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COMEM

BENCHMARKING ANALYSIS OF PORT SERVICES FROM A PERSPECTIVE OF FREIGHT FORWARDERS

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Benchmarking Analysis of Port Services from a Perspective of Freight Forwarders

By

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Abstract

In the time when the World can experience volatility of international trade due to World economic crisis, concentration of the shipping industry and liberalisation of transport markets, port competition is becoming fiercer over the time. In such an environment, freight forwarders' role is becoming more and more important, representing a valuable link in the whole supply chain.

This research attempts to analyse and benchmark port services based on the factors and criteria most important to freight forwarders' port choice, the operational efficiency and performance benchmarking of container ports and terminals, situated in the area of the United Kingdom and Balkan Peninsula. It does so by applying different techniques, starting from questionnaire survey among freight forwarders in these regions in order to determine the most important port choice factors, followed by analytical benchmarking technique such as DEA to analyse impact of operating factors on port efficiency and concluded with productivity analysis to measure terminal productivity changes during, before and after the World economic crisis.

The study found that region where freight forwarders are acting has impact on their port choice. Geographical location seems to be the most important factor while choosing a port, followed by terminal intermodal connection efficiency and reliability, frequency of ship calling, inland delivery cost, port accessibility, flexibility to answer freight forwarders demands and port working hours. Benchmarking analysis showed that most of the terminals from the sample are inefficient, where mainly larger terminals based in the UK depicted higher efficiency scores above 80 %. Study found terminal operational efficiency is positively related to both seaside and landside terminal connectivity and port customer service. Productivity analysis showed high volatility in productivity change during the World economic crisis, with overall productivity loss, suggesting that terminals were mainly focused on terminal expansion rather than rationalisation of input use

Dedication

I would like to dedicate this work to my parents, to whom I am indebted for their selfless support and encouragement.

I would like to give special dedication to my late grandfather, who first started to work in maritime shipping and will always be in my memory and to my nephew, who was born during these master studies and made me happy and proud through my study period.

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List of Abbreviations

AE	Allocative efficiency
AHP	Analytical Hierarchy Process
BCC	Banker, Charnes, Cooper (DEA Model)
BPR	Business Process Reengineering
BSC	The Balanced Scorecard
CCR	Charnes, Cooper, Rhodes (DEA Model)
COLS	Corrected Ordinary Least Square
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
e.g.	For example
EE	Cost Efficiency
EEA	Economic Engineering Analysis
FDH	Free Disposal Hull
FF	Freight Forwarders
i.e.	Namely
MFP	Multi-Factor Productivity
MPI	Malmquist Productivity Index
OLS	Ordinary Least Square
PEC	Pure Efficiency Change
PFP	Partial Productivity Indicator
SE	Scale Efficiency
SEC	Scale Efficiency Change
SFA	Stochastic Frontier Analysis
SFP	Single Factor Productivity
TC	Technical Change
TE	Technical Efficiency
TEC	Technical Efficiency Change
TEU	Twenty-Foot Equivalent Unit
TFP	Total Factor Productivity
TFPC	Total Factor Productivity Change
US	United States
UK	United Kingdom
UNCTAD	United Nations Conference on Trade and Development
VRS	Variable Return to Scale

Chapter 1 - Introduction

1.1 Background

In the time when the World can experience rise of international trade, concentration of the shipping industry and liberalisation of transport markets, port competition is becoming fiercer over the time, constantly changing its nature (Huybrechts et al. 2002). Port services are no longer provided in isolation, but they need to fit into door-to-door supply chains. In this context, port competition has moved from competition between ports to competition between transport chains resulting that ports are eager to enhance the quality of their hinterland transport services (Notteboom & Winkelmans 2001). Moreover, the World economic crisis during 2008 contributed to fiercer port competition for each port user and each commodity.

In such an environment, freight forwarders' role is becoming more and more important. Acting as intermediary between shippers/consignees on the one hand and shipping lines and ports on the other, freight forwarders represent valuable link in the whole supply chain. For example, from shippers' point of view freight forwarders help reducing related coordination costs such as costs of finding the right transport company, negotiating tariffs, preparing and concluding transport contracts, and monitoring the execution of agreements. From shipping liners perspective, working with only one freight forwarder, who consolidates all shipment, can help in their attempt to fulfil the whole shipping space on their ships and avoid loss of cargo lacking without having to work with all shippers separately.

So far, most of the studies that have benchmarked and examined the port services are from the shippers' or shipping liners' perspective. Only few are focused on port choice made by freight forwarders.

This study will try to systematically analyse and present the most important factors in port choice from the perspective of freight forwarders. By doing so, it will attempt to access these factors in terms of port competitiveness in attracting its users and port performance benchmarking analysis in order to measure and compare port efficiency in the regions of the United Kingdom and Balkan Peninsula.

1.2 Research Problem and Objectives

This research attempts to analyse and benchmark port services based on the factors and criteria most important to freight forwarders when choosing a port, the operational efficiency and performance benchmarking of container ports and terminals. The research problem can be formulated as follows: *How can port services be benchmarked from a perspective of freight forwarders point of view?*

Besides that, the purpose is to identify what are the main factors and criteria influencing the freight forwarders decision of choosing a port. When analysing these factors it is relevant to bear in mind that the choices of the economic actors will be based on several and different elements. Such elements are related not only to the technical characteristics of the port, but also to hinterland and logistic services offered.

Having above in mind some most important research questions can be drawn:

1. What are the main factors and criteria that influence freight forwarders choice of the port?
2. How can container port performance and efficiency be benchmarked based on these factors?
3. How can we measure and quantify the impact of these factors and criteria?

In trying to answer above questions, this study adopts an approach that incorporates framework of qualitatively data analysis, measures and techniques for benchmarking container terminal efficiency.

The main objectives of this dissertation are as follows:

1. To investigate the role of qualitative factors of port choice from a freight forwarders' perspective and outline the differences in the freight forwarders' view in port choice factor selection in terms of region they act and cover;
2. To apply an analytical model for measuring and benchmarking the operational efficiency of international container terminal operations;
3. To identify and incorporate the variations in container port operating sites and production technologies;
4. To provide appropriate platform for further research on port attractiveness, competitiveness and choice based on freight forwarders' decision.

To address these objectives, qualitative and quantitative techniques will be used to examine these factors that are features of the container port and terminal industry.

In overall, some specific objectives and steps of this research include the followings:

1. Review and critically analyse the port choice determinants that are likely to impact the choice of specific port;
2. Review and critically analyse the theoretical and practical literature on port operational efficiency and performance benchmarking;
3. Apply appropriate functional modelling techniques for benchmarking the port services and port operational efficiency and performance;
4. Build up and validate aggregate and specific datasets, including the definition and selection of relevant input and output variables;
5. Formulate and apply appropriate models for efficiency benchmarking and productivity change analysis;
6. Report, assess, and analyse the variations in efficiency levels across sampled container terminals, based on factors determined from freight forwarