (ECMT, 1998; Notteboom, 2012).

The efficiency structure hypothesis explains that performance of firms in a certain market is positively related to their efficiency. This is because market concentration emerges from competition where firms with low cost structure increase profits by reducing prices and expanding market share. A positive relationship between firm profits and market structure is related to the benefits made in market share by more efficient firms. As such, these benefits lead to increased market concentration. That is, increased profits are presumed to accrue to more efficient firms because they are more efficient and not because of collusive activities as the traditional SCP paradigm would suggest (Molyneux and Forbes, 1995).

Traditionally, these hypotheses have been tested using profit/profit margin as indicators of efficiency. As indicated in chapter three, in the efficiency literature there is increased focus on the use of efficiency as a tool to analyse the economies of scale and economies of scope accounting for risk, and policy implications. This section analyses the results of the first step of the two- stage efficiency analysis of Mediterranean main container ports that illustrates the results of the output oriented DEA models used for the efficiency measurement of the container ports under study.

6.3.1 Benchmarking the operational efficiency

Port efficiency is usually associated with performance and productivity; however, their focus is narrow, measuring total traffic volumes or operating technology of ports, which are not the only indicators. There are other elements that are related to the more organisational side of production, such as how efficiently ports use inputs to produce current output levels and whether the technologies adopted by ports are the most efficient, that are essential to determining port efficiency (Wang et al, 2005).

As indicated in chapter four, the Banxia Frontier analyst software is used to solve the DEA models. Without accurate data on the returns to scale of the port production function, two types of DEA models, namely the CCR and BCC models of cross-sectional and panel data (window, contemporaneous and inter-temporal) analysis, are used to analyse the efficiency of the main container ports in the Mediterranean as well as return to scale efficiency. The comparison between cross-sectional data and panel data are presented in Table 6.5.

In the context of cross-sectional data for the year of 2012, Table 6.5 and appendix 6.1 indicate the efficiency estimates of The DEA-CCR and DEA-BCC output oriented models. It is clear from Table 6.5 that, as one would expect, the DEA-CCR model yields lower average efficiency scores than the DEA-BCC model, with respective mean values of 0.71 and 0.82 and where an index value of 1.00 equates to maximum efficiency. Four out of the twenty-two ports included in the analysis are recognised as efficient when the DEA-CCR and the DEA-BCC models are applied. These ports are Valencia, Port Said, GioiaTauro and Algeciras, while the rest of the study ports are inefficient. The rest of the ports under study recorded as inefficient with relative efficiency scores of less than unity in 2012. The ports of Constantza and Naples showed the lowest efficiency scores of 0.233 and 0.126 under the DEA-CCR model and 0.421 and 0.397 under DEA-BCC model respectively.

This result is not surprising since a DEA-CCR model with an supposition of constant returns to scale offers information on pure technical and scale efficiency taken together, while a DEA-BCC model with the supposition of variable returns to scale identifies technical efficiency alone. A Spearman’s rank order correlation coefficient between the efficiency estimates derived from DEA-CCR and DEA-BCC analyses was 0.979. The positive and strong Spearman’s rank order correlation coefficient indicated that the rank of each port derived from using the two different models was similar.

Empirical results explain that there exists considerable waste in the production of the container ports in the sample. For example, the average efficiency of container ports derived from using the DEA-CCR model amounts to 0.71.This demonstrates that, in theory, the sample ports can, on average, increase the level of their outputs (throughput) to 1.4 (=1/0.71) times as much as their current level while using the same inputs. However, this relies on the proper approaches to production being adopted and the appropriate scale of production implemented.

As with the analysis of cross-sectional data using DEA models, in the absence of categorical empirical *a priori* evidence that the efficiency of container ports shows either constant or variable returns to scale, the DEA–CCR and DEA–BCC models were selected from among various DEA models to assess port efficiency. As mentioned in chapter four, various versions of DEA panel data analyses were applied as part of this stage. These included DEA- CCR/BCC models that are integral to the Window, Contemporaneous and Inter-temporal analysis to the evaluation of efficiency using panel data for the period between 1998 and 2012.

While it is comparatively uncomplicated to calculate efficiency scores using Contemporaneous and Inter-temporal analyses, caution should be exercised in determining the window width for conducting a Window analysis. Preferably, it should be determined to match the standard cycle time between technological innovations so that the efficiency scores derived from Window analysis reveal solely the difference between the actual level of production of a port and the best level of contemporaneous production (Wang et al, 2002).Nevertheless, even if such a case should exist, in practice, it is difficult to observe the technological innovation cycle time within the port industry. Thus, as in many previous studies of this kind, it is difficult to find a justification for the selection of window size (Cullinane & Wang, 2010).

As such, the length of the window used herein is defined as five time periods that present the average cycle time of the shipping and port market (Stopford, 2009). Eleven separate windows are denoted as separate rows in Appendices 6.2 and 6.3. The average of the 22 DEA efficiency estimates and their associated standard deviations are presented in the columns denoted ‘Mean’ and ‘St. Dev.’.

Table 6. 5- DEA Cross-section and panel data mean technical efficiency scores for main Mediterranean container ports (1998-2012).

Port	Country	Cross-section and Panel data mean and standard deviation of technical efficiency scores													
		Cross-section (2012)		Window				Contemporaneous				Inter-temporal			
		DEA-CCR	DEA-BCC	DEA-CCR		DEA-BCC		DEA-CCR		DEA-BCC		DEA-CCR		DEA-BCC	
				Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Valencia	**Spain**	1.000	1.000	0.827	0.052	0.870	0.071	0.913	0.073	0.949	0.051	0.803	0.126	0.881	0.111
Port Said	**Egypt**	1.000	1.000	0.787	0.085	0.828	0.151	0.897	0.048	0.917	0.039	0.730	0.172	0.762	0.154
GioiaTauro	**Italy**	1.000	1.000	0.898	0.104	0.899	0.103	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000
Algeciras	**Spain**	1.000	1.000	0.903	0.094	0.916	0.087	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000
Ambarli	**Turkey**	0.953	0.972	0.649	0.107	0.724	0.103	0.753	0.142	0.885	0.064	0.506	0.159	0.587	0.194
Marsaxlokk	**Malta**	0.961	0.984	0.855	0.130	0.876	0.132	0.914	0.051	1.000	0.000	0.982	0.019	1.000	0.000
Tangier	**Morocco**	0.835	0.876	0.655	0.129	0.751	0.100	0.767	0.094	0.899	0.055	0.527	0.171	0.625	0.178
Barcelona	**Spain**	0.783	0.847	0.676	0.114	0.763	0.094	0.838	0.071	0.905	0.052	0.574	0.137	0.651	0.152
Genoa	**Italy**	0.836	0.881	0.741	0.086	0.807	0.069	0.882	0.057	0.913	0.041	0.630	0.157	0.674	0.137
La Spezia	**Italy**	0.729	0.835	0.506	0.083	0.669	0.128	0.631	0.108	0.757	0.051	0.440	0.149	0.529	0.165
Haifa	**Israel**	0.708	0.819	0.463	0.113	0.549	0.109	0.577	0.094	0.653	0.116	0.391	0.159	0.478	0.198
Damietta	**Egypt**	0.643	0.816	0.399	0.098	0.512	0.121	0.504	0.224	0.598	0.180	0.362	0.180	0.422	0.238
Mersin	**Turkey**	0.653	0.785	0.450	0.070	0.535	0.093	0.543	0.196	0.634	0.153	0.388	0.168	0.441	0.189
Marseilles	**France**	0.687	0.784	0.373	0.093	0.478	0.070	0.422	0.148	0.562	0.155	0.329	0.129	0.399	0.152
Piraeus	**Greece**	0.886	0.973	0.639	0.165	0.696	0.154	0.717	0.154	0.773	0.122	0.486	0.200	0.570	0.205
Alexandria	**Egypt**	0.730	0.853	0.500	0.072	0.650	0.099	0.586	0.145	0.667	0.109	0.411	0.172	0.521	0.204
Izmir	**Turkey**	0.759	0.895	0.425	0.089	0.525	0.121	0.516	0.126	0.632	0.131	0.367	0.186	0.430	0.205
Livorno	**Italy**	0.438	0.747	0.355	0.087	0.459	0.080	0.411	0.177	0.544	0.187	0.304	0.114	0.390	0.164
Taranto	**Italy**	0.373	0.603	0.318	0.104	0.406	0.118	0.314	0.181	0.485	0.159	0.254	0.087	0.344	0.161
Cagliari	**Italy**	0.276	0.468	0.258	0.103	0.325	0.126	0.287	0.107	0.317	0.146	0.221	0.099	0.238	0.100
Constantza	**Romania**	0.233	0.421	0.293	0.120	0.397	0.156	0.308	0.098	0.459	0.158	0.233	0.096	0.328	0.118
Naples	**Italy**	0.126	0.397	0.208	0.090	0.261	0.145	0.266	0.098	0.269	0.097	0.214	0.091	0.230	0.092
Mean		0.710	0.816	0.554	0.099	0.632	0.110	0.638	0.109	0.719	0.094	0.507	0.126	0.568	0.142

The panel data efficiency estimates are reported in Appendices 6.2–6.7. The approaches used in formulating Appendices 6.2 and 6.3 lend themselves to analyse 'trends' of efficiency over time. This achieved through the adoption of a 'row view'. For example, a cursory glance at Appendix 6.2 may prompt the inference that the efficiency of a container port differs significantly over time. Taking Valencia as an example, its DEA-CCR and DEA-BCC window efficiency scores vary from 0.711 in 1998 to 0.950 in 2012 and from 0.732 in 1998 to 1.000 in 2012 respectively.

As shown in Table 6.5, the identification of efficiency is explained by the mean value, while the stability is assigned by the standard deviation. Table 6.5 shows that the calculated mean TE (CCR) and PTE (BCC) values are less than 1.00 for all the container ports under panel data analysis. The DEA-CCR and DEA-BCC window analysis mean efficiency estimates are 0.554 and 0.632 respectively. The mean efficiency scores of DEA-CCR and BCC models for the contemporaneous analysis are 0.638 and 0.719 respectively, while the respective values of the Inter-temporal efficiency estimates are 0.507 and 0.568.

Table 6.5 also shows that ports of GioiaTauro and Algeciras had the highest mean efficiency estimates of 0.903 and 0.898 for the DEA-CCR and 0.916 and 0.899 for DEA-BCC window analysis. The ports also achieved mean efficiency scores of 1.000 for DEA-CCR and DEA-BCC models for the contemporaneous and Inter-temporal analysis over the study period. In contrast, ports of Cagliari and Naples had the lowest mean DEA-CCR/BCC efficiency scores for all panel data analysis. Port of Cagliari window analysis DEA-CCR and DEA-BCC mean efficiency scores were 0.258 and 0.325 respectively. The port's contemporaneous mean efficiency scores were 0.287 for the DEA-CCR and 0.317 for the DEA-BCC, while the port's Inter-temporal mean efficiency scores for the same models were 0.221 and 0.238 respectively.

Port of Naples window analysis mean DEA-CCR and DEA-BCC efficiency scores were 0.208 and 0.261 respectively. The port's contemporaneous mean efficiency scores were 0.266 for the DEA-CCR and 0.269 for the DEA-BCC, while the port's Inter-temporal mean efficiency scores for the DEA-CCR and BCC models were 0.214 and 0.230 respectively.

Distinct from the other two approaches, Window analysis also offers the assessment of the ‘stability’ of efficiency within windows by the adoption of a ‘column view’. By using this perception, it is possible to observe that the efficiency of a DMU within the different windows can also vary considerably. The study of ‘stability and trend’ in window analysis reveals both the relative efficiency of a port in comparison to the others in the sample and the absolute efficiency of a port over time (Cullinane & Wang, 2007).

Table 6.5 also shows that some container ports such as Valencia, Algeciras, Barcelona, Marseilles, Genoa, Mersin and Livorno are stable in terms of their technical and pure technical efficiency as their standard deviation indicates lower values in relation to other ports in the sample. This is related to the involvement of the private sector in terminal operations in the ports of Valencia, Algeciras and Barcelona and the continuous investment in port infra/superstructure in the ports of Genoa, Marseilles, Mersin and Livorno. In contrast the standard deviation of some ports such as Cagliari, Constantza and Naples showed higher values, indicating unstable performance, in comparison to other ports in the sample.

It is clear that substantial inefficiency exists in some container ports. The overall average efficiency of the container ports under study over time is 0.64 and 0.51 respectively for contemporaneous and inter-temporal analyses. The former demonstrates that, on average, the sample ports could have theoretically reduced their input level by about 36%, while maintaining output levels, if industry best practice had been applied to their production process during the period of study. While maintaining the same level of output, the latter explains that during the period of study the ports in the sample could theoretically have reduced their inputs by around 49% on average, if they had not only followed industry best practice, but had also kept abreast of technological innovation.

The comparison between the large, medium and small size container ports shows a decline in the efficiency level of the large ports over time (Cullinane & Wang, 2010). Some small container ports are efficient despite their limited throughput compared to large container ports. In order to examine the efficiency trend and to analyse to what extent the efficiency of the container ports fluctuates over time, the relationship between the mean efficiency scores and their standard deviations is examined. In this context hypothesis three **(H3)**, as mentioned in chapter one, presumes that "*the technical efficiency of container ports is not related to scale of production*".

Panel data provide the basis upon which hypothesis three is tested. To examine the degree to which port efficiency fluctuates with scale of production (throughput), the standard deviation of efficiency estimates of each port over time and the mean container throughput at each port over time are correlated using the Spearman's rank correlation coefficient.

Spearman's rank correlation coefficient or Spearman's rho, First introduced by, (Spearman, 1904) is a non-parametric technique for measuring the degree of correlation between two independent variables. It evaluates how well the relationship between two variables can be analysed using a monotonic function. If there are no repeated data values, a perfect Spearman correlation of +1 or −1 occurs when each of the variables is a perfect monotone function of the other. Spearman's coefficient, like any correlation calculation, is suitable for both continuous and discrete variables, including ordinal variables (Lehman, 2005).

It is similar to Pearson's product moment correlation except that it operates on the rank of the data rather than the raw data. There are some advantages to applying Spearman's rank correlation over the more common Pearson's product moment correlation coefficient. It is a non-parametric technique so it is unaffected by the distribution of the population. It operates on the rank of the data so that it is relatively insensitive to outliers and there is no requirement that the data be collected over regularly spaced intervals. It can be applied with very small sample sizes and it is easy to use. However, the Spearman correlation coefficient also has some disadvantages as there is a loss of information when the data are converted to ranks. If the data are normally distributed, it is less powerful than the Pearson correlation coefficient (Gauthier, 2001).

The results of this analysis are reported in Table 6.6 where the calculation of the standard deviation of efficiency estimates derived from applying Window analysis is based on all of the efficiency estimates for an individual container port in different windows. Table 6.6 shows the relationship between the Mediterranean container ports' throughput and the fluctuation of their efficiency, represented by the standard deviation of efficiency scores, as measured by the Spearman's rank order correlation coefficient (ranging from -0.06 to -0.74). Since these correlations are statistically insignificant, hypothesis three cannot be rejected.

Table 6. 6- Relation between scale of ports' throughput and fluctuation of efficiency.

Data Type	DEA model	Correlation between Throughput & Efficiency fluctuation
		Spearman's rank order correlation
Panel	DEA-CCR-Window	-0.0633
	DEA-BCC-Window	-0.2571
	DEA- CCR-Contemporaneous	-0.5880
	DEA- BCC-Contemporaneous	-0.7410
	DEA- CCR-Inter-temporal	-0.0876
	DEA- BCC-Inter-temporal	-0.2370

For the purpose of comparing the efficiency estimates of the study ports using window, contemporaneous and Inter-temporal analyses, hypothesis four, as mentioned in chapter one, can be tested. Hypothesis four **(H4)** implies that "*The technical efficiency of the Mediterranean main container ports has improved over time*".

This hypothesis can be appropriately tested by tracking the year-on-year average efficiency of all of the container ports under study using the Window, Contemporaneous and Inter-temporal analyses indicated in Figure 6.1 and summarised in appendices 6.2–6.7. Figure 6.1 and appendices 6.2-6.7 depict the development of year-by-year average efficiency of all the container ports in the sample using window, contemporaneous and inter-temporal analyses, presuming in each case both the CCR and BCC model forms. It is clear from Figure 6.1 that the general trend of average efficiency for the results from applying window, contemporaneous and inter-temporal analysis during the study period is upward from 1998 to 2007, compared with the downward trends, with some fluctuations, in the period between 2007 and 2009. The former can be explained by the fact that long term technological advancement and continuous investment in ports infra/superstructure provide an important impetus for improving efficiency of container ports under study, while the latter can be attributed to the economic and financial crisis that took place in 2008 and 2009 and had its negative impact on the world trade and shipping market accordingly.

Consequently, the decision as to whether to accept or reject hypothesis four hinges on the definition of efficiency that is applied. Hypothesis four cannot be rejected if the efficiency under study refers to an overall efficiency that is affected by technological innovation and management. However, hypothesis Four can be rejected if it is held to refer solely to whether a firm follows best practice at any particular time.

Through the use of a time period presented by a window width of five years, in this research, the different container ports, DMUs, (it is important to highlight herein that the same port observed at different time periods is treated as being different ports) are assumed to apply the same or similar management and technology. In such a case, the efficiency results are not greatly affected by the management and technology utilised. Thus, advances in technology do not necessarily entail overall efficiency enhancement.

Figure 6.1 also explains that the average efficiency for window, contemporaneous and inter-temporal analyses exhibit an upward trend. This is not surprising as each port in this study is compared with 21 other counterparts and the frontier defined by all the ports in the same set for contemporaneous analysis. However, each port is benchmarked with 110 and 330 other counterparts and the frontier defined by all the ports in each of these sets for window and inter-temporal analyses respectively.

A large sample is clearly more likely to make a port appear inefficient. An ANOVA of the mean efficiency of each port over time for Window, Contemporaneous and inter-temporal analyses, F =11.19 and 9.96 corresponding, respectively, to DEA–CCR and DEA–BCC analyses, demonstrates that the means of the efficiency measures calculated using these three different approaches are significantly different at the 1% level. On the other hand, Spearman's rank order correlation coefficient between the efficiency derived from the three approaches ranges from 0.95 to 1.0. The strong value of this coefficient explains that the three approaches yield similar rankings of efficiency for container port production.

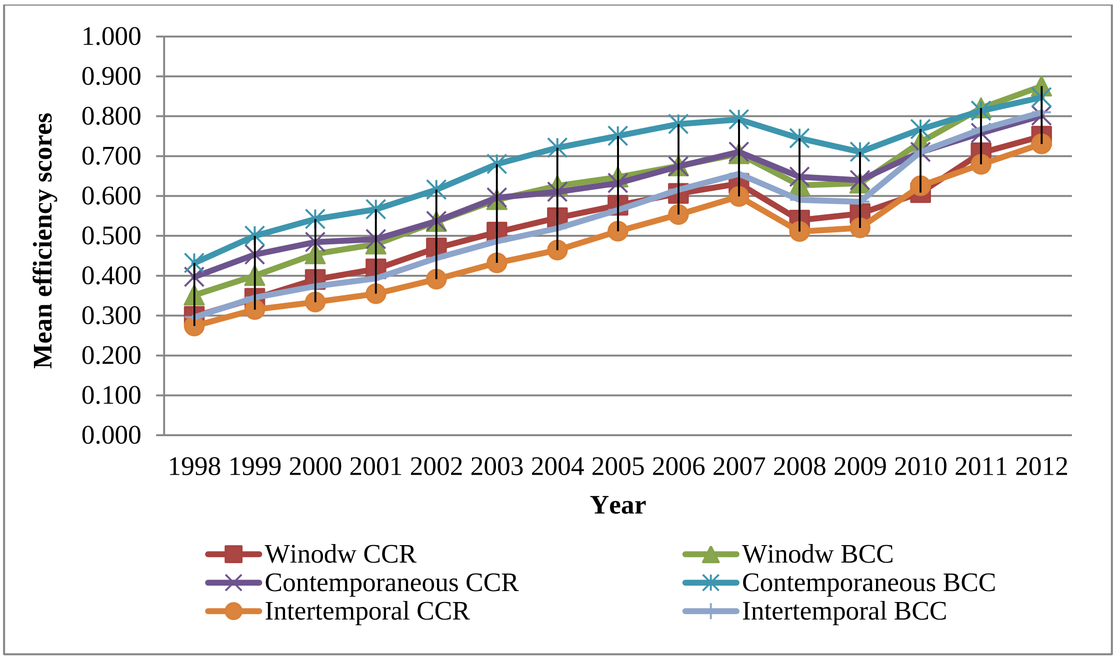

Figure 6. 1- Year by year mean efficiency scores for Mediterranean main container ports (1998-2012)

Table 6.7 shows the Spearman's rank order correlation coefficient of various levels of efficiency calculated by different models indicated above. The correlation coefficient between the efficiency rankings derived from DEA-CCR and DEA-BCC analyses varies between 0.85 and 1.0. The high coefficient values demonstrate that these alternative approaches have similar efficiency scores in terms of the rankings of the ports under study and support the results of Bauer et al. (1998).

The results attained in this study reveal that ports with greater transhipment traffic tend to be more technically and scale efficient than those with greater local traffic. As such, when the results are analysed with respect to the presence within the sample ports that are dedicated to transhipment containers such as SCCT in Port Said, they seems to be no evidence of any difference in technical efficiency between ports that adopt a strategy of establishing dedicated terminal operations or otherwise.

However, as explained by Wang et al. (2005) this may be more realistic and explain the comparative lack of managerial competence in container ports operations amongst shipping lines and the inevitable slack periods of inactivity associated with the dedicated terminal exclusively servicing a single shipping line.

Table 6. 7- Spearman's rank order correlation coefficient for DEA models

DEA model	Cross-section		Window		Contemporaneous		Inter-temporal	
	DEA-CCR	DEA-BCC	DEA-CCR	DEA-BCC	DEA-CCR	DEA-BCC	DEA-CCR	DEA-BCC
Cross-section DEA-CCR	1.000							
Cross-section DEA-BCC	0.984	1.000						
Window DEA-CCR	0.895	0.849	1.000					
Window DEA-BCC	0.895	0.849	1.000	1.000				
Contemporaneous DEA-CCR	0.895	0.849	1.000	1.000	1.000			
Contemporaneous DEA-BCC	0.894	0.850	0.978	0.955	0.980	1.000		
Inter-temporal DEA-CCR	0.895	0.849	1.000	1.000	1.000	0.990	1.000	
Inter-temporal DEA-BCC	0.894	0.850	0.960	0.970	0.990	1.000	0.990	1.000

Note: Correlation is significant at the 0.01 level (2-tailed).

Another inference of the results attained in this analysis is that gateway ports such as Genoa, Marseilles, Izmir and Naples appear to exhibit lower levels of technical efficiency than ports that specialise in transhipment such as Algeciras, GioiaTauro, Port Said and Marsaxlokk. This result is partially explained by the quasi-captive nature of gateway traffic that is destined for or sourced from well-defined hinterlands, in preference to the footloose nature of transhipment traffic. Obviously, in the case of the latter, there exists more of an incentive for increasing efficiency so as to improve port competitiveness in a competitive market (Cullinane et al, 2006).

However, In the case of the former, the fast expansion and overlapping of hinterlands is fast eroding the extent to which traffic can be guaranteed (Cullinane & Khanna, 2000). This result also entails a relationship between hub or feeder port status and technical efficiency. In the same context, it is also significant to know that the efficiency scores may also be a function of the incentives that exist upon management in order to be efficient. Where resources are limited, there is a likelihood of lower levels of efficiency. This goes some way to express why ports such as Valencia and

Barcelona, where land is at a premium and are habitually more efficient than where this is less of a constraint, have emerged as technically efficient even though it is known that they encounter problems of port congestion.

In other words, in spite of an excess of demand for the use of these ports, it would seem that every effort is being made to service their customer base to the maximum of their ability. In this context, the next part of this section analyses the relation between ports' production (throughput) and their scale efficiency. The study of the ports scale efficiency provides a tool for decision makers in ports to set their future investment plans according to the current efficiency status of a port as well as the estimated future demand, in terms of container traffic, on port services.

6.3.2 Scale efficiency analysis

The issue of scale of operation is problematic. Given the homogeneity of the container throughput that represents the output variable within all the models applied herein, the analysis does enable the determination of the relationship between efficiency and scale. Obviously, the economies of scale do exist in container port operations (Cullinane et al, 2006). As such, ports with the largest throughput tend to show the highest levels of technical efficiency. However, the largest ports are not necessarily scale efficient, with some container ports such as Piraeus and Alexandria all showing average scale efficiency. Seemingly, this might seem to propose that appropriate management decision making on the utilisation of existing resources seems not to be inconsistent with sound decisions on the nature and timing of infrastructure investment (Wang et al, 2005).

As explained in chapter four, CRS and VRS are the efficiency scores derived from respectively assuming constant and variable returns to scale. When SE is less than1, ports encounter scale inefficiency, driving higher overall inefficiency compared to pure technical inefficiency. In contrast, when SE equals to 1, ports are operating at efficient scales, producing at the optimal level for which they were designed (Cullinane and Wang, 2010). However, the appropriate direction in scale adjustments can be identified only with the nature of returns to scale, that is, increasing (IRS) or decreasing (DRS).

Merk and Dang (2012) illustrated that for ports operating at IRS (output increases proportionally more than the increase in inputs), production level should be expanded. This is normally the case for ports operating below optimal levels as long as current business traffic, while building up gradually, remains below the optimal capacity of port infrastructure. On the contrary, when ports operate at DRS (output increases proportionally less than the increase in inputs) they should reduce their production toward lower optimal levels to limit inefficiencies, for instance, in case of congestion. However, in the long-term, the choice of increasing the optimal level of production through investing in higher port infrastructure should also be considered.

The status of returns to scale explains essential information; the various statuses are due to the different utilisation of variable inputs and fixed inputs (Lin and Tseng, 2007). Table 6.8 and appendices 6.8-6.10 shows three different statuses of returns to scale. When a port encounters constant returns to scale, it demonstrates that its current size is optimal (scale optimal). When the current size of the port is smaller than the optimal size, the port encounters increasing returns to scale. In contrast, when the size of the port is larger than the optimal size, the port exhibits decreasing return to scale (Cullinane et al, 2004).

Compared with the traditional self-appraisal of the DEA-CCR and BCC models, the SCE model was applied to calculate a simple cross-sectional efficiency value for peer-appraisal. Table 6.8 shows that the scale efficiency values of four out of 22 ports of the study, Valencia, Port Said, Algeciras and GioiaTauro, are 1.00 with constant return to scale in 2012. The next four ports which are Ambarli, Marsaxlokk, Tangier and Genoa have scale efficiency close to unity which is 0.980, 0.977, 0.953 and 0.949 respectively. All these ports experience decreasing return to scale except Ambarli which has increasing return to scale. Under such a peer-evaluation regime, Constantza and Naples showed poor performances over the study period. They had scale efficiency scores of 0.553 and 0.317 respectively with an increasing return to scale.

In order to analyse these results on economies of scale, a caution must be exercised. This is because of the inconsistent investment in port infrastructure (Wang et al, 2005; Cullinane et al, 2006). Investments of substantial capital sums are made very rarely and, with an objective to cater for future growth in port demand, often have the impact of expanding capacity to levels well above what may be currently needed. It is a clear redundancy to indicate that this is more likely to be the case for large ports, rather than for smaller ports. Thus, this is a possible limitation of any cross-sectional analysis and offers support for an approach based on panel data that may capture the dynamics related to the characteristics of the port industry (Cullinane & Wang, 2006).

Port panel data allows a comprehensive benchmark of the returns to scale status to be made. The panel data window analysis contains 5 observations which form a panel data set of 22 container ports in the Mediterranean basin for 15 years, 1998 –2012. Table 6.8 and appendices 6.8-6.11 detail the scale properties of each container port at various times and over different windows. In our panel, Table 6.8 and appendices 6.8-6.10 show that 28.7% of the ports under study exhibit constant returns to scale compared with 43.9% of the ports exhibiting decreasing returns to scale and 27.4% exhibiting increasing returns to scale.

With respect to panel data contemporaneous analysis, appendix 6.12 shows that in 1998, 4 out of 16 ports - it is an unbalanced panel dataset where the information of ports of Port Said, Ambarli, Tangier, Taranto, Cagliari and Constantza are not available for the year of 1998 - showed constant returns to scale, while 6 ports showed increasing returns to scale and 6 ports exhibited decreasing returns to scale.

In 2012, 9 ports exhibited constant returns to scale, 7 ports exhibited decreasing returns to scale and 6 ports exhibited increasing returns to scale. Appendix 6.13 shows the inter-temporal panel data set of 330 observations of 22 ports for 15 years from 1998 to 2012. Appendix 6.13 demonstrates that 67 out of 314[3] (21.3%) ports (observations) show constant returns to scale, while 142 (45.2%) ports exhibit decreasing returns to scale and 105 (33.4%) show increasing returns to scale.

In general, decreasing return to scale dominates in the cross sectional and panel data sets of the window, contemporaneous and inter-temporal analysis. Table 6.8 also shows that the mean scale efficiency for the study ports is relatively above average, between 0.844 and 0.872 for the panel data analysis and the standard deviation for the

[3]It is an unbalanced panel dataset where the information of ports of Port Said, Ambarli, Tangier, Taranto, Cagliari and Constantza are not available for certain years. There are 16 missing observations.

scale efficiency scores is between 0.07 and 0.12 that means that the scale of production for most of the study ports is almost stable during the period of study. Table 6.8 and appendices 6.11-6.13 are evidence that the majority of the container ports with throughput of one million TEUs and higher in a year tend to operate at decreasing returns to scale (DRS).

This is because the port capital investments are often made in large amounts intermittently with the expectation of a long working life. As such, ports often design their capacity to be higher than its current market demand, even if port traffic only increases gradually over time (Cullinane and Wang, 2006).In contrast, smaller sized container ports with output below one million TEUs a year, show either CRS or IRS. This outcome corresponds to the findings in Wang and Cullinane (2006b) in their investigation of the efficiency of 104 container terminals in European ports.

In the context of comparing the relative efficiency of container ports in this research, variable inputs represent the inputs that can be changed during the period of study and the fixed inputs remain constant during the study period. In this study the variable inputs are the container ports' infrastructure such as terminals areas, quay length and maximum depth and ports' superstructure such as handling equipment.

Variable inputs are the inputs indicated in the model, whereas fixed inputs are not captured by the model because they remain the same throughout the study. Therefore, the elements that restrict the adjustment of variable inputs (infrastructure and equipment) are considered as the fixed inputs such as available land for port use.

For all the ports that encounter increasing return to scale in their operations, increases in inputs will result in more than a proportional increase in outputs. Hence, the ports that operate with IRS could attain significant efficiency gains by increasing their scale of operations.

Table 6. 8- DEA Cross-sectional and panel data mean scale efficiency scores for main Mediterranean container ports (1998-2012).

Port	Cross-section (2012)		Window			Contemporaneous			Inter-temporal		
	Scale efficiency	Return to scale	Mean	St. Dev.	Return to scale	Mean	St. Dev.	Return to scale	Mean	St. Dev.	Return to scale
Valencia	1.000	CRS	0.953	0.035	DRS	0.961	0.032	DRS	0.908	0.045	DRS
Port Said	1.000	CRS	0.953	0.037	DRS	0.978	0.017	DRS	0.953	0.046	DRS
GioiaTauro	1.000	CRS	0.999	0.004	CRS	1.000	0.000	CRS	1.000	0.000	CRS
Algeciras	1.000	CRS	0.985	0.035	CRS	1.000	0.000	CRS	1.000	0.000	CRS
Ambarli	0.980	IRS	0.735	0.356	DRS	0.846	0.120	DRS	0.869	0.044	DRS
Marsaxlokk	0.977	DRS	0.977	0.037	DRS	0.914	0.051	DRS	0.982	0.019	DRS
Tangier	0.953	DRS	0.642	0.389	DRS	0.852	0.071	DRS	0.839	0.081	DRS
Barcelona	0.924	DRS	0.883	0.072	DRS	0.925	0.031	DRS	0.886	0.065	DRT
Genoa	0.949	DRS	0.916	0.048	DRS	0.965	0.028	DRS	0.928	0.060	DRS
La Spezia	0.873	DRS	0.772	0.135	DRS	0.840	0.164	DRS	0.829	0.060	DRS
Haifa	0.864	IRS	0.838	0.084	IRS	0.888	0.066	IRS	0.820	0.104	IRS
Damietta	0.788	IRS	0.788	0.115	IRS	0.818	0.165	IRS	0.884	0.087	IRT
Mersin	0.832	DRS	0.847	0.092	DRS	0.839	0.126	DRS	0.881	0.052	DRS
Marseilles	0.876	DRS	0.783	0.165	DRS	0.737	0.077	DRS	0.823	0.069	DRS
Piraeus	0.911	DRS	0.919	0.063	DRS	0.922	0.076	DRS	0.843	0.094	DRS
Alexandria	0.856	DRS	0.774	0.072	DRS	0.874	0.112	DRS	0.789	0.087	DRT
Izmir	0.848	IRS	0.812	0.104	IRS	0.825	0.149	IRS	0.847	0.063	IRS
Livorno	0.586	IRS	0.773	0.141	IRS	0.744	0.107	IRS	0.804	0.095	IRS
Taranto	0.619	DRS	0.784	0.135	DRS	0.609	0.210	DRS	0.773	0.144	DRS
Cagliari	0.590	IRS	0.823	0.138	IRS	0.889	0.072	IRS	0.906	0.101	IRS
Constantza	0.553	IRS	0.754	0.250	IRS	0.696	0.139	IRS	0.712	0.107	IRS
Naples	0.317	IRS	0.848	0.126	IRS	0.985	0.022	IRS	0.915	0.049	IRS
Mean	0.831		0.844	0.120		0.869	0.083		0.872	0.067	

The scale could be changed through internal growth or consolidation in the sector. For the ports that are operating at decreasing returns to scale, a further increase in inputs would only results in a smaller proportional raise of outputs. The ports that encounter DRS should reduce their scale inefficiency by decreasing their scale of operations by giving up some of the terminal assets and operational functions to other specialised entities through concessions and leaseholds.

In practice, the main difference between increasing and decreasing returns to scale is about the investment decision. For an increasing return to scale port, more investment will increase the port's productivity. For a decreasing return to scale port, more investment will decrease the port's overall productivity. In order to increase their capacity, ports that show increasing returns to scale can therefore invest in the variable inputs. Ports that exhibit constant and decreasing returns to scale cannot increase their capacity quickly by merely investing in the variable inputs because the fixed inputs are limiting their capacity expansion, as such, fixed inputs must also be addressed in order to increase the capacity.

As explained in chapter 1, the world container port traffic is growing at an average rate of 12.2% per year. In this context, returns to scale status would be more desirable for container ports and terminals because they can adapt quickly to the fast-growing demand for ports. As illustrated in Table 6.8, some container ports in the Mediterranean basin appear to be ready to meet future growth in demand, since they exhibit increasing returns to scale, whereas most ports exhibit decreasing returns to scale.

Even though the container handling operation can be managed by port authorities and different private terminal operators, container ports as a whole are commonly managed and operated through the Public-Private Partnership concept. On the other hand, when container ports are operated by private sector, the ports are considered to be private organisations. Nowadays increasing numbers of container terminals are managed and operated by private companies such as Hutchison Port Holdings, APM Terminals and DP world. Therefore, the result of the analysis conducted here proposes that, in the container handling industry, the private sector is better able than the public sector to adapt to market demand.

In this context, the fifth hypothesis **(H5)**, as mentioned in chapter one reveals that "*The technical efficiency increases as the scale of a container port increases"*. In other words, a large-scale container port is more likely to be associated with high efficiency than a small one. To test this hypothesis, efficiency estimates based on both cross-sectional and panel data are utilised. This is because in the case of the former every single firm is observed only once and, hence, the efficiency estimates that result may be influenced by random effects and, therefore, may be misleading. This potential drawback is largely overcome through the use of panel data. Another advantage of using panel data in this study is that the sample size increases from 22 DMUs, in cross-sectional analysis to 1210 DMUs in the window analysis. Thus, the statistical validity of the results and inferences drawn from the analysis of this enlarged sample are able to provide more reliable results than would otherwise be the case.

Table 6.9 shows the relationship between production size, ports' throughput, and efficiency, as measured by the Spearman's rank order correlation coefficient (ranging from 0.88 to 0.92). The fact that the signs for Spearman's rank order correlation coefficient are positive does entail that the production volumes of container ports are positively associated with efficiency scores. On the other hand, the high absolute value, 0.92, of the Spearman's rank order correlation coefficient would seem to denote that the efficiency of ports under study is significantly related to scale of production.

The inefficient seaports in the region are of two types; first, the medium sized container ports are inefficient as they have an increase in return to scale, such as Haifa, Damietta and Izmir which need to boost more and more their scale size of production to be more efficient; second, the big seaports such as Barcelona and Genoa are inefficient as they have a decrease in return to scale and need to boost their scale size of production to be more efficient.

The comparison between the large container ports and medium sized container ports in the Mediterranean is to ensure that the indicators of production scale are not the main factors of efficiency and inefficiency, as some container ports with lower scale of production are efficient and others with higher scale are inefficient. In this research, the large container ports under study are more efficient than the medium sized container ports because of economies of scale. In other words, the size of operations and technical efficiency of ports are systematically positively related to each other. This finding is consistent with that of other studies in the literature (Turner et al, 2004; Tongzon and Heng, 2005; Niavis and Tsekeris, 2012) which have shown a clear positive relationship between the size and efficiency of ports.

Table 6. 9- Relation between ports throughput and ports' efficiency

Data Type	DEA model	Correlation between Throughput & Efficiency
		Spearman's rank order correlation
Cross-sectional	DEA-CCR-O	0.9240
	DEA-BCC-O	0.8880
Panel	DEA-CCR-Window	0.8950
	DEA-BCC-Window	0.8950
	DEA- CCR-Contemporaneous	0.8960
	DEA- BCC-Contemporaneous	0.8910
	DEA- CCR-Inter-temporal	0.8960
	DEA- BCC-Inter-temporal	0.8910

This differs from the usual informal assumption that prompted the formulation of hypothesis five in the first place and also contradicts some prior empirical evidence (Kim and Sachish, 1986; Tongzon, 1993; Jara-Diaz et al., 1997; Drewry Shipping Consultants, 2000; Jara-Diaz et al, 2001; Robinson, 2002).

One possible justification for this is that the apparent relative inefficiency of large container ports in the Mediterranean such as Piraeus and Ambarli is due, not only to managerial deficiencies, but more so to the overcapacity that results from the more intensive efforts of larger ports to maintain or enhance productivity levels. These efforts display themselves through the introduction of more significant investment than their smaller counterparts and, therefore, the wider availability of large numbers and sophisticated equipment. As such, the competitiveness of larger container ports or terminals is thereby increased, relative to the rest of the market. Thus, although empirical support for hypothesis five using this methodology is hardly categorical, neither can it be rejected with alacrity. Instead, it is most appropriate to presume that it should be accepted but cautiously.

This is not unexpected considering the fact that large container ports are more likely to utilise more state-of-the-art equipment than their smaller counterparts. This finding is consistent with that of the distinctive work established by De Neufville and Tsunokawa (1981) who studied a sample of a mere five container ports in the USA over the time period 1970–1978 and found that the production of smaller container ports had a tendency to follow the law of increasing returns to scale.

Having analysed and benchmarked the returns to scale status for container ports in the Mediterranean Sea, Although CCR and BCC models offer a method to classify container ports into efficient and inefficient DMUs, it is impossible to determine the relative rankings among the efficient DMUs. When there are several efficient ports with an efficiency index equal to unity, like in this study, it is difficult to tell which port is more efficient than other ports. To overcome this limitation, in order to decide the rank of each container port in the view of overall technical efficiency, the next section ranks the efficiency scores of Mediterranean container ports under study by using the DEA super-efficiency (A&P) 1993 model applied to the output-oriented CCR model.

6.3.3 Super efficiency (A&P) analysis

Although DEA-CCR and BCC models can classify container ports into efficient and inefficient DMUs, it is impossible to verify the relative rankings among the efficient DMUs. When there are a number of efficient ports, with efficiency scores equal to one, as in this research, it is difficult to determine the most efficient ports and to categorize these ports in relation to each other. In order to overcome this limitation, reinforce the discriminatory power of the DEA-CCR model and to determine the rank of each container port in terms of technical efficiency, the research uses the DEA-CCR (CRS), A&P, Super-Efficiency scores in an output-oriented model.

Table 6.10 and Appendices 6.1, 6.14-6.16 illustrate the DEA-CCR cross-sectional super efficiency scores for 2012 as well as the mean super-efficiency scores of the panel data for the period between 1998 and 2012 for the main Mediterranean container ports. In the context of the cross-sectional data, Table 6.10 shows that four ports out of the 22 ports of the study have efficiency scores more than one. These top four ports are Algeciras, Port Said, Valencia and GioaTauro and have super-efficiency scores of 1.858, 1.591, 1.093 and 1.006 respectively. In contrast, as the super-efficiency estimates of inefficient container ports are equivalent to the efficient indices in the CCR model, Naples is the most inefficient. While the inefficiency on inputs and outputs in efficient container ports are all zero (So et al, 2007), there are several inputs or insufficient output in inefficient container ports. In this context, Cagliari, Constantza and Naples show the lowest super-efficiency scores of 0.276, 0.233 and 0.126 respectively.

As far as the panel data analysis is concerned the DEA-CCR super- efficiency window, contemporaneous and inter-temporal analysis are applied to rank the relative efficiency of the 22 container ports in the Mediterranean for the period of 15 years from 1998 to 2012. For the window analysis, Table 6.10 and appendix 6.14 indicate that the port of Algeciras is the only port that exhibits a mean value of greater than 1 under the super-efficiency model, while the analysis showed that all container ports under study have a mean value of less than one. In terms of the DEA-CCR contemporaneous analysis, Table 6.10 and Appendix 6.15 illustrate that the top two ports that have super-efficiency scores of more than one are the ports of Algeciras and GioiaTauro that have super-efficiency scores of 1.527 and 1.314 respectively.

The rest of the study ports have recorded super-efficiency scores of less than one during the study period. The inter-temporal analysis has also indicated the same results over the study period. Table 6.10 and appendix 6.16 show that ports of Algeciras and GioiaTauro are the top ports with super-efficiency scores of 1.238 and 1.120 respectively. The rest of the sample ports have recorded super-efficiency scores of less than one during the study period. In particular, ports of Cagliari, Constantza and Naples show the lowest super-efficiency scores under all panel data analyses.

Table 6. 10- DEA-CCR Cross-section and mean panel data super-efficiency scores for main Mediterranean container ports (1998-2012).

Port	DEA-CCR mean super-efficiency (A&P) scores						
	Cross-section (2012)	Window		Contemporaneous		Inter-temporal	
	(A&P)	(A&P)	St. Dev.	(A&P)	St. Dev.	(A&P)	St. Dev.
Valencia	1.093 (3)	0.827	0.052	0.913	0.074	0.803	0.126
Port Said	1.591 (2)	0.787	0.085	0.898	0.050	0.730	0.172
GioiaTauro	1.006 (4)	0.940	0.192	1.314	0.277	1.120	0.090
Algeciras	1.858 (1)	1.020	0.314	1.527	0.274	1.238	0.094
Ambarli	0.953 (6)	0.649	0.107	0.753	0.142	0.506	0.159
Marsaxlokk	0.961 (5)	0.915	0.260	0.992	0.015	0.913	0.053
Tangier	0.835 (9)	0.655	0.129	0.767	0.094	0.527	0.171
Barcelona	0.783 (10)	0.676	0.114	0.838	0.071	0.574	0.137
Genoa	0.836 (8)	0.741	0.086	0.882	0.057	0.630	0.157
La Spezia	0.729 (13)	0.506	0.083	0.631	0.108	0.440	0.149
Haifa	0.708 (14)	0.463	0.113	0.577	0.094	0.391	0.159
Damietta	0.643 (17)	0.399	0.098	0.504	0.224	0.362	0.180
Mersin	0.653 (16)	0.450	0.070	0.543	0.196	0.388	0.168
Marseilles	0.687 (15)	0.373	0.093	0.422	0.148	0.329	0.129
Piraeus	0.886 (7)	0.639	0.165	0.718	0.154	0.486	0.200
Alexandria	0.730 (12)	0.500	0.072	0.586	0.145	0.411	0.172
Izmir	0.759 (11)	0.425	0.089	0.516	0.126	0.367	0.186
Livorno	0.438 (18)	0.355	0.087	0.411	0.177	0.304	0.114
Taranto	0.373 (19)	0.318	0.104	0.323	0.181	0.254	0.087
Cagliari	0.276 (20)	0.258	0.103	0.287	0.107	0.221	0.099
Constantza	0.233 (21)	0.293	0.120	0.308	0.098	0.233	0.096
Naples	0.126 (22)	0.208	0.090	0.266	0.098	0.205	0.083
Mean	0.779	0.564	0.119	0.681	0.132	0.520	0.136

It is noted that the throughputs of container ports in this region are not stable, due to the instability in the shipping market. The establishment of container hubs in the Mediterranean region will increase the ships entrance into the container ports and this will contribute effectively to development of the economy and at the same time to enrich maritime traffic in the region. The ports authorities should modify their policies to stimulate shipping lines to call their ports, such as to ensure port security, decreasing the port dues and to enhance service performance.

The relation between the DEA-CCR (CRS) mean super efficiency scores and their standard deviation is examined by using the correlation coefficient. The CRS Super-

Efficiency scores are chosen for the analysis because they capture the total technical efficiency and adequately discriminate between the efficient DMUs. The correlation between mean super-efficiency scores with their standard deviation for the window, contemporaneous and inter-temporal analysis are 0.6011, 0.2140 and 0.4247 respectively. The correlation coefficients are statistically positive for super-efficiency scores. The comparison of the container ports efficiency over the time window set and across different reference sets, shows fluctuation in the efficiency score.

This fluctuation is the result of the comparison between the large container ports, which have high production, and medium container ports, which have medium/low production. It may also have resulted for reasons such as the world and financial crisis that took place in the years of 2008 and 2009 and had significant impacts on the world liner trade and accordingly the container ports traffic.

The above outcomes demonstrate that both the lack of managerial skills and scale diseconomies are important sources of inefficiency for most of the container ports in the defined market. A detailed knowledge of the results of this analysis would help the port management to determine where they stand in the efficiency hierarchy and which ports they need to benchmark themselves against in order to enhance their own efficiency. The next section illustrates the sensitivity analysis that is used to investigate the impact when outputs or inputs are added or withdrawn from consideration (Cooper et al, 1999) when benchmarking the operational efficiency of the ports under study.

6.3.4 Sensitivity analysis

Sensitivity analysis is used to estimate the degree of variables' contribution to the value of DEA-CCR efficiency scores. This can be conducted by eliminating input or output variables, one by one, from the variables' combination. In this study, only the input variable is removed due to the use of a single output variable represented by the ports' throughput. Table 6.11 explains the sensitivity analysis of the Mediterranean main container ports in 2012. Table 6.11 shows that the removal of terminal area decreased the efficiency values of Port Said from being efficient, with efficiency score equal to unity, to 0.879. It also reduced the efficiency scores of Genoa from

0.836 to 0.816 and Haifa from 0.708 to 0.543 and Marseilles from 0.687 to 0.508 and Cagliari from 0.276 to 0.226.

The removal of storage capacity from the input variable combination has shifted the port of Algeciras from being efficient, with an efficiency score equal to unity, to an inefficient port with an inefficiency score of 0.903. The removal of the same variable has significantly reduced the efficiency estimates of ports of Marsaxlokk, Barcelona and La Spezia from 0.961, 0.783 and 0.729 to 0.767, 0.544 and 0.537 respectively. Similarly, the efficiency scores of ports of Mersin, Alexandria, Izmir and Livorno were reduced form 0.653, 0.730, 0.759 and 0.438 to 0.211, 0.246, 0.528 and 0.332.

The omission of the quay length as an input variable in the efficiency benchmarking model has shifted the ports of Port Said and GioiaTauro from being efficient to inefficient port with an efficiency score of 0.953 and 0.937 respectively. The elimination of the same variable reduced the relative efficiency of ports of Ambarli and Tangier form 0.953 and 0.835 to 0.338 and 0.568. It also reduced the efficiency estimates of ports of Genoa, Haifa, Damietta, Mersin, Taranto and Constantza from 0.836, 0.708, 0.643, 0.653, 0.373 and 0.233 to 0.625, 0.530, 0.525, 0.483, 0.324 and 0.215 respectively.

The removal of the port's maximum depth has shifted the ports of Valencia, Port Said, GioiaTauro and Algeciras from being efficient to inefficient ports with inefficiency scores of 0.919, 0.785, 0.577 and 0.469 respectively. It also reduced the efficiency scores of ports of Marsaxlokk Barcelona, La Spezia, Haifa, Alexandria and Livorno from 0.961, 0.783, 0.729, 0.708, 0.730 and 0.438 to 0.809, 0.711, 0.527, 0.594, 0.529 and 0.312 respectively.

The omission of the handling equipment variable has also shifted the ports of Valencia, Port Said, GioiaTauro and Algeciras from being efficient to inefficient ports in 2012. The ports’ relative efficiency scores reduced from unity to 0.674, 0.806, 0.620 and 0.714 respectively. The elimination of the same variable has reduced the relative efficiency scores of ports of Tangier, Barcelona and Damietta from 0.835, 0.783 and 0.643 to 0.616, 0.725 and 0.610 respectively. Similarly, it reduced the relative efficiency estimates of ports of Piraeus, Cagliari and Naples from 0.886, 0.276 and 0.126 to 0.453, 0.187 and 0.095 in 2012 respectively.

Table 6.11 explains that the storage capacity, quay length, ports’ maximum depth and handling equipment are the main influential variables that affect the study ports operational efficiency. The storage capacity, quay length and ports’ maximum depth affected the relative efficiency scores of 8 ports out of the 22 ports under study, while the handling equipment, as an input variable, affects the relative efficiency of 10 of the ports under study.

The above analysis indicates the importance and the validity of using the input variables that are used in the context of this study when benchmarking the relative efficiency of container ports. Table 6.11 illustrates that the ports’ relative efficiency scores have declined after the omission of every individual input variable. Moreover, the DEA-CCR sensitivity analysis allows for the identification of the most significant variable (inputs) that have a great impact on port technical efficiency. As such, the management of each port should therefore strive for complete and detailed data collection with regard to its operations, and conduct an annual detailed analysis. This will not only help management to respond to the ever increasing pressure of port competition, but also serve as a basis for objective decision-making with respect to on-going improvement in operational efficiency and accordingly the enhancement of a port’s competitiveness.

Table 6. 11- Sensitivity analysis of Mediterranean main container ports (2012)

Port	DEA-CCR (2012)	Efficiency score after input deleted (2012)				
		Terminal area (ha)	Storage capacity (TEU)	Quay length (m)	Maximum depth (m)	Handling equipment
Valencia	1.000	1.000	1.000	1.000	**0.919**	**0.674**
Port Said	1.000	**0.879**	1.000	**0.953**	**0.785**	**0.806**
GioiaTauro	1.000	1.000	1.000	**0.937**	**0.577**	**0.620**
Algeciras	1.000	1.000	**0.903**	1.000	**0.469**	**0.714**
Ambarli	0.953	0.953	0.953	**0.338**	0.953	0.953
Marsaxlokk	0.961	0.961	**0.767**	0.961	**0.809**	0.961
Tangier	0.835	0.835	0.835	**0.568**	0.835	**0.616**
Barcelona	0.783	0.783	**0.544**	0.783	**0.711**	**0.725**
Genoa	0.836	**0.816**	0.836	**0.625**	0.836	0.836
La Spezia	0.729	0.729	**0.537**	0.729	**0.527**	0.718
Haifa	0.708	**0.543**	0.708	**0.530**	**0.594**	0.708
Damietta	0.643	0.643	0.643	**0.525**	0.643	**0.610**
Mersin	0.653	0.653	**0.211**	**0.483**	0.653	0.653
Marseilles	0.687	**0.508**	0.687	0.687	0.687	0.687
Piraeus	0.886	0.886	0.886	0.886	0.886	**0.453**
Alexandria	0.730	0.730	**0.246**	0.628	**0.529**	0.730
Izmir	0.759	0.759	**0.528**	0.759	0.759	0.759
Livorno	0.438	0.438	**0.332**	0.438	**0.312**	0.438
Taranto	0.373	0.366	0.373	**0.324**	0.368	0.373
Cagliari	0.276	**0.226**	0.276	0.274	0.276	**0.187**
Constantza	0.233	0.230	0.231	**0.215**	0.232	**0.224**
Naples	0.126	0.126	0.126	0.126	0.124	**0.095**

In addition to examining and analysing the sensitivity of input variables being used for efficiency analysis, the next section provides other measurement related to the inefficient DMUs. Particularly, DEA determines the efficient feature being used for benchmarking as well as a combination of the inputs which are being inefficiently used and the divergence of specific outputs from the efficient level. Because efficient DMUs do not have any slack, this measurement is only useful for inefficient DMUs.

6.3.5 Slack variable analysis

DEA models provide analysis of input surplus and output deficit for resource utilisation. The slack analysis of DEA investigates the use of input and output resources to enhance efficiency estimates, and hence set benchmarks for other ports (Lin and Tseng, 2007). In the context of this research, since there is only one output and five inputs, we may have at most one output shortfall and two or three input excesses for relatively inefficient ports. In this context, this research should demonstrate where potential efficiency gains could be enhanced, providing insights for guiding development policy strategies that yield more efficient ports. Table 6.12 shows the cross-sectional slack analysis of the main container ports in the Mediterranean for 2012. Table 6.12 shows that there are four ports considered as efficient as they achieved the optimum utilisation of their facilities with relative efficiency scores of 1.0 under the DEA-CCR model in 2012. These ports are Valencia, Port Said, GioiaTauro and Algeciras. The slack variable analysis showed that the ratios of input variables to output variable of these ports were appropriate, and they were capable of applying their input resources effectively to achieve improved efficiency.

In contrast, the rest of the ports under study (18 ports) are considered as relatively inefficient and they have to either increase their output or minimize their inputs to increase their efficiency scores to be equal to one. The Port of Ambarli that has the sixth place in the super-efficiency analysis with DEA-CCR super-efficiency score of 0.953 should increase its container throughput by 22.3% or reduce the storage capacity by 25.7%. The port could also reduce the utilisation of the quay length by 44.2% and the handling equipment by 68.9%.

Port of Genoa, that has the eighth place in the DEA-super efficiency ranking with an efficiency score of 0.836, needs to either increase its throughput by 5.0% or reduce its terminal area by 9.0%, Quay length by 10.0% and number of handling equipment by 8.0%. Port of Taranto that needs to either increase its throughput by 44.0% or to reduce its terminal area by 41.0%, storage capacity by 38.0%, quay length by 6.0% and handling equipment by 10.0%. Port of Cagliari needs to either increase its container throughput by about 43.0% or to reduce the utilisation of its storage capacity by 32.5%, reduce its port draft by about 7% or to minimize the utilisation of the handling equipment by 28.2%. Another example is the port of Naples that has the last position in the super-efficiency rank (22). The port has to either increase its container throughput by 108.6% or to reduce the utilisation of its storage capacity by 27.5%, reduce the occupation of the terminal length by about 7% or to reduce the utilisation of the handling equipment by 27.5%.

By having a cursory glance on Table 6.12, it can be noticed that most of the inefficient ports under study need to either increase their output in terms of annual container throughput or reduce the utilisation of their inputs in terms of ports' infrastructure and handling equipment. In the context of the output maximisation, Table 6.12 reveals that most of the inefficient ports that have a relative medium efficiency scores, less than 1.000 and greater than 0.700, should increase their throughput by a percentage between 2.0% & and 25%. However, the odd cases in this study are the ports that have low relative inefficiency scores, below 0.500, such as Livorno, Taranto, Cagliari, Constantza and Naples. In order to be efficient, these ports have to increase their throughput by a percentage between 30% and 108%.

In the context of inputs minimization, Table 6.12 reveals that most of the inefficient ports under study have problems with the utilization of their infrastructure and, in particular, the storage capacity. The percentage of the bad utilisation of this input varies between about 2.0% and 38.0%. It should also be noticed that the problem of poor utilisation of storage capacity arises with those ports that are operated under increasing returns to scale such as Ambarli, Taranto, Cagliari and Naples. In order to enhance their relative efficiency, these ports should adjust their storage capacity by 25.7%, 38.1%, 32.5% and 27.5% respectively.

Table 6. 12- DEA-Slack analysis and super-efficiency ranking for Mediterranean container ports in 2012

Port	DEA-CCR (2012)	Efficiency targets and potential improvement for each input and/or output								
		Throughput (TEU)			Terminal area (ha)			Storage capacity (TEU)		
		Actual	Target	Potential improvement	Actual	Target	Potential improvement	Actual	Target	Potential improvement
Valencia	1.000	4469754	4469754	0.00%	181.49	181.49	0.00%	112471	112471	0.00%
Port Said	1.000	4831165	4831165	0.00%	106.7	106.7	0.00%	48000	48000	0.00%
GioiaTauro	1.000	2721104	2721104	0.00%	160	160	0.00%	75000	75000	0.00%
Algeciras	1.000	4114231	4114231	0.00%	84.73	84.73	0.00%	43272	43272	0.00%
Ambarli	0.953	3097464	3788615	22.31%	77.96	77.96	0.00%	54062	40197	-25.65%
Marsaxlokk	0.961	2540000	2860370	12.61%	68.05	68.05	0.00%	15087	14465	-4.12%
Tangier	0.835	2220000	2273489	2.41%	79	50.22	-36.43%	35000	30900	-11.71%
Barcelona	0.783	1756429	1820321	3.64%	105.07	97.24	-7.45%	12020	12020	0.00%
Genoa	0.836	2064806	2120400	4.69%	143.1	130.44	-8.85%	66656	66656	0.00%
La Spezia	0.729	1247218	1328959.61	6.55%	43.2	43.2	0.00%	28500	26600	-6.67%
Haifa	0.708	1372209	1452209	5.83%	50	50	0.00%	18000	16800	-7.14%
Damietta	0.643	760000	820000	7.89%	60	60	0.00%	30000	27800	-7.33%
Mersin	0.653	1263495	1329933.97	5.26%	110	88.8	-19.27%	10000	8735	-12.65%
Marseilles	0.687	1061000	1172000	10.46%	83	74	-10.84%	2500	2500	0.00%
Piraeus	0.886	2745012	2745012	0.00%	77.6	77.6	0.00%	30500	30500	0.00%
Alexandria	0.730	1500000	1600000	6.67%	86.9	83	-4.49%	54914	52700	-4.03%
Izmir	0.759	700000	875000	25.00%	106.7	106.7	0.00%	3000	3000	0.00%
Livorno	0.438	1600000	2100000	31.25%	32.3	32.3	0.00%	20378	17280	-15.20%
Taranto	0.373	563461	897530	59.29%	105	62	-40.95%	80000	49550	-38.06%
Cagliari	0.276	627609	1100370.90	42.96%	40	40	0.00%	24000	16193.7	-32.53%
Constantza	0.233	620000	1262827.89	103.68%	61	56.7	-7.05%	20477	20477	0.00%
Naples	0.126	546818	1140690	108.61%	13.5	13.5	0.00%	4000	2900	-27.51%

Port	DEA-CCR (2012)	Efficiency targets and potential improvement for each input and/or output									Super efficiency scores (Ranking)
		Quay length (m)			Maximum depth (m)			Handling Equipment (unit)			
		Actual	Target	Potential improvement	Actual	Target	Potential improvement	Actual	Target	Potential improvement	
Valencia	1.000	4793	4793	0.00%	16	16	0.00%	220	220	0.00%	1.093 (3)
Port Said	1.000	2550	2550	0.00%	16.5	16.5	0.00%	127	127	0.00%	1.591 (2)
GioiaTauro	1.000	3011	3011	0.00%	15	15	0.00%	200	200	0.00%	1.006 (4)
Algeciras	1.000	2526	2526	0.00%	16	16	0.00%	97	97	0.00%	1.858 (1)
Ambarli	0.953	4330	2414.82	-44.23%	15.5	15.5	0.00%	290	235.24	-18.88%	0.953 (6)
Marsaxlokk	0.961	2258	2258	0.00%	15.5	15.5	0.00%	93	81	-12.90	0.961 (5)
Tangier	0.835	1200	1200	0.00%	18	7.76	-56.86%	66	59.76	-9.45%	0.835 (9)
Barcelona	0.783	4048	4048	0.00%	16	16	0.00%	178	165	-7.30%	0.783 (10)
Genoa	0.836	4713	4257.33	-9.67%	15	15	0.00%	186	170.95	-8.09%	0.836 (8)
La Spezia	0.729	1748	1748	0.00%	14.5	14.5	0.00%	53	49.1	-7.36%	0.729 (13)
Haifa	0.708	1360	1360	0.00%	14	14	0.00%	39	35	-10.26%	0.708 (14)
Damietta	0.643	550	550	0.00%	14.5	14.5	0.00%	88	81	-7.95%	0.643 (17)
Mersin	0.653	2425	2425	0.00%	12	12	0.00%	118	105.15	-10.89%	0.653 (16)
Marseilles	0.687	2750	2750	0.00%	14.5	14.5	0.00%	136	122	-10.29%	0.687 (15)
Piraeus	0.886	3100	3100	0.00%	16.5	16.5	0.00%	105	105	0.00%	0.886 (7)
Alexandria	0.730	2463	2463	0.00%	14	14	0.00%	121	110	-9.09%	0.730 (12)
Izmir	0.759	1325	1210	-8.68%	17	17	0.00%	101	88	-12.87%	0.759 (11)
Livorno	0.438	1883	1883	0.00%	14	14	0.00%	47	40	-14.89%	0.438 (18)
Taranto	0.373	1500	1414.36	-5.71%	15.1	15.1	0.00%	39	35	-10.26%	0.373 (19)
Cagliari	0.276	1520	1520	0.00%	16	14.86	-7.13%	39	28.1	-28.20%	0.276 (20)
Constantza	0.233	1722	1722	0.00%	14.5	14.5	0.00%	69	53.32	-22.72%	0.233 (21)
Naples	0.126	850	791	-6.94%	12	12	0.00%	15	11.2	-26.70%	0.126 (22)

Table 6.12 also indicates that 18 out of the 22 ports under study need to optimize the utilisation of their handling equipment. The percentage of poor utilisation of the handling equipment varies between 6.50% and 28.20%. Again the worst utilisation of that input appears in ports that operate under increasing returns to scale such Cagliari and Naples. In order to improve their relative efficiency, these ports need to reduce the utilisation of their handling equipment by 28.20% and 26.70% respectively.

From the above analysis, it can be noticed that the DEA technique determines the slacks associated with the container ports that have been identified as inefficient, and so offers a reference set of specific recommendations for each port to enhance efficiency. However, DEA does not express any possible root causes of the estimated (in)efficiency.

In fact, many factors affecting the efficiency of a container port could be posited. In this context the truncated regression analysis will be used in the next chapter to examine the effect of some explanatory (exogenous) factors on container ports efficiency and to derive the determinants of container port efficiency. Efficiency scores from the inter-temporal DEA-CCR super-efficiency model will be applied as the dependent variable within the regression model.

6.4 Chapter summary

The improvement of technical efficiency is critical for facilitating the role of ports as drivers of economic success in the modern competitive environment. The significance of this research is that it applies a three-stage procedure model that examines the impact of port technical efficiency on port competitiveness in the Mediterranean container market. As a second stage of the research model, by concentrating on the technical efficiency analysis of Mediterranean container ports, five non-parametric, DEA models are used to obtain technical efficiency scores for the cross-sectional data for the year of 2012 and panel data for the period between 1998 and 2012.

The use of five DEA models enabled a comprehensive assessment of the relative efficiency of the main container ports in the Mediterranean. The application of DEA-CCR/BCC models benchmarked the technical and pure technical efficiency of the ports under study. The analysis revealed that four ports are considered as efficient as they achieved the optimum utilisation of their facilities with relative efficiency scores of one. These ports are Valencia, Port Said, GioiaTauro and Algeciras. However, the rest of the ports under study are considered as relatively inefficient. To be efficient, they have to either increase their output or minimize their inputs to increase their efficiency scores to be equal to one.

The application of the super-efficiency (A&P) model identified the super-efficient ports. The use of the scale efficiency model has determined trends in port efficiency and has established a return to scale (constant, increasing or decreasing) for each port. Using sensitivity analysis and slack variable analysis has also provided useful information that demonstrates how a relatively inefficient container port can improve its operational efficiency. The former identified the most important variables that affect the technical efficiency of each port, while the latter provided solutions to port managers of inefficient ports that allow them to achieve the best utilisation of port resources.

The main findings reveal that the overall efficiency of the Mediterranean container ports has improved with time. A positive relationship exists between the scale of production and the efficiency of the Mediterranean container ports. In other words, efficiency increases with the scale of a container port and large container ports are more likely to be associated with high efficiency than their smaller counterparts. A good correlation exists between scale of production, ports' throughput, and their efficiency scores over time.

The results also signify the existence of inefficiency pertaining to the management of container ports in the region, since the total technical efficiency is found to be 50 % on average. This relatively limited technical efficiency of the Mediterranean container ports indicates the need for appropriate capital investments for ports' infra/superstructure. In particular, those ports whose efficiency is not favoured by factors such as size, geographical position and socio-economic conditions of the region wherein they are located, must adopt suitable reform strategies to promptly improve their efficiency and competitive position. These strategies should aim at upgrading the port facilities and equipment, adopting best practices and implementing training and know-how transfer from other port authorities. New funding sources for these strategies can be obtained through effective regulatory reforms and private concession schemes with global terminal operators for selected terminals.

The next chapter demonstrates the third stage of this research model to analyse the impact of port efficiency on port competitiveness. The bootstrapping truncated regression as well as Spearman's rank order correlation is used to test the hypotheses related to the relationship between port efficiency and port competitiveness in the Mediterranean container market.

CHAPTER SEVEN

THE IMPACT OF TECHNICAL EFFICIENCY ON THE MEDITERRANEAN CONTAINER PORTS COMPETITIVENESS

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THE IMPACT OF TECHNICAL EFFICIENCY ON THE MEDITERRANEAN CONTAINER PORTS COMPETITIVENESS

7.1 Introduction

The market structure conduct and performance (SCP) paradigm was established from the neo-classical analysis of markets. There are two competing hypotheses in the SCP paradigm: the traditional “structure performance hypothesis” and “efficient structure hypothesis”. The structure performance hypothesis argues that the degree of market concentration is inversely related to the degree of competition. This is because market concentration stimulates firms to cooperate (Edwards et al, 2006). the standard SCP framework asserts that there is a direct relationship between the degree of market concentration and the degree of competition among firms. This hypothesis will be confirmed if a positive relationship between market concentration and performance exist, regardless of the firm’s efficiency. Thus firms in more concentrated markets will gain higher profits than firms operating in less concentrated markets, regardless of their efficiency (Funke et al, 2012).

The efficiency structure hypothesis denotes that performance of the firm is positively related to its efficiency. This is because market concentration emerges from competition where firms with low cost structures increase their profits by reducing costs and expanding market share. A positive relationship between a firm’s profits and market structure is related to the expansion in market share by more efficient firms. In turn these expansion lead to increased market concentration. That is, increased profits are presumed to accrue to more efficient firms because they are more efficient and not because of collusive activities as the traditional SCP paradigm would propose(Molyneux and Forbes, 1995).

The aim of this chapter is twofold: firstly, to analyse the impact of port technical efficiency on port competitiveness in the Mediterranean container market; and secondly to test the reliability and the validity of the research design and results. In order to achieve these objectives, the hypotheses formulated in chapter one will be tested by using the results of port competitiveness analysis derived in chapter five and the efficiency estimates derived in chapter six. Light can be shed on the relevance of fundamental economic theory in underpinning the relationship between port technical efficiency and port competitiveness. Despite their respective strengths and weaknesses, as concluded from the analysis presented in chapter six, non-parametric and parametric models for analysing efficiency generate similar estimates of efficiency when utilising cross-sectional and panel data but the former yield less convincing estimates of efficiency than the latter when significant differences exist between the efficiency scores estimated by the two approaches. For these reasons, in this chapter, the results derived from the non-parametric set of models constitute the fundamental basis for testing the hypotheses expounded in chapter one.

In doing so, this chapter constitutes six sections. Section one includes chapter introduction, aims and plan. In order to examine the impact of exogenous factors on port efficiency, the bootstrapped truncated regression analysis is reported in section two. Section three illustrates the relationship between port efficiency scores and the competitive position of the main container ports in the Mediterranean and draws a comparison between Mediterranean container ports' super-efficiency scores and the K-firm concentration. Section four analyses the relation between average growth rate and average efficiency scores of the panel data, window and inter-temporal and scale analysis. In section five, the reliability and validity of the research design and results are tested. The summary of this chapter is derived in section six.

7.2 Impact of port efficiency on ports' competitiveness

7.2.1 Bootstrapped truncated regression analysis

A significant limitation of DEA is that it does not determine the main reasons of (in)efficiency, whereas in this stage of the study, a primary objective is to find out the relationship between the possible reasons of inefficiency and the efficiency scores derived from the application of DEA. In order to conquer the deficiency of DEA in this respect, a positive relationship is hypothesised between DEA efficiency scores and seven explanatory variables: efficiency trend and efficiency trend square as applied by Barros and Managi (2008), scale of operation (as used in Cullinane et al, 2002; Tongzon and Heng, 2005; Wang and Cullinane, 2006a;Cheon et al, 2010);

transhipment (hub) or gateway status as used by (Notteboom et al, 2000; Cullinane et al, 2006), port location presented by nautical distance from nearest trunk route (Sanchez et al, 2003; Yeo et al, 2008), both of which explained that the negative effect of deviation distance on transport costs and port competitiveness can be compensated for by a high level of port efficiency. These hypothesised relationships are examined by using the truncated regression model to test the determinants of efficiency in container ports.

For the purpose of this research, the explanatory variables are used as exogenous variables to examine the impact of the external environment on the efficiency of the ports under study. Table 7.1 shows the descriptive statistics of such variables. As explained in chapter four and as shown in Table 7.1, the explanatory variables are classified into two types, the dependent and independent variables.

Table 7.1 shows that the range between the minimum and maximum values of the DEA-CCR mean super efficiency scores is 1.033. The range and variance for this variable are 0.520 and 0.081 respectively. The small value of the variance indicates that the data set tend to be very close to the mean. The kurtosis parameter for this variable is (1.024), which means that the distribution of data is almost fair. In terms of the dependent variables, the range across the efficiency trend, efficiency trend square and countries GDP per-capita data sets are 0.786, 0.954 and 31,025 respectively. There is a high dispersion of the data far from the mean, in which the standard deviation is slightly high 0.252, 0.313 and 11,732 respectively. The Skewness coefficients of such variables are 0.909, 1.418 and -0.36 respectively. This means that the distribution of data is skewed to the right except for the GDP per-capita data which is skewed to the left. In both cases the data is not normally distributed. The kurtosis parameter for these variables are 0.209, 0.825 and -1.65 respectively which means that the data is not normally distributed.

Similarly, for the ports location, number of competitors, scale of production and study ports' hub status data sets the range across these variables data set are 780, 6.0, 2,438,311 and 1.0 respectively. There is a high dispersion of the data far from the mean, in which the standard deviation is 233.16, 1.47, 774,917 and 0.49 respectively.

Table 7. 1- Descriptive statistics of the dependent and independent variables.

Variables	Dependent variable	Independent (Explanatory) variables						
	Mean DEA-CCR super-efficiency	Trend (DEA-CCR)	Trend (sq.) DEA-CCR (sq.)	GDP per-capita	Location	No. of Competitors	scale	Hub status
Minimum	0.205	0.214	0.046	1,822.56	0.00	3.00	401,237.53	0.00
Maximum	1.238	1.000	1.000	32,847.89	780.00	9.00	2,839,549.07	1.00
Range	1.033	0.786	0.954	31,025.33	780.00	6.00	2,438,311.53	1.00
Mean	0.520	0.507	0.318	18,392.18	247.18	5.50	1,236,520.79	0.36
Std. Deviation	0.284	0.252	0.313	11,732.21	233.16	1.47	774,917.56	0.49
Variance	0.081	0.063	0.098	137,644,670.99	54363.58	2.17	600,497,222,185.93	0.24
Skewness	1.257	0.909	1.418	-0.359	0.944	0.493	0.990	0.609
Kurtosis	1.024	-0.209	0.825	-1.652	0.180	0.481	-0.110	-1.802

The Skewness coefficients of such variables are 0.944, 0.493, 0.990 and 0.61 respectively. That means that the distribution of data is skewed to the right and the data is not normally distributed. The kurtosis parameter for these variable are 0.180, 0.481, -0.110 and -1.80 respectively which also means that the data is not normally distributed. The data set for the ports location and number of competitors are skewed to the right, while the data of scale of production and the ports' hub status are skewed to the left.

In this stage of the research model, the bootstrapped truncated regression is used for two reasons. First, is to test the sixth hypothesis **(H6)**, mentioned in chapter one that the operational efficiency of container ports in the Mediterranean is influenced by a number of exogenous variables. Second, is to distinguish between the local and hub ports under study by statistically testing the potential for some local ports under study whether they can be future hubs. As mentioned in chapter one, the hypothesis that can be drawn from the below mentioned formula is that if the bootstrapped regression, as shown in Table 7.3, is greater than the DEA-CCR mean super efficiency score, the port is or can be, a potential hub.

In order to test such hypothesis that the efficiency of the Mediterranean container ports is affected by various exogenous variables, the research followed the two-stage approach, as proposed by Coelli et al. (1998), to estimate the regression shown below. It is recognised in the DEA literature that the efficiency estimates attained in the first stage are correlated with the explanatory variables used in the second stage, and that the second-stage efficiency scores will then be inconsistent and biased.

A bootstrap procedure is required to conquer this problem (Efron and Tibshirani, 1993). As such, as expressed in chapter four, the Simar and Wilson (2007)approach is used and the estimated specification is as follows:

$$\theta_{i,t} = \beta_0 + \beta_1.Trend_{i,t} + \beta_2.Trend_{i,t}^2 + \beta_3.GDP_{i,t} + \beta_4.Location_{i,t} + \beta_5.Competitor_{i,t} + \beta_6.Scale_{i,t} + \beta_7.Hub_{i,t} + \varepsilon_{i,t}$$

Where θ represents the inter-temporal DEA-CCR mean super-efficiency scores estimated in Table 6.10. The use of the mean values allow ports' efficiency estimates to be considered along the whole period of study (15 years). $Trend_{i,t}$ is a yearly efficiency trend. $Trend_{i,t}^2$ is the square value of the trend. $GDP_{i,t}$ (Appendix 7.1) is the country gross domestic product; this aims to capture the local market effect related to each Mediterranean container port. $Location_{i,t}$ refers to the distance of each port from the main liner trade route within the Mediterranean container market, which denotes the relative importance of the ports' geographical position in the region. $Competitor_{it}$ represents the number of rivals of each port from the hinterland and foreland sides. The use of this variable allows splitting between ports located in the East, centre and West of the Mediterranean. $Scale_{i,t}$ is the mean container throughput (TEU) of port i; $Hub_{i,t}$ is a dummy variable; If the port is a hub, this is equal to unity (1); otherwise it is equal to zero (0). Following Simar and Wilson (2007), SPSS was used to bootstrap the confidence intervals, with 1000 replications. The results are presented in Table 7.2.

The truncated regression with a bootstrap model appears to fit the data well, with positive t-statistics, which are statistically significant for all parameters. The estimates conform to pre-expectations. Table 7.2 shows that the efficiency trend, with a *p*-value = 0.016, and efficiency trend-square, with a *p*-value = 0.031, are statistically significant to the sample ports efficiency scores. It is observed that the efficiency scores increase over the observation period, according to the trend with an increasing rate since square trend is positive. GDP is positive (*p*-value = 0.014), signifying that local wealth contributes to the trade and therefore to the technical efficiency of the seaports. The demand for port services increases with the increase of cargo traffic.

Table 7. 2- Summary output for truncated bootstrapping regression analysis

Independent variables	Coefficient (B)	Truncated bootstrapping regression				
		Bias	Std. Error	Sig. (2-tailed) *p*-value	95% Confidence Interval	
					Lower	Upper
(Constant)	0.503243	-0.052676	0.318910	0.242	0.000000	1.142134
Trend (DEA-CCR)	0.536548	0.130754	0.908406	**0.016**	-2.497231	1.000000
Trend (sq.) DEA-CCR (sq.)	1.278072	0.006780	0.703136	**0.031**	0.000000	2.590707
GDP per-capita	0.517E-07	0.046E-07	0.000000	**0.014**	0.397E-06	0.581E-06
Location	0.000524	0.000033	0.000113	0.297	-0.000330	0.004787
No. of Competitors	-0.030148	0.006989	0.021473	0.309	-0.064419	0.015074
Scale (throughput)	-2.551E-008	-1.007E-08	0.469E-07	**0.027**	-3.315E-07	-1.189E-07
Hub status	-0.316203	-0.005492	0.063856	0.506	-0.732704	0.097559

The absence of any statistically significant relationship between deviation distance, with *p*-value = 0.297, and efficiency scores is a very interesting finding. Container ports which are located at greater distance from main line (trunk) shipping routes might be assumed to provide a much more efficient service to shipping lines so that time lost during the deviation distance to access these ports is compensated for by the time saved in efficient and relatively fast handling in the port. Alternatively, they could offer the same service levels but at lower direct cost, so that the total transport costs of the shipping lines are minimized (Demirel et al, 2012).

In general, it is accepted that container shippers usually prefer fast and direct transport, although not all goods are time-sensitive. Transhipment is actually a carrier's need to seek higher load factors and fewer port calls. This becomes essential on main line voyages. The solution of this problem has always been the coordination of the main line and of the feeder services, while keeping port call frequency at a reasonable level for the shippers. Moreover, some of these ports, Cagliari in particular, have a competitive advantage as far as the geographical position is concerned (Fleming, 2000). The port of Cagliari has some characteristics; it can be considered as a special node, natural intersections, facilitating connectivity between interacting places in the Western Mediterranean. However the geographic location and intermediary are relative concepts, as hub ports encounter declines and booms, usually caused by the carriers' decision or shippers' requests. According to this rationale the Mediterranean ports that have a low competitive position can become hub ports for the mega-carriers, if only the existing trade routes keep on undertaking goods and maintain their significance in international trade.

However, there are some basic assumptions hidden above. First of all mega- ships can access those ports. The second point is that the service will be at a satisfactory level of quality and at a competitive price. As almost all main container ports in the Mediterranean offer access to Suez-max vessels as their reported depth is about15.0 m. The ports of Algeciras, Valencia, Piraeus, Alexandria, Genoa, Marseilles, La Spezia, Damietta, GioiaTauro, Marsaxlokk, Barcelona and Izmir, are expected to compete. Some ports, such as Damietta, GioiaTauro and Genoa report depths equal to or lower than 15.0 m, and Marsaxlokk is very close to the limit; it is expected that these ports may proceed in dredging activities, in order to attract carriers. Moreover, these ports are seaports, and are easily accessed by sea-going ships.

Accordingly the decisive point is competitiveness. In the literature explained in chapter two, the focus of competitiveness has lately shifted from the analysis of comparative advantages to the study of factors determining the advantages. In the case of port industry, Porter's ideas, and particularly the 'diamond' framework has been assessed academically and evolved to a 'double diamond' by Rugman and D'Cruz (1993) (Haezendonck et al, 2000). The creation of two groups off actors reveals the nature of the business, as local and international features influence the performance of the port, as well as the contemporary logistics concept, that the chain is as strong as it weakest part. Haezendock et al. (2000) asserted that at least in the case of the northern ports, the use of a port's superstructure by actors involved in freight forwarding activities as well, is considered as a real competitive advantage.

This lies in the increased flexibility and productivity of the labours in such a case. Furthermore, nautical elements and marine access can really hinder port efficiency, as carriers avoid river ports, like Rotterdam or Hamburg, but this is not the case for the Mediterranean ports. Haezendock et al. (2000) suggested inter alia that Porter's framework can be applied as a tool for the identification of port competitiveness (Notteboom et al, 2000).

The results of the analysis explained here demonstrate that, at least within the geographic region under analysis, the issue of the price elasticity of demand for container handling services within the Mediterranean region should be considered. As explained by Demirel et al. (2012), It may also be the case that there is an inverse relationship between throughput and deviation distance that actually works to suppress efficiency levels. The variable representing the number of competitors has also a statistical negative significance and is therefore ignored.

As explained in Chapter 3, only a few studies have concluded that scale of operation is not one of the main determinants of port efficiency (Coto-Millan et al, 2000; Tongzon, 2001a; Cullinane et al, 2004; Al-Eraqi et al, 2008). The scale effect has proved to be positively and strongly significant in explaining empirically derived efficiency estimates (Liu 1995; Martinez-Budria et al, 1999; Notteboom et al, 2000; Cullinane et al, 2002; Turner et al, 2004; Wang and Cullinane, 2006a,b; Cullinane and Wang 2006; Herrera and Pang 2008). The truncated regression analysis applied herein has also found that scale (throughput), with a p-value = 0.027, is a significant determinant of port efficiency.

As such, the hypothesis that the efficiency of a container port is influenced by its scale of production (output) cannot be rejected, which reveals that economies of scale exist in the container port sector. Wang and Cullinane (2006a) indicated that this scale effect exists because large container ports are more likely than their smaller counterparts to utilise state-of-the-art equipment and to possess sophisticated management.

Some previous studies (Notteboom et al, 2000; Cullinane et al, 2006) have found that higher levels of technical efficiency are associated with transhipment (Hub), as opposed to gateway, ports. However, it is not surprising to find that, in this research, there is no significant relationship between the hub or gateway status of the ports, *p*-value = 0.506, and their efficiency levels. Even though a transhipment container is counted twice in the container throughput of a port, while utilising only a single slot in the container yard, this is not a very significant point as, in general, the amount of work associated with the handling of a transhipment container within a port does not, in reality, differ much from that associated with an import or export container (Wang and Cullinane 2006b; Demirel et al, 2012).

In order to examine the sixth hypothesis, mentioned above, Table 7.3 shows the inter-temporal DEA-CCR mean super efficiency scores and their corresponding values after bootstrapping. Table 7.3 indicates that the bootstrapped regression of the ports of Port Said, GioiaTauro, Algeciras, Marsaxlokk, and Tangier is greater than its corresponding DEA-CCR mean super-efficiency scores. This result is plausible as these ports are the current hub ports in the Mediterranean container market. However, Table 7.3 also shows that the bootstrapped regression of the ports of Valencia, Barcelona, Ambarli, La Spezia and Haifa is also greater than their mean super efficiency scores.

This means that, on the one hand, these ports are highly affected by the above mentioned explanatory variables and as such have the potential for being hub ports in the defined market whilst on the other hand, although the rest of the ports under study are affected by the explanatory variables, their relative technical inefficiency hinders them from being potential transhipment (hub) ports in the Mediterranean container market.

The next section examines the relation between ports technical efficiency and ports' competitiveness through the use of various parameters that represent both aspects (ports' efficiency and ports' competitiveness). The Spearman's rank order correlation coefficient is used to test the hypotheses that examine the impact of port technical efficiency on port's competitiveness in the Mediterranean container market.

Table 7. 3- Bootstrapping the Inter-temporal DEA-CCR mean super-efficiency scores

Port	DEA-CCR mean super efficiency score	Bootstrapped regression	Port	DEA-CCR mean super efficiency score	Bootstrapped regression
Valencia	0.803	**0.849**	**Damietta**	0.362	0.343
Port Said	0.730	**0.825**	**Mersin**	0.388	0.290
GioiaTauro	1.120	**1.330**	**Marseilles**	0.329	0.318
Algeciras	1.238	**1.337**	**Piraeus**	0.486	0.464
Ambarli	0.506	**0.543**	**Alexandria**	0.411	0.408
Marsaxlokk	0.913	**1.134**	**Izmir**	0.367	0.316
Tangier	0.527	**0.557**	**Livorno**	0.304	0.284
Barcelona	0.574	**0.605**	**Taranto**	0.254	0.254
Genoa	0.630	0.611	**Cagliari**	0.221	0.216
La Spezia	0.440	**0.444**	**Constantza**	0.233	0.227
Haifa	0.391	**0.405**	**Naples**	0.205	0.197

7.2.2 Relation between ports' efficiency and ports' competitiveness

Port competition can lead to optimal levels of operation and better prices. Long coastlines in the Mediterranean basin, along with a high concentration of regional ports have a significant impact on the ports' technical efficiency. This could in turn affect the port competitiveness level. In this context, hypothesis seven **(H7)** assumes that "*ports technical efficiency could affect container ports competitiveness in the Mediterranean market"*. In other words, Mediterranean container ports that encountered external competition are more efficient than their counterparts in the same market.

The first step in testing hypothesis seven is to develop a quantitative measure of the level of competition and market concentration. As illustrated in chapters four and five, among the numerous methods that have been proposed for analysing market dynamics and port competition (Alam, 1984; Amato, 1995; Riccardo, 2000; Nanuenberg et al, 2001), the Herfindahl–Hirschman index (HHI) was selected as the most appropriate measure of the level of competition. Although strictly speaking this is a measure of the degree of concentration rather than competition within an industry, classical economic theory, as well as numerous worldwide investigations into anti-competitive behaviour, would imply that industry concentration has a direct bearing upon the degree of competition in the market.

Later refinements, such as that of the competitive markets hypothesis of Baumol et al. (1982) and concepts such as the difference between 'competition for the market' and 'competition in the market' would seem to contest the direct relationship between market concentration and the degree of competition faced by incumbents. Nevertheless, as discussed in chapter four, because of its advantages and its suitability for application to the container port industry, the Herfindahl–Hirschman index (HHI) is the preferred measure for use within this study.

In principle, hypothesis seven can be tested through analyses based on either cross-sectional or panel data. The former is conducted by analysing the Mediterranean container port market concentration for the year of 2012, while the latter is undertaken by observing movements in the value of efficiency scores over time and across ports. However, as mentioned in chapter four, some drawbacks always exist with cross-sectional data analysis because each port is observed only once and, therefore, random effects may be present and might be exerting a disproportionate influence on the results. To avoid this problem, as explained in chapter six, the panel data are analysed by using both DEA Inter-temporal and Contemporaneous models.

The market definition and the HHI for each port in the Mediterranean container port market are reported in chapter five. The relationship between port competitiveness and the efficiency scores derived from the DEA–CCR and DEA–BCC models are showed in Table 7.4 and plotted in Appendices (7.2-7.5). Table 7.4 shows the relationship between the competitive position of the Mediterranean container ports, as presented by HHI, and ports' efficiency scores. Such a relationship is measured by Spearman’s rank order correlation coefficient (ranging from 0.88 to 0.92). The positive signs for the Spearman’s rank order correlation coefficient reveal that the technical efficiencies of container ports in the Mediterranean are indeed positively related to their competitive position in the defined market.

On the other hand, the relatively high absolute value, 0.92, of the Spearman’s rank order correlation coefficient would seem to demonstrate that the competitive positions of the Mediterranean container ports are significantly related to their technical efficiency. This implies that as far as port competitiveness is concerned, the higher the efficiency of the container ports the fiercer is the competition among ports in the same market. Therefore, as reported in Table 7.4, on the basis of both cross-sectional and panel data analyses, hypothesis seven cannot be rejected.

Table 7. 4- Relation between ports’ competitiveness and efficiency

Data Type	DEA model	Correlation between HHI & Efficiency
		Spearman's rank order correlation
Cross- sectional	DEA-CCR-O	0.9242
	DEA-BCC-O	0.8884
Panel	DEA-CCR-Window	0.905
	DEA-BCC-Window	0.905
	DEA- CCR-Contemporaneous	0.906
	DEA- BCC-Contemporaneous	0.901
	DEA- CCR-Inter-temporal	0.906
	DEA- BCC-Inter-temporal	0.901

A low HHI ratio implies a low level of market concentration with a move towards a purely competitive market. Thus, a low HHI may lead to production efficiency. However, if there are many ports in the Mediterranean region, over-competition and an unfavourable pricing strategy may lead to inefficiency in the service provided. This happens in circumstances, such as in this study, when the HHI index is low. The relatively small HHI ratio implies a highly competitive market.

The above results contrast with the assumption introduced by Van den Broeck et al. (1994, p. 274) who implied that a less competitive environment leads, to some extent, to higher efficiency. They stated that "*From an economic point of view, the need to survive in a competitive environment of most economic units induces a belief that many of them are close to the frontier, i.e., full efficiency. However, given the dynamic character of competition itself, strategic policies in the long run (secular inefficiency) could keep units away from their frontier. In many cases, this will be compounded with organisatorial inefficiency in the short run*".

The results also contradict the results formulated by Wang et al. (2005) who explained that there is no clear-cut relationship between the HHI and the efficiency of container ports. Their research results provided a low correlation coefficient between the inter-port competition index, as presented by the HHI, and the efficiency estimates that have been derived by the application of different DEA techniques.

7.2.3 Relation between ports' super efficiency and competitiveness

As expressed in Chapters four and five, the K-firm concentration ratio is used as an index that represents the Mediterranean container ports competitive position through the use of ports' market shares. For the purpose of this study, market share is the percentage of a Mediterranean container port market accounted for by a specific port. The main advantage of using market share as a measure of port competitiveness is that it is less dependent upon macro-environmental variables such as the state of a port's economy or changes in port policy. Market share is a vital indicator of market competitiveness. It shows how well a port is doing against its rivals and helps port managers to evaluate both primary and selective demand in their ports.

On the other hand, as explained in chapter six, the super efficiency score is used to benchmark between ports in terms of their efficiency. The super-efficiency model, developed by Andersen and Petersen (1993), is used to provide distinctions among the efficient ports, DMUs, in the DEA. This model eliminates efficient DMUs, and then evaluates the production frontier again. This imparts a new efficiency value for the efficient DMUs that had previously been eliminated. The new efficiency score can thus be greater than unity.

From this perspective, hypothesis eight **(H8)**, as mentioned in chapter one, was formulated. Hypothesis eight presumes that ”*There is a positive relation between the level of ports efficiency and the competitive position of the container ports in the Mediterranean market”.* In order to test hypothesis eight, Table 7.5 compares between ports ranks in terms of their market share that presents the competitive position of the ports in the Mediterranean market and the ranking of ports according to their super-efficiency scores in 2012. Table 7.5 shows that the ports' competitive position is, more or less, the same as the ports' efficiency level represented by ports' super-efficiency score.

For instance, Table 7.5 shows that Valencia has the second most competitive position in the Mediterranean container market, while it ranked as the third port in the market in terms of its super-efficiency score. Similarly, Port Said, GioiaTauro and Algeciras have the first, sixth and third places respectively in terms of their competitive position in the defined market, while they occupied the second, fourth and first places respectively as far as their super-efficiency estimates are concerned. Cagliari, Constantza and Naples had the ninetieth, twentieth and twenty-second positions respectively, in terms of their competitiveness, while they occupied the twentieth, twenty-first and the twenty second positions as far as their super-efficiency scores are concerned.

Table 7. 5- Benchmarking ports market share and super-efficiency scores ranks

Port	Throughput (2012)	Market Share (2012)	Rank	Super efficiency scores (2012)
Valencia	4,469,754	10.50%	2	1.093 (3)
Port Said	4,831,165	11.40%	1	1.591 (2)
GioiaTauro	2,721,104	6.40%	6	0.987 (4)
Algeciras	4,114,231	9.70%	3	1.858 (1)
Ambarli	3,097,464	7.30%	4	0.953 (6)
Marsaxlokk	2,540,000	6.00%	7	0.961 (5)
Tangier	2,220,000	5.20%	8	0.835 (9)
Barcelona	1,756,429	4.10%	10	0.783 (10)
Genoa	2,064,806	4.90%	9	0.836 (8)
La Spezia	1,247,218	2.90%	15	0.729 (13)
Haifa	1,372,209	3.20%	13	0.708 (14)
Damietta	760,000	1.80%	17	0.643 (17)
Mersin	1,263,495	3.00%	14	0.653 (16)
Marseilles	1,061,000	2.50%	16	0.687 (15)
Piraeus	2,745,012	6.50%	5	0.886 (7)
Alexandria	1,500,000	3.50%	12	0.730 (12)
Izmir	700,000	1.70%	18	0.759 (11)
Livorno	1,600,000	3.80%	11	0.438 (18)
Taranto	563,461	1.30%	21	0.373 (19)
Cagliari	627,609	1.50%	19	0.276 (20)
Constantza	620,000	1.50%	20	0.233 (21)
Naples	546,818	1.30%	22	0.126 (22)

In the same context, Figure 7.1 shows the relation between the efficiency level of the container ports under study and their competitive position in the Mediterranean market. Figure 7.1 shows that there is a high and positive correlation of 0.87 between a port's competitive position and their super- efficiency scores. Figure 7.1 asserts the above mentioned analysis and, as such, hypothesis eight cannot be rejected.

Nevertheless, it should be highlighted that the above result is derived from the cross-sectional data analysis for the year of 2012. As such, this result does not reveal the impact of port efficiency on ports' competitiveness on the dynamic characteristics of the Mediterranean container market. To overcome the disadvantages of the cross-sectional data, the relationship between the average growth rate of the container ports, under study, and their average efficiency scores over time, for the period between 1998 and 2012, is analysed in the next section.

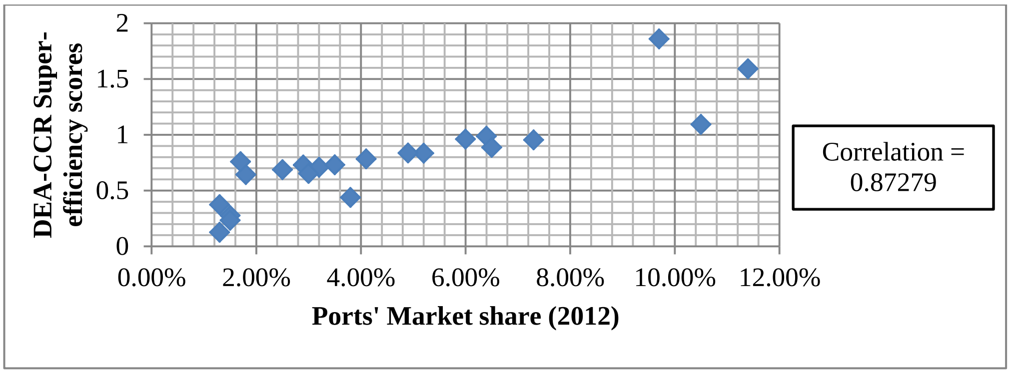

Figure 7. 1- Relationship between super-efficiency scores and market share of Mediterranean container ports.

7.2.4 Relation between ports' average growth rate and average efficiency scores

In this section, the research examines the relationship between container port average growth rate and their technical efficiency scores in the Mediterranean market. From this perspective, as mentioned in chapter one, hypothesis nine **(H9)** can be formulated. Hypothesis nine presumes that "*there is a positive relation between Mediterranean container ports average growth rates and their technical efficiency*". As explained in chapter five, the average growth rate of container ports' throughput is calculated for the period between 1998 and 2012. As expressed in chapter six, the efficiency scores are calculated through the use of DEA-CCR/BCC models that are applied to the window, contemporaneous and inter-temporal panel data. As such the relationship between the average growth rates of container ports throughput in the

Mediterranean market and the changes of their efficiency scores over time can be analysed. Spearman correlation coefficients are calculated to examine such relationship for every panel data set. The reason for using different panel data sets is that every data set explains the changes in port efficiency scores in a different manner. As explained in chapter four, window analysis helps to study efficiency over time considering that production technology may also change with time. DEA window analysis extends the comparison set for a particular port (DMU). It allows benchmarking the efficiency estimates of ports under study for several years instead of studying the efficiency scores for one year only. Thus, window analysis treats an identical unit in different time periods as different DMUs (Charnes et al, 1985).

In the contemporaneous panel data analysis, the efficiency of each unit is assessed by benchmarking it to other units in the same period, independent from other periods (Tulkens and Eeckaut, 1995). Therefore, the efficiency measures from a DEA contemporaneous analysis do not reflect a relative efficiency from year to year, but rather within the same year. However, inter-temporal analysis analyses the efficiency trends from a different perspective. All DMUs from all periods may be put together in a pool and thus can be assessed against each other. An inter-temporal analysis provides a better basis if efficiency measures are used to compare between years.

Table 7.6 and Appendices (7.6-7.8) show the relationship between the average growth rates of the Mediterranean container ports throughput and their efficiency scores for the period between 1998 and 2012. Such a relationship is measured by Spearman's rank order correlation coefficient, ranging from 0.15 to 0.38. The positive signs reveal that there is a relationship between the Mediterranean container ports' average growth rates and their technical efficiency scores. On the other hand, the relatively lower absolute value, 0.38, of the Spearman's rank order correlation coefficient would seem to demonstrate that the average growth rates of the Mediterranean container ports are, to some extent, related to their technical efficiency. This indicates that the average growth rates of container ports in the Mediterranean are mainly related to a number of exogenous factors such as the ports demand, the amount of container traffic that need to be handle in a particular port, and the number of ships calling that port.

Table 7. 6- Relationship between ports' average growth rate and efficiency scores

Data Type	Correlation between Av. Growth rates & Efficiency scores	
	DEA model	**Spearman's rank order correlation**
Panel	DEA-CCR-Window analysis	0.1459
	DEA-BCC-Window analysis	0.1459
	DEA- CCR-Inter-temporal	0.1505
	DEA- BCC-Inter-temporal	0.1449
	DEA-Window scale efficiency	0.3795
	DEA-Inter-temporal scale efficiency	0.2359

The next section examines the reliability and validity of the research design and results. As such, different types of reliability and validity that are related to the research conceptual framework, approach, design and model will be tested and verified.

7.3 Research Reliability and Validity

Researchers who use positivist paradigm or quantitative research use experimental techniques and quantitative methods to examine hypothetical generalisations (Hoepfl, 1997) and they also focus on the measurement and analysis of causal relationships between variables (Denzin and Lincoln; 1998, Williams, 2007).

Quantitative researchers need to create an instrument to be administered in a standardised manner according to predefined stages. But the question is does the measuring instrument measure what it is intended to measure? In general, devising a test (Crocker & Algina, 1986; Golafshani, 2003) or the validity of an instrument is the focus. The importance of this test is to ensure reliability or repeatability of the results. In this context, Winter (2000, p.7) stated that *“Reliability and validity are tools of an essentially positivist epistemology*”.

Joppe (2000) defined reliability as the extent to which results are consistent over time and a precise demonstration of the total population under study is referred to as reliability and if the results of a research can be replicated under a similar methodology, then the research instrument is considered to be reliable. As shown in Figure 7.2, Kirk and Miller (1986) identified three types of reliability referred to in quantitative research: equivalency reliability, which reveals the degree to which a measurement, given repeatedly, remains the same; the stability reliability which explains the stability of a measurement over time; and internal consistency reliability that explains the similarity of measurements within a given time period. Lincoln and Guba (1985) defined system reliability and stability as the consistency of measurement, or the extent to which the system measures the same way each time it is applied under the same condition with the same subjects. The more consistent and stable the measurement system is, the more reliable it is. The consistency of the measurement refers to the validity to use the model in future to assess efficiency and competitiveness.

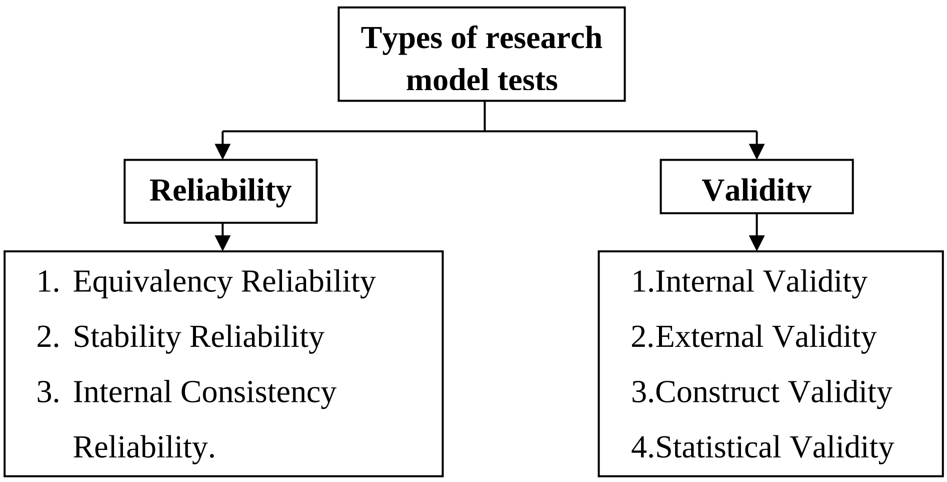

Figure 7. 2- Types of research model tests

The conventional criteria for validity find their roots in a positivist tradition, and to some extent, positivism has been identified by a systematic theory of validity. Within the positivist terminology, validity resided amongst, and was the result and culmination of other empirical conceptions: evidences, truth, actuality, objectivity, reasons, deduction, facts, universal laws, and mathematical data to name just a few (Winter, 2000). Joppe (2000) explained the meaning of validity in quantitative research. He expressed that validity verifies whether the research truly measures that which it was intended to measure or how truthful the research results are. Researchers normally determine validity by asking a number of questions, and will often look for the answers in the research of others.

Shepherd and Helms (1995) argued that the best validity exists when an assessment model is properly designed and implemented, reliable and accurate data have been collected and the model is used easily by managers. They set four procedures for testing validity. Firstly, face validity that is based on the subjective evaluation of the researcher. The second procedure is the content validity, which concerns the sampling adequacy. Criterion related validity is the third procedure. It concerns how the measure can predict future outcomes. Finally, construct validity is composed of many types of validities; such as trait validity, convergent validity, etc. Mentzer and Flint (1997) argued that validity in research is actually a hierarchy of procedures to ensure that the research outputs are stated with some confidence. As indicated in Figure 7.10, they argued that validity is composed of four components; internal, external, construct and statistical conclusion validity.

Internal validity provides evidence that the relationship between two variables is causal. Mentzer and Flint (1997) defined the external validity as the degree to which the research findings can be generalised to the broader population. They argued that external validity is based on an appropriate sample size and adequate response rates. Construct validity concerns how the process of constructing formal definitions of the concepts within the theory can be achieved. In other words, it verifies how the definition of each concept is constructed from the theory. Statistical conclusion validity refers to whether there is a relationship between two variables. Mentzer and Flint (1997) argued that reliability is important as it assures the consistency between measures. Without reliability, no model can be tested against validity.

Zumbo (2007) discussed the criterion-related validity, which comprises two types of validity; concurrent validity and predictive validity. The criterion-related validity refers to the extent of effectiveness with which performance on a test or procedure expects performance in a real-life situation. Sireci and Parker (2006) explained that reliability is considered as part of validity. He argued that reliability and validity refer to interpretations of test scores. For reliability, it concerns how consistent the scores are over time.

Brahma (2009) emphasised that measuring a theoretical construct comprises errors. Hence, testing reliability is required to assure the validity. He argued that reliability can be examined by the number of items and variables that define the scale because an assessment model depends on the extent of items and variables. Reliability means the consistency of the items that are used in the measurement process (Tongzon et al, 2009). Trafford and Leshem (2008) claimed that a deductive approach provides conclusions which are high in reliability and low in validity, and consequently, it becomes possible to generalise conclusions. Reliability is present if the conclusions can prove the hypotheses. It can be concluded from these previous studies and research that model reliability and validity exist if it has a number of features. Table 7.7 indicates the main features of research reliability and validity and the place at which each of these features are confirmed within the context of this research at the next sections of this chapter.

Table 7. 7- The main features of research reliability and validity

No.	Features	Section
1	A model has a hierarchy of procedures	Construct validity
2	A model has an appropriate sample size	Construct validity
3	A model has a number of relevant and relative variables that define the scale	Construct validity
4	A model shows a relationship between variables	Construct validity
5	A model has a causal relationship between its variables	Internal validity
6	A model provides generalised findings	External validity
7	A model is easy to use	External validity

Next section tests the research reliability through the examination of four different types of reliability. As mentioned above these types of reliability are; equivalency reliability, stability reliability and internal consistency reliability.

7.3.1 Research Reliability

Based on the above explained definition of the research reliability, *equivalency reliability* is the extent to which two items measure identical concepts at the same level of difficulty. Equivalency reliability is verified by relating two sets of test scores to one another to underline the extent of relationship or association. In quantitative research and particularly in experimental research, a correlation coefficient, statistically referred to as *r*, is applied to demonstrate the strength of the correlation between a dependent variable (the subject under study), and one or more independent variables, which are manipulated to determine effects on the dependent variable. A significant concern is that equivalency reliability is concerned with correlational, not causal, relationships (Drost, 2011).

In this context, as far as port competitiveness analysis is concerned, equivalency reliability can be tested through the use of four different techniques that are applied to measure and analyse market concentration and deconcentration tendency. These techniques are; the k-Firm concentration ratio (K-CR), the HHI, the Gini coefficient and the entropy index. Although these techniques are different, there scores indicated the same result which is the Mediterranean container port market has a deconcentration tendency during the period of study.

With respect to the efficiency analysis and benchmarking, the use of two different DEA models which are the DEA-CCR, the DEA-BCC and the DEA-super efficiency models has also led to almost the same results in terms of the distinction between the efficient and inefficient DMUs (container ports) and also in terms of the ranks of such DMUs with reference to their efficiency estimates. As such, equivalency reliability can be confirmed for the purpose of this research for both the port competitiveness analysis and efficiency benchmarking.

Stability reliability (sometimes called test, re-test reliability) is the agreement of measuring instruments over time. To measure stability, a measure or test is repeated on the same subjects at a different date or period. Results are compared and correlated with the initial test to give a measure of stability (Smallbone & Quinton, 2004). As such, for the purpose of analysing the Mediterranean container ports competitiveness and market dynamics, again the K-CR, the HHI, the Gini coefficient and the Entropy index are applied to the cross-sectional data and panel data for 15 years period, from 1998 to 2012. The results of the four different techniques have led to the same conclusion which is the Mediterranean container port market has a deconcentration tendency, moving towards pure and perfect competition, during the study period.

Similarly, for benchmarking the technical efficiency of the Mediterranean container ports under study, the research applied two DEA models, DEA-CCR/BCC, to the cross-sectional data and panel data (Window, Contemporaneous and Inter-temporal) analysis. The efficiency estimates for both the DEA-CCR and DEA-BCC models have indicated the same results in terms of the identification of the efficient and inefficient DMUs (container ports) for both the cross-sectional data and panel data analysis. As such, for the purpose of this research, stability reliability can be confirmed as far as port competitiveness and technical efficiency analysis are concerned.

Internal consistency reliability is the degree to which tests or procedures evaluate the same characteristic, quality or skill. It is a measure of the accuracy between the observers or of the measuring tools used in a research. This type of reliability often helps researchers explain data and estimate the value of scores and the limits of the relationship among variables. Internal consistency is usually measured with Cronbach's alpha, first introduced by Cronbach (1951), a statistic calculated from the pairwise correlations between variables. Internal consistency ranges between negative infinity and one (Zinbarg et al, 2006).

In the context of this research, Cronbach's alpha is calculated twice. The first calculation is applied to measure the internal consistency reliability among variables that are used to benchmark the technical efficiency of the Mediterranean container ports under study. The Cronbach's alpha for such variables equal 0.85 which reveals an excellent internal consistency among variables being used for the purpose of this study. The second calculation is applied to the DEA-CCR/BBC models that are used in cross-sectional and panel data analysis to benchmark the technical efficiency of ports under study. The Cronbach's alpha of this model equals 0.95 which also indicates excellent internal consistency reliability for the models used for the purpose of this research. However, it is very important to assess the conceptual and scientific soundness of a research study (Graziano & Raulin, 2004). Thus, research validity will be assessed in the next section.

7.3.2 Research Validity

As discussed in chapter 4, the main objective of all types of positivist research is to generate valid conclusions. Moreover, researchers are interested in clarification for the impacts and interactions of variables as they occur across a wide diversity of different settings. To really recognize these interactions requires particular attention to the concept of validity, which explains the need to eliminate or reduce the effects of extraneous effects, variables, and explanations that might detract from a study's ultimate findings (Trochim, 2006).

Therefore, validity is a very significant and valuable concept in all types of research methodology. Its main objective is to increase the precision and effectiveness of findings by reducing or controlling as many confusing variables as possible, which enables greater confidence in the results of a given research. There are four distinctive types of validity (internal validity, external validity, construct validity, and statistical conclusion validity) that act together to control for and reduce the effect of a wide variety of extraneous elements that can confound a research and decrease the accuracy of its results (Shadish et al, 2002).

Internal validity signifies the ability of a research design to exclude or make implausible alternative explanations of the results, or plausible rival hypotheses (Campbell, 1957; Kazdin, 2003). A plausible rival hypothesis is an alternative explanation of the researcher's hypotheses about the interaction of the independent and dependent variables that provides a logical interpretation of the findings other than the researcher's initial hypotheses (Rosnow & Rosenthal, 2002). Although evidence of absolute causation is rarely attained, the objective of most experimental designs is to reveal that the independent variable was directly responsible for the effect on the dependent variable and, eventually, the results found in the research.

In other words, the researchers ultimately want to know whether the observed phenomenon is due to the manipulated independent variables or to some uncontrolled or unknown extraneous variables (Pedhazur & Schmelkin, 1991;Kazdin 2003).Preferably, at the research conclusion, the researcher would like to make a statement showing some level of causation between the independent and dependent variables. By designing strong experimental controls into a study, internal validity is increased and rival hypotheses and extraneous effects are reduced. This enables the researcher to relate the results of the research more confidently to the independent variable or variables (Rosnow & Rosenthal, 2002).

One of the most commonly used methods that can describe internal validity is the confidence that we can place in the cause and effect relationship in a study. In this context, In order to prove that the research model has a causal relationship between its variables the research used the DEA-sensitivity analysis model. As explained in chapter six, the use of the sensitivity analysis allows for identifying the significant variables that affect ports' technical efficiency. As indicated in table 6.10, the omission of some variables such as the quay length, ports' maximum depth and handling equipment have shifted some ports like Valencia, Port Said, GioiaTauro and Algeciras from being efficient, with efficiency scores equal to unity, to inefficient ports. Such an example explains that these variables have a significant impact on ports technical efficiency and as such a cause and effect relationship exists between such variable that represents the ports' infra/superstructure and the ports' technical efficiency.

Causal relationship is also supported in this research through the use of the bootstrapping truncated regression analysis. As explained earlier in this chapter, there is a remarkable effect of the exogenous factors (independent variables) on the Mediterranean container ports' technical efficiency. The exogenous variables included in the truncated regression formula led to an increase in some ports' DEA-super-efficiency scores. As such, the existence of such variables could affect the status of some Mediterranean container ports under study from being gateway ports to be a future transhipment (Hub) ports.

External validity is concerned with the generalizability of the results of a research study. In all types of research design, the results and conclusions of the research are limited to the participants and conditions as defined by the outlines of the study. External validity signifies the extent to which research results generalise to other participants, conditions, places, and times (Graziano & Raulin, 2004). As such, a research has more external validity when the results generalise beyond the study sample to other populations, circumstances and settings. External validity refers to results that can be formulated about the strength of the inferred causal relationship between the dependent and independent variables to circumstances beyond those experimentally studied. It answers the question of would the results of our research apply to different settings, populations or sets of circumstances? If so, then the research has strong external validity (Jiménez-Buedo & Miller, 2010).

As such, a number of generalised findings and results can be drawn from the research hypotheses that are tested in chapters five, six and seven these general findings are;

1. The Mediterranean container port market moves toward deconcentration and pure and perfect competition.
2. The competitiveness level of the ports under study is changed over the period of study.
3. The technical efficiency of the Mediterranean main container ports is not related to scale of production.
4. The technical efficiency of the Mediterranean main container ports has improved over time.
5. The technical efficiency of the Mediterranean container ports increases as the scale of a container port increases.
6. The technical efficiency of the Mediterranean container ports is affected by different exogenous variables.
7. Ports technical efficiency could affect container ports competitiveness in the Mediterranean market.
8. There is a positive relation between the level of ports efficiency and the competitive position of the container ports in the Mediterranean market.
9. There is a positive relation between Mediterranean container ports average growth rates and their technical efficiency.

All the above mentioned findings can be generalised and tested in different port markets through the use of either the same model and approach or completely different model and measurement tools. Moreover, this model can be easily used to assess the impact of port technical efficiency on ports competitiveness and can be applied to any types of ports at any particular market. As explained in chapter two, the measurement tools and techniques that are used for assessing the ports competitiveness are widely applied by researchers who focused in analysing market dynamics and ports' competitiveness (Notteboom, 1997, 2010, 2012; Zondag et al, 2008; Kaselimi et al, 2011 and Musso et al, 2013).

On the other hand, these techniques can be applied through the use of different variables that can be obtained from secondary data sources that are available and published in reliable and reputable sources. So that it can be easily gathered. Similarly, the DEA models that are used to benchmarking the relative technical efficiency of the Mediterranean container ports have been used extensively in previous studies that focused on evaluating and analysing ports' technical efficiency (Niavis and Tsekeris, 2012; Bichou, 2013).

In the context of research design and methodology, the term *construct validity* refers to explaining the basis of the causal relationship, and it relates to the similarity between the research's results and the theoretical underpinnings guiding the research (Kazdin, 2003). The construct validity usually emphasises on the study's independent variable. Basically, construct validity asks the question of whether the theory supported by the findings provides the best available clarification of the results. In other words, is the reason for the relationship between the observed phenomenon (dependent variable) and the experimental intervention (independent variable) due to the underlying construct or explanation provided by the researchers (Campbell & Stanley, 1963; Cook & Campbell, 1979; Christensen, 1988; Kazdin, 2003; Graziano & Raulin, 2004)?

In this context, in order to have strong construct validity, there are two main methods for enhancing the construct validity of a study. First, the fundamental theory of the research should have a strong conceptual basis and be based on well-validated constructs. Second, the research should be based on clearly stated and accurate operational definitions of a research variables (Graziano & Raulin, 2004).

In the context of the underlying theory and the construction of the research, as explained in chapters one and four, this research aims to assess the impact of ports technical efficiency on ports' competitiveness. Based on the positivism deductive approach, the theory of industrial organization (IO) and the structure, conduct, performance (SCP) paradigm, this research followed a three-stage procedure that examine and analyse the impact of port efficiency on ports' competitiveness in the Mediterranean container market. Based on the above mentioned procedures, it can be said that the research model has a hierarchy of procedures.

With respect to the accurate definition of the research variables, a significant part of the judgment of variable selection in port benchmarking research lies in the recognising of the relationship between controllable (endogenous) and uncontrollable (exogenous) factors. However, only variables derived from controllable factors should be included in the benchmarking analysis. On the other hand, the degree to which uncontrollable elements affect port efficiency should also be considered. It is important to realise this aspect in the context of benchmarking port efficiency because as one goes down the decision-making hierarchy, the port manager is assigned a specific input and output collection under his control.

Port researchers often include non-discretionary variables that either show inconsistency with the type of efficiency being evaluated or fall outside the control of the DMUs under study. For the purpose of analysing the Mediterranean container market dynamics and the assessing the Mediterranean container ports' competitiveness, as explained in chapters four and five, three main variables are used. These variables are the ports' annual throughputs; ports' annual market shares and ports' average growth rates. As demonstrated in chapter two, a wide range of research that focused in studying port market dynamics and ports competitiveness has intensively used these variables either individually or collectively as input or output variables (Notteboom, 1997, 2009b, 2010, 2012; Veldman and Buckmann, 2003; Song, 2003; Yap and Lam, 2004; Yap et al, 2006; Lam and Yap, 2006; Comtois and Dong, 2007; Zondag et al, 2008; Kaselimi et al, 2011 and Musso et al, 2013).

With respect to ports relative technical efficiency evaluation, as mentioned in chapter four and six, two groups of variables are used. The first group represents the endogenous variables that are used to benchmark the Mediterranean container ports' technical efficiency. This group of variables is classified into two types. The first type is the output (dependant) variable that represents the ports' annual container throughput. The second type is the input variables (independent) that represent ports' infra/ superstructure which are terminals' area, storage capacity, terminals' length, terminals' depth and handling equipment.

In this research, the correlation coefficient is calculated to find the relationship between every group of variables, endogenous (controlled) and exogenous (uncontrolled), that assess the relative technical efficiency of the main container ports in the Mediterranean. As indicated in chapter six, the correlation coefficient between the controlled variables, output and input variables, were relatively good (greater than 0.44) for the cross-sectional data set and greater than 0.48 for the panel data set. The correlation coefficient between the input variables is greater than 0.2 for the cross-sectional data set and is greater than 0.30 for the panel data set. As such, the positive values of the correlation coefficients demonstrate that there is a positive relationship between the whole variables and that all variables complied with the isotonicity.

Statistical validity is the final type of validity that will be discussed in this section. Statistical validity is the critically significant yet often-ignored concept. As its name entails, statistical validity(also known as statistical conclusion validity) refers to aspects of quantitative assessment that influence the precision of the conclusions drawn from the results of a research (Campbell & Stanley, 1966; Cook & Campbell, 1979; Schram, 2005). Statistical procedures are normally applied to examine the relationship between two or more variables and determine whether an observed statistical effect is due to chance or is a true indication of a causal relationship (Rosnow & Rosenthal, 2002). At its simplest form, statistical validity addresses the question of whether the concepts of hypothesis testing, the statistical results and statistical evaluation are interrelated, and they provide the base for assessing statistical validity.

Statistical evaluation refers to the theoretical basis, rationale, and computational aspects of the actual statistics applied to assess the nature of the relationship between the independent and dependent variables. Among other things, the selection of statistical tools usually depends on the nature of the hypotheses being examined in the research. This is where the concept of hypothesis testing enters the discussion of statistical validity. Every study, as in this research, is driven by one or more hypotheses that guide the methodological design of the study, the statistical analyses, and the resulting conclusions (Trochim, 2000).

Statistical (conclusion) validity is the extent to which conclusions we reach about relationships in our data are reasonable. Based on this definition of statistical (conclusion) validity, in order to examine the research main objective which tries to find out the relationship between the Mediterranean container ports' technical efficiency and their competitiveness, this research tested a number of hypotheses through the use of some statistical measures. such as a Spearman's' rank order correlation coefficient.

As mentioned in chapter one and five, the fifth hypothesis **(H5)** reveals that "*The technical efficiency increases as the scale of a container port increases"*. This hypothesis tests the relationship between production size (ports' throughput), as proxy for port competitiveness, and ports' technical efficiency. The positive signs for the Spearman's rank order correlation coefficient entail that the production volumes of container ports are positively associated with efficiency scores. On the other hand, the high absolute value of 0.92 of the Spearman's rank order correlation coefficient would seem to denote that there is a strong relationship between the efficiency of ports under study and their competitiveness.

Hypothesis seven **(H7)**, as mentioned in chapter one and earlier in this chapter, assumes that "*ports technical efficiency could affect container ports competitiveness in the Mediterranean market".* In this context, the relationship between the competitive positions of the Mediterranean container ports is presented by HHI and ports technical efficiency are presented by ports' efficiency scores. Such a relationship is measured by Spearman's rank order correlation coefficient. The positive signs for the Spearman's rank order correlation coefficient reveal that the technical efficiency of container ports in the Mediterranean are positively affecting their competitive position in the defined market.

On the other hand, the relatively high absolute value, 0.92, of the Spearman's rank order correlation coefficient would seem to demonstrate that the competitive positions of the Mediterranean container ports are significantly related to their technical efficiency. That implies that as far as port competitiveness is concerned, the higher the efficiency of the container ports the fiercer is the competition among ports in the same market.

Similarly, hypothesis eight **(H8)**, as mentioned in chapter one and earlier in this chapter, presumes that "*There is a positive relation between the level of ports efficiency and the competitive position of the container ports in the Mediterranean market".* Here, the relation between the efficiency levels of the container ports under study, presented by their DEA super-efficiency scores, and their competitive position, presented by their market share in the Mediterranean market is tested by using correlation coefficient. A high and positive correlation of 0.87 between the ports competitive position and their super- efficiency scores is figured out. That, in turn asserts that there is a strong relation between ports' technical efficiency and their competitive position in the Mediterranean container port market.

In the same context, hypothesis nine **(H9)** presumes that "*there is a positive relation between Mediterranean container ports average growth rates and their technical efficiency"*. As such the relationship between the average growth rates of container ports throughput in the Mediterranean market and the changes of their efficiency scores over time is analysed. Spearman's rank order correlation coefficients is calculated to examine such relationship for every panel data set. The relatively medium absolute values of the Spearman's rank order correlation coefficient demonstrate that the average growth rates of the Mediterranean container ports are, to some extent, related to their technical efficiency. That indicates that, the average growth rates of container ports in the Mediterranean are also related to a number of exogenous factors such as the ports demand, the amount of container traffic that need to be handle in a particular port, and the number of ships calling that port.

7.4 Chapter summary

This chapter has presented a number of empirical tests of hypotheses formulated on the basis of a corpus of traditional economic theory of port efficiency. What differentiates this work from previous studies on the subject is that both cross-sectional and panel data have been used and analysed at the level of individual container ports in the Mediterranean. Another significant feature of the analysis is that it is based on a wide range of methodologies, both parametric and non-parametric, that have ensured the validity of the empirical examination that has been undertaken and the results obtained.

The adoption of Simar and Wilson (2007), a bootstrapped parametric procedure, enhances both efficiency of estimation and inference. Particularly, the adoption of the functional form (truncated functional form) in the second stage enables consistent inference with models explaining efficiency estimates, while simultaneously creating standard errors and confidence intervals for these efficiency estimates.

Moreover, the analysis has also permitted the comparative assessment of the consistency of the results obtained from the different approaches and models used to assess port competitiveness and efficiency. This, to a large extent, has provided an empirical validation of the approaches and techniques themselves. The results of this chapter explain the relation between port efficiency and competitiveness. It also expresses the impact of such relation on the dynamics of the Mediterranean container port market.

CHAPTER EIGHT

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER EIGHT
CONCLUSIONS AND RECOMMENDATIONS

8.1 Introduction

This chapter presents the overall conclusions and main findings derived from this research, followed by recommendations for future work. It starts by discussing the realisation of the research aim and objectives through reviewing the research processes which have been undertaken to address these objectives. Then, it demonstrates the research significance and contribution to theory and practice. Finally, the limitations of the study are identified, upon which areas for further research are suggested. The remainder of this chapter is organised as follows. Section two evaluates the realisation of the research aim and objectives. The research contributions to knowledge are discussed in section three. Section four illustrates the research limitations. Finally, section five suggests recommendations for future work through which this research could be further developed.

8.2 Realisation of the research aim and objectives

As mentioned in chapter one, the aim of this research was to assess the impact of port technical efficiency on port competitiveness (section 1.5). To achieve this aim the research methodology explained in section 1.8 has successfully addressed the five research objectives stated in section 1.5 and formulated the nine research hypotheses that mentioned in section 1.7. Table 8.1 shows the summary of the research objectives and indicating the place at which every objective is achieved within the context of the research. Table 8.1 also identifies the methodology and techniques that are used to achieve each objective.

As shown in Table 8.1, Chapter two and three achieved the first objective of this research which is '*To review the literature in port competition and efficiency*'. Chapter two answered the first research question stated that '*What is port competitiveness and competition and how it is assessed?*'. The literature illustrated that research on port competition has focused on specific objectives such as analysing the competitiveness level of ports in a particular market or region, exploring the factors affecting port competitiveness and developing models for port competition. It also revealed that most studies on port competition have focused on specific markets such as the Far East and Chinese container ports, European container market and US container ports.

Table 8. 1– Research objectives and methodology

No.	Research objectives	Research chapter	Methodology
1	Review the literature in port competition and efficiency.	Chapter 2 Chapter 3	Descriptive analysis Exploratory research
2	Analyse the Mediterranean container ports' competitiveness through studying the dynamics of the Mediterranean container port market.	Chapter 5	**SCP paradigm** K-CR, HHI, GC and EI.
3	Study the current changes of market structure, conduct and performance.	Chapter 5	BCG matrix Shift-Share analysis
4	Evaluate and benchmark the technical efficiency of container ports in the defined market.	Chapter 6	**DEA models** DEA-CCR/BCC, DEA super-efficiency analysis, Sensitivity analysis and Slack variable analysis.
5	Assess the impact of port technical efficiency on port competitiveness and study the ability of some gateway ports to become future hubs.	Chapter 7	Bootstrapping truncated regression and Spearman's rank order correlation coefficient.

The previous studies in port competition indicated a gap in that there is a lack of research that addresses the issue of port competitiveness in the Mediterranean container market. The Mediterranean container port market cannot be deemed as an identical group of ports. It features showed large ports as well as a number of medium-sized to smaller ports each with certain characteristics in terms of transhipment incidence, the hinterland markets served and the locational characteristics. This distinctive blend of various container port sizes and types combined with a massive economic hinterland provides an incentive to container port competitiveness in that market.

As such the literature reviewed in chapter two highlighted the need to analyse the competitiveness of major Mediterranean container ports by considering the Mediterranean in its totality, including south Europe, Middle East and North Africa. The study puts forward a way to assess container port efficiency based on simple, yet validated and meaningful competition measures. Moreover, the significance of this research can be realised in assessing the competitiveness level of the top 22 container ports in the Mediterranean and, on the other hand, in analysing the dynamics of this market through the use of the Structure, Conduct and Performance (SCP) paradigm.

Chapter three also achieved the first research objective and answered the second research question stated that '*What is the port technical efficiency and how it can be evaluated*'. Chapter three discussed the concepts, definitions, types and theories of port efficiency and productivity. The review on port efficiency illustrated that researchers have addressed different aspects that affect port efficiency through the use of different methods. The chapter also indicated the gap in previous studies as the researchers focused their studies on ports located in different markets such as North Europe, Far East, USA and Latin America. However, the studies that focus on the Mediterranean container ports tend to be limited in scope; they use data from one single country, compare between ports of two countries, or use only the Mediterranean European ports. This is mainly due to limitations in data availability for such a wide and diverse group of ports belonging to various countries and different continents.

The gap in the literature on port efficiency identified the need to benchmark and ranks the efficiency of major Mediterranean container ports. As illustrated in chapter four, the first stage constituted the study of market structure and conducting the ports' competitiveness analysis. The second stage involved the study of market performance, the efficiency analysis through the use of different DEA models. Thus, it highlights the potential for inefficient ports to improve the utilisation of port infra/superstructure. The third stage analysed the impact of port efficiency on port competitiveness in the Mediterranean container market through the use of bootstrapping truncated regression analysis.

Chapter five achieved the second research objective*, to analyse the Mediterranean container ports competitiveness through studying the dynamics of the Mediterranean container port market*, and the third research objective, *To study the current changes of market structure, conduct and performance*'. Chapter five also answered the third research question stated that '*What are the main characteristics of the Mediterranean container port market in terms of market structure (ports' competitiveness) and market conduct?'.* Chapter five analysed the recent dynamics in the Mediterranean container port market for the period from 1998 to 2012 in terms of market concentration and deconcentration tendencies, and the impact of such tendencies on the container ports' competitiveness. As indicated in chapter four, the research followed the concept of the Industrial Organization (IO) and the Structuralists (Harvard school) methodology to assess the market structure, dynamics and port competitiveness. In doing so, the (SCP) approach is used.

The research provided an in-depth analysis of the concentration, deconcentration and inequality levels of the Mediterranean container port market. The scope of the research mainly focuses on the measurement criteria and techniques perceived, not an in-depth study of the causes of the observed results. Table 8.2 indicates a summary for the research hypotheses and the place at which each hypothesis is tested and analysed within the research context. Table 8.2 also shows the status of each hypothesis that indicates whether each of these hypotheses is proved or rejected. The research findings demonstrated that the recent deconcentration tendency of the Mediterranean container port market is due to the increased number of market players and the distribution of container traffic among the ports under study. This can clearly be noticed from the analysis of the K-CR and HHI. The K-CR analysis revealed that the market shares of the top four and top ten container ports in the defined market have decreased within the study period. Similarly, the value of the HHI also decreased in the same period. Thus the first hypothesis **(H1)** is supported as '*the market moves toward deconcentration and pure and perfect competition*'.

As far as the inequality analysis is concerned, chapter five assessed inequality at the level of the Mediterranean container ports under study. The reduction in the value of Gini coefficients as well as the increase in Entropy indices for the Mediterranean container port market indicated a remarkable deconcentration trend within the period of study. The recent hub battle certainly influences the existing hierarchy in the Mediterranean port market. Hence, new ports are built to accommodate Round-The-World (RTW) services with the best technology and location such as Algeciras in Spain, Marsaxlokk in Malta, Port Said (SCCT) in Egypt and GioiaTauro in southern Italy, meanwhile medium-sized ports are strengthening their position vis-a-vis larger ones. Using the Gini coefficient and Entropy indices as analytical techniques enables observations to be made in relation to the net contribution of the inequality between individual ports to overall traffic concentration in the defined port market. By doing so, the research is able to extract more information on spatial dynamics in the Mediterranean container port market than provided solely by the Gini coefficient. This establishes a useful and distinct contribution to the literature of port geography.

Table 8. 2– Status of research hypotheses and their measurement tools

No.	Research hypotheses	Status	Measurement Tools/models
1	The Mediterranean container port market is moving towards de-concentration and pure and perfect competition.	Supported	K-CR, HHI, GC and EI.
2	The competitiveness level of the ports under study has changed over the period of study.	Supported	BCG matrix, Shift-Share analysis
3	The technical efficiency of the Mediterranean main container ports is not related to scale of production.	Supported	Spearman's rank order correlation coefficient
4	The technical efficiency of the Mediterranean main container ports has improved over time.	Supported	DEA-CCR/BCC DEA super-efficiency
5	The technical efficiency of the Mediterranean container ports increases as the scale of a container port increases.	Supported	Spearman's rank order correlation coefficient
6	The technical efficiency of the Mediterranean container ports is affected by different exogenous variables.	Supported	Bootstrapped truncated regression
7	Ports technical efficiency could affect container ports competitiveness in the Mediterranean market.	Supported	Spearman's rank order correlation coefficient
8	There is a positive relation between the level of ports' efficiency and the competitive position of the container ports in the Mediterranean market.	Supported	Spearman's rank order correlation coefficient
9	There is a positive relation between Mediterranean container ports average growth rates and their technical efficiency.	Supported	Spearman's rank order correlation coefficient

The research also concluded that the dynamic characteristics of the Mediterranean container market have a significant impact on determining not only the degree of market concentration but also the competitiveness level of container ports in such a market. In this context, the BCG matrix is used to test the second hypothesis **(H2)** that presumes that '*the competitiveness level of the ports under study has changed over the period of study*'.

The results indicated by the BCG matrix confirm such hypothesis as the ports of GioiaTauro, Valencia and Barcelona were the market leaders in 1998, while the ports of Algeciras, GioiaTauro, Piraeus and Ambarli took the lead in 2012. Meanwhile, there is potential for some ports such as Port Said and Tangier to enhance their competitive position and become market leaders as hub ports in the Mediterranean basin. The former has the potential to increase its average growth rate, while the latter has a good opportunity to increase its market share through transhipment traffic.

In the context of the analysis of market conduct, the shift-share analyses illustrated that the level of port concentration in the Mediterranean container port market reduced in the period of study. The reduction in the level of concentration was a result of container shifts to medium-sized (new) ports such as Tangier and Port Said (SCCT) which offer a more favourable location to receive RTW services. The recent hub battle in the Mediterranean will most probably lead to further traffic distribution for the containerised cargoes between east-west and north-south. The level of this traffic distribution will mainly depend upon the productivity gains in the Mediterranean load centres and the developments in land container services, roads and rails operating on multimodal transport networks, and feeder services between container ports in the Mediterranean basin and their hinterlands.

Port authorities in the Mediterranean market could use these results as a guide to assess whether the observed spatial growth of the respective container port market is in line with their policy aims. The results also provide a useful basis for evaluating the impacts of present changes in liner service schedules, hinterland services and market organisation on the spatial distribution of container handling activities. This in itself is a clear motivation to embark on a quest to further unravel the underlying dimensions through comparative studies.

Recently, shipping lines serving the trade passing through the Mediterranean are trading off between direct call and hub and spoke services. This, in turn, will not only reshape the market structure and dramatically change the container port hierarchy, but also intensify the competition between ports as the market shifts from oligopoly to pure competition. In order to keep pace with the market demand and enhance its competitive position, Mediterranean container ports need to optimize their resources to be able to achieve the win-win situation between ports and their users and to make the ports increasingly function, not only as individual nodes, but also as integrated players in the shipping networks.

According to the above mentioned analysis of the Mediterranean container port market structure and conduct, in terms of port hierarchy; the market can be segmented into two main categories, the present hub-ports and the potential hubs. The former such as GioiaTauro, Marsaxlokk, Algeciras and Port Said (SCCT) have a competitive advantage in their strategic location near to the main liner trade routes, while the latter such as Valencia, Barcelona, Genoa and Ambarli are trying to utilize their resources in terms of terminals infra/superstructure in order to enhance their competitive position and increase their market share.

Chapter six achieved the research objective four, '*to evaluate and benchmark the technical efficiency of container ports in the defined market*'. Chapter six also answered the fourth research question stated that '*What is the relative technical efficiency level of the Mediterranean main container ports?'.* As a second stage of the research model, five DEA models are used to obtain technical efficiency scores for the cross-sectional data for the year of 2012 and panel data for the period between 1998 and 2012.These models are; the DEA-CCR, DEA-BCC, DEA-Super efficiency, sensitivity analysis and Slack variable analysis models. The use of five DEA models enabled a comprehensive assessment of the relative technical efficiency of the main container ports in the Mediterranean.

The application of DEA-CCR/BCC models benchmarked the technical and pure technical efficiency of ports under study. The cross-section and panel data analysis revealed that:

1. There are four ports considered as efficient as they achieved the optimum utilisation of their facilities with relative efficiency scores of one. These ports are Valencia, Port Said, GioiaTauro and Algeciras. However, the rest of the ports under study are considered as relatively inefficient. To be efficient, they have to either increase their output or minimize their inputs to increase their efficiency scores to be equal to one.

2. The results signify the existence of inefficiency pertaining to the management of container ports in the region, since the total technical efficiency is found to be 50 % on average. This relatively limited technical efficiency of the Mediterranean container ports indicates the need for appropriate capital investments for ports' infra/superstructure. In particular, those ports whose efficiency is not favoured by factors such as size, geographical position and socio-economic conditions of the region wherein they are located, must adopt suitable reform strategies to promptly improve their efficiency and competitive position. These strategies should aim at upgrading the port infrastructure and equipment, adopting best practices and implementing training and know-how transfer from other port authorities. New funding sources for these strategies can be obtained through effective regulatory reforms and private concession schemes with global terminal operators for selected terminals.

3. The observation of 'stability and trend' in window analysis reflects both the relative performance of a port in comparison to the others in the sample and the absolute performance of a port over time. The result showed that some container ports such as Valencia, Algeciras, Barcelona, Marseilles, Genoa, Mersin and Livorno are stable in

terms of their technical and pure technical efficiency. This is related to the involvement of the private sector in terminal operations in the ports of Valencia, Algeciras and Barcelona and the continuous investment in port infra/superstructure in the ports of Genoa, Marseilles, Mersin and Livorno. In contrast, some ports such as Cagliari, Constantza and Naples showed unstable performance in comparison to other ports in the sample.

4. There is no relation between scale of production (ports' throughput) of the Mediterranean container ports under study and the fluctuations in their efficiency over time as the correlations between the two variables are statistically insignificant. This implies that the efficiencies of all of the ports in the sample exhibit a similar level of fluctuation over time. As such, hypothesis three **(H3)** stated that "*the technical efficiency of container ports are not related to scale of production"* cannot be rejected.

5. The technical efficiency of the Mediterranean main container ports has improved over time. However, the decision as to whether to accept or reject hypothesis four hinges on the definition of efficiency that is applied. Hypothesis four **(H4)** presumed that "*The technical efficiency of the Mediterranean main container ports has improved over time"* cannot be rejected if the efficiency under study refers to an overall efficiency that is affected by technological innovation and management. However, hypothesis four can be rejected if it is held to refer solely to whether a firm follows best practice at any particular time.

6. Gateway ports such as Livorno, Marseilles, Izmir, Constantza and Naples appear to show lower levels of technical efficiency than ports that specialised in transhipment such as Algeciras, GioiaTauro, Port Said and Marsaxlokk. This result is partially understandable by the quasi-captive nature of gateway traffic that is obtained from or directed to well-defined hinterlands, as opposed to the footloose nature of transhipment traffic. In the case of the latter, there exists more of an incentive for improving efficiency to improve competitiveness in a competitive environment.

7. The majority of the container ports under study tend to operate at decreasing returns to scale (DRS). This is due to the fact that port capital investments are often made in large amounts irregularly with the estimation of a long working life. Thus, ports often design their capacity in advance higher than its current market demand, even if port traffic only builds up gradually over time.

8. The positive correlation between production size, ports' throughput, and port efficiency estimates entails that the production volumes of container ports under study are positively associated with efficiency scores. As such Hypothesis five **(H5)** presumed that "*The technical efficiency increases as the scale of a container port increases"* is confirmed.

9. The ranks of ports under study in terms of super-efficiency scores showed that the ports of Algeciras, Port Said, Valencia and GioaTauro have the highest super-efficiency scores, while the ports of Cagliari, Constantza and Naples show the lowest super-efficiency scores. In this context, the lack of managerial skills and scale diseconomies are considered as important sources of inefficiency for most of the container ports in the defined market. A detailed knowledge of the results of this study would help port managers to realise where they stand in the efficiency hierarchy and which ports they need to compare themselves against in order to enhance their own efficiency.

10. The sensitivity analysis revealed that the storage capacity, quay length, ports' maximum depth and handling equipment are the main influential variables that affect the study ports' operational efficiency. The storage capacity, quay length and ports' maximum depth affected the relative efficiency scores of 8 out of the 22 ports under study, while the handling equipment affected the relative efficiency of 10 ports.

11. The slack variable analysis revealed that most of the inefficient ports under study need to either increase their output in terms of annual container throughput or to

reduce the utilisation of their inputs in terms of ports infrastructure and handling equipment. In the context of inputs minimization, most of the inefficient ports under study have problems with the utilization of their infrastructure and, in particular, the storage capacity. The problem of bad utilisation of storage capacity arises with those ports that are operated under increasing returns to scale such as Ambarli, Taranto, Cagliari and Naples.

Using sensitivity analysis and slack variable analysis has also provided useful information that demonstrates how a relatively inefficient container port can enhance its operational efficiency. The former identified the most important variables that affect the technical efficiency of each port, while the latter provided solutions to port managers of inefficient ports that allow them to achieve the best utilisation of port resources.

Chapter seven achieved the fifth research objective, '*To assess the impact of port technical efficiency on port competitiveness and study the ability of some gateway ports to be a future hub'* and answered the fifth research question stated that '*What is the relation between the Mediterranean container ports efficiency and their competitiveness?'.* As a third stage of this model, the impact of port efficiency on port competitiveness is analysed through the use of Simar and Wilson's (2007) procedure to bootstrap the DEA scores with a truncated regression. Using this approach creates more reliable evidence compared to previous studies analysing the efficiency of seaports. This is because the Simar and Wilson (2007) procedure ensures the efficient estimation of the second-stage estimators, which is not a property of alternative methods.

Firstly, the true efficiency score is not observed directly but is empirically estimated. Secondly, the empirical estimates of the efficiency frontier are obtained based on the chosen sample of seaports, thereby ruling out a number of efficiency production possibilities not observed in the sample. Thirdly, the three-stage procedure also depends upon other explanatory variables which are not taken into account in the second-stage efficiency estimation. This implies that the error term must be correlated with the second-stage explanatory variables. The method introduced by Simar and Wilson (2007) overcomes these difficulties by adopting a procedure based on a double bootstrap that enables consistent inference within models, explaining efficiency scores while simultaneously producing standard errors and their confidence intervals. As such the main results of the bootstrapping regression analysis are as follows.

The bootstrapped regression of the ports of Algeciras, GioiaTauro, Marsaxlokk, Port Said and Tangier is greater than its corresponding DEA-CCR super-efficiency scores. This result is plausible as these ports are the current hub ports in the Mediterranean container market. However, the bootstrapped regressions of the ports of Valencia, Barcelona, Ambarli, Genoa, La Spezia and Haifa are also greater than their super-efficiency scores. This means that these ports are highly affected by the explanatory variables, mentioned in chapter four, and as such have the potential for being hub ports in the defined market. Although the rest of the ports under study are also affected by the explanatory variables, their relative technical efficiency hinders them from being potential hubs in the Mediterranean region. As such, the sixth hypothesis **(H6)** presumed that '*The technical efficiency of the Mediterranean container ports is affected by different exogenous variables*' is confirmed.

The relationship between ports' competitiveness and their technical efficiency is also examined by using some parametric statistical analysis. The Spearman's rank order correlation coefficient is used to test the seventh hypothesis **(H7)** that presumed that '*The Ports technical efficiency could affect container ports competitiveness in the Mediterranean market'.* The results revealed that there is a positive correlation between the technical efficiency of the main container ports in the Mediterranean, presented by the DEA-CCR/BCC efficiency scores and port competitiveness, presented by the HHI. As such hypothesis seven is confirmed.

Moreover, Hypothesis eight **(H8)** presumed that '*There is a positive relation between the level of ports efficiency and the competitive position of the container ports in the Mediterranean market'.* Hypothesis eight is tested by comparing the ports ranks in terms of their market share that presents the competitive position of the ports in the Mediterranean market and the rank of ports according to their super-efficiency scores in 2012. The results revealed that there is a high positive correlation between the ports' competitive position and ports' technical super-efficiency scores and the ports' competitive position is, more or less, the same as the ports' efficiency level. As such hypothesis eight is confirmed.

In order to examine the relationship between ports' competitiveness and ports' technical efficiency in the Mediterranean container market for the panel data set from 1998 to 2012, hypothesis nine was formulated. Hypothesis nine **(H9)** presumed that "*there is a positive relation between Mediterranean container ports average growth rates and their technical efficiency"*. Spearman's rank order correlation coefficients is calculated to examine such relationship for every panel data set. The results revealed that there is a positive relationship between the Mediterranean container ports' average growth rates, as a proxy for ports' competitiveness and their technical efficiency scores. As such hypothesis nine is confirmed.

8.3 Contribution to the development of knowledge

The research findings shed light on the Mediterranean container port market and have significant policy and managerial implications. Governments may be influenced in formulating policies with reference to the findings. As such, the most important contribution of this research is that it analysed the relationship between port competitiveness and technical efficiency in the Mediterranean container port market by studying the potential influence of market structure, conduct and performance. Given the empirical findings herein, from observing their own individual relative efficiency estimates, port managers and operators may obtain useful insights into the state of their own technical efficiency and to learn where shortcomings exist by identifying the sources which may be contributing to their own technical inefficiency. A benchmarking analysis such as in this research, conducted on a purely objective and scientific basis, could then contribute and constitute the starting point for a port to further improve its efficiency, to the probable benefit of its competitiveness, profitability, its shareholders, society and the national economy as a whole in which it might be located.

One of the main contributions of this research is that it analyses the competitiveness of major Mediterranean container ports by considering the Mediterranean in its totality, including south Europe, Middle East and North Africa. The study puts forward a way to assess container port efficiency based on simple, yet validated and meaningful, competition measures. Moreover, the significance of this research, from one hand, can be realised in its contribution in not only assessing the competitiveness level of the top 22 container ports in the Mediterranean but also in analysing the dynamics of this market through measuring the market tendency towards concentration or deconcentration.

This study finds advantages in applying non-parametric approaches to measuring container port or terminal efficiency, mainly in the form of the DEA models. One significant advantage of a non-parametric approach such as DEA is that it does not impose any form of functional assumptions on the efficiency estimates or error structure of this family of models. As such, the data are said to be able to ‘speak for themselves’. In particular, non-parametric approaches exhibit their advantages in analysing panel data. DEA-Window, Contemporaneous and inter-temporal analyses were found to be consistent with traditional production theory. Furthermore, the efficiency results revealed by these different models have shown that they have valuable policy implications.

For instance, DEA inter-temporal analysis is capable of analysing whether a port is keeping abreast of both technological advancements and management improvements, while DEA contemporaneous analysis can theoretically filter the enhancement in efficiency attributed to technological advancements over time. Such a comprehensive comparison of various approaches to estimating efficiency measures is of great significance not only in its own right, but also in preparing for the use of these and other methodologies in the further analysis of the container port industry or, for that matter, for any other industry of interest.

On the other hand, the research applied the structure, conduct and performance (SCP) approach derived from the Industrial Organisations theory to analyse the Mediterranean container port market dynamics. That in turn enabled the examination of the impact of port efficiency, as a proxy for market performance, on port competitiveness, as a proxy for market structure and conduct. Although the SCP approach has widely been used in industrial economy and shipping market, the literature revealed that the SCP approach has not been applied to the container port market and, in particular, the Mediterranean market.

The bootstrapping truncated regression analysis allowed investigation and identification of key factors impacting container port infrastructure productivity during the study period. The use of a combination of endogenous (controlled) and exogenous (uncontrolled/explanatory) variables enabled to comprehensively assess the impact of port technical efficiency on port competitiveness. This approach can be considered as integrated: it helps the container port operators to realize both their weaknesses in relation to direct competitors and how the internal and external operational environment affects the efficiency of their production process. In the light of the above observations, the present research is a methodological improvement in this field, since it estimates the efficiency scores with alternative DEA models and then tests statistically several hypotheses.

8.4 Research limitations

This study is based on, and limited to, a historical data set for the period between 1998 and 2012. Thus, the model is not able to predict if the efficiency of the ports under study will be maintained over a period of time. The study is also limited to the previously mentioned 22 container ports in the Mediterranean that represent the large and medium sized container ports in the defined market. The research has intentionally not included small container ports because, as far as port competitiveness and ports efficiency are concerned, one of the main objectives of this research is to examine the ability of the Mediterranean container ports to be a future hub. As such, small ports that have an annual throughput of less than 500,000 TEUs are out of the scope of this study as they do not have the fundamentals that enable them to achieve such a target.

The research has analysed the Mediterranean container ports' competitiveness by using some quantitative measures such as ports' annual container throughput, market share and annual growth rate. However the research did not use other factors that determine ports' competitiveness such as the ability of ports to reduce port costs for users through higher productivity, the ability of a port that enables users to compete effectively with other transport modes, the ability to capitalize on the complementary and strengthening effects of the port cluster and the ability to be a key driver of the local economy. However, such factors are not used here in this study due to the scarcity and the confidentiality of data as port managers do not release information that affects the competitive position of the port in the market.

In terms of benchmarking port efficiency, this research aimed merely to analyse and assess the technical efficiency of main container ports in the Mediterranean. The study did not include any economic measures that enable benchmarking the allocative efficiency of the sample ports in the defined market. Such analysis needs financial data such as port dues, terminals handling charges, labour cost, maintenance cost and other costs. Such data is confidential and is not readily obtained from port authorities and managers. Another limitation of this research relates to the input variables: infrastructure and machinery information. These variables provide fundamental and necessary information about container port and terminal operations, but they do not capture the various physical configurations of ports. Labour information was also difficult to obtain and such information would have enriched the analysis.

The research is also limited to analyse the impact of port technical efficiency on port competitiveness through the use of a group of quantitative measures. Qualitative measures such as shippers and shipping lines perceptions in terms of sample ports' competitiveness and technical efficiency are not included in this study. That is due to the weak and unreliable response from them to the e-mails and interviews conducted at the data collection phase at the beginning of this research.

In this thesis, the role of hinterland in deciding port competitiveness acting as transhipment hubs is not analysed. Although transhipment means a transfer of cargoes from a vessel to another vessel, hinterland also plays its role in affecting a port's potential in becoming a transhipment hub. This is especially true for the Mediterranean ports where their immediate surrounding regions are traditionally the economic power houses of Europe and the vast consumption centers in North Africa and the Middle East. Nevertheless, the role of hinterland itself was a very big topic and it was by no means an exaggeration to argue that its inclusion here could actually mean doubling the size of this thesis.

8.5 Recommendation for future research

As far as the port efficiency evaluation is concerned, it is clear that much work needs to be done to improve and enhance the application of econometric models to analysing the efficiency of container ports. Various DEA models were thoroughly examined in this research and applied to the container ports under study. However, this research has shown that DEA exhibits certain weaknesses in its application to the container ports. It will be interesting to expand the boundaries of current research by applying a more extensive range of parametric models within a more comprehensive parametrically focused analysis. It would be beneficial if, using stochastic frontier analysis, it would be possible to decompose efficiency estimates, especially where these change over time, into elements that are due to technological innovation to examine how much a port is keeping abreast of state-of-the-art technology and those that are due purely to improvements in technical efficiency.

As the contents of this research emphasize specifically the issue of technical efficiency, it has ignored the financial performance of the sample container ports. Another important aspect of overall economic efficiency that the research has deliberately not addressed, however, is the influence of factor prices. Accounting for this is achieved by examining the allocative efficiency of the sample under study. An interesting extension to the study contained within this research, therefore, could be to examine the relationship between technical and allocative efficiency for the container port industry. This is especially significant in that optimum technical efficiency in the processing of inputs into outputs does not necessarily guarantee the financial success or survival of a container port.

Despite the numerous advantages it does possess, especially in comparison to some alternative approaches, the DEA methodology does not enable the incorporation of statistical noise. It will be interesting to examine and apply to the container port industry any newly developed DEA approach of this kind that may come to fruition. In the final conclusion, estimating the efficiency of container ports is the beginning and not the end of any analysis which intends to define or determine a port's competitiveness and the subsequent amount of business that it might secure as a result.

This study has explored the potential reasons behind (in)efficiency associated merely with the Mediterranean container ports understudy and has found it to be an extremely difficult, if not impossible, task to isolate or discover a single universal factor that influences the efficiency of the whole port industry. Certainly each port has its distinctive and unique context within which it operates and competes and that its level of efficiency will contribute to its operational and competitive success or otherwise. As well as applying a systematic comparative analysis as advocated and contained within this research, therefore, this entails that such an analysis needs to be complemented by an examination of other more singular aspects of individual ports on a case-by-case basis, not least of which will be pricing policies. It will then be interesting to explore the more subtle reasons behind the degree to which each individual container port is competitive.

Other areas for future research lie with forming suitable clusters of ports in the sample that can be benchmarked against one another in order to determine causes of inefficiency and measures for its improvement; extending the set of input variables to consider environmental or instrumental variables, such as geographical proximity to main trade routes, accessibility to other ports via the liner shipping network (Wang & Cullinane, 2006a) and hinterland locations via the general transport network serving the port; determining the causal elements that affect port efficiency (Cullinane & Song, 2006).

Other potential areas of future research can be formulated to expand the range of port outputs considered beyond just container port throughput, to encompass other types of terminals or activities, such as dry and liquid bulks, to account for the labour input more explicitly, preferably by accessing consistent and reliable sources of data. Alternatively, deducing an accurate relationship between labour and capital input factors for ports in the Mediterranean region would go some way towards achieving greater reliability in the efficiency estimates produced, to validate the findings from this analysis by applying alternative methodologies, particularly stochastic frontier analysis (SFA), to the same data set.

On the other hand, as far as port competitiveness is concerned, in this thesis, the roles of minor ports are not considered. How will port competition differ if minor ports are included and what will be the current and future prospects of these ports in the Mediterranean container market? Currently, ports mainly regard their counterparts as competitors. Will it be possible to collaborate and achieve win-win solutions? If so, how can it be achieved? What agreements should be made for such collaborations? For example, will it be possible for ports to join together to negotiate with liners so as to make it possible for ports to have a more active voice in the network-routing process(Co-opetition concept)?

Last but not least, what is the role of hinterland in affecting the potential of a port in becoming a region's transhipment hub? Acting as the continent's traditional economic powerhouse, how important do these surrounding regions of the Mediterranean ports affect their attractiveness and thus competitiveness? Despite extensive research, some issues are still unresolved. The following questions warrant further investigation: What is a hinterland and which ports are competing? How will the issue of port security influence port efficiency and competitiveness?, Is privatization effective in making ports more competitive? How can differences in the relative efficiency of competing ports be assessed?

Various results that have been drawn on these topics from previous research are due, at least in part, to design problems. Indeed, Cullinane et al. (2005) argued that the most important criteria for judging whether two container ports are competing against each other is to examine if they serve identical or overlapping hinterlands. This may be a starting point in initiating new research to address the outstanding questions listed above. In designing the research attention needs to be paid to how contemporary hinterlands are evolving in response to the changing economic environment stemming from the restructuring of the value-driven logistics activities and supply chain industry.

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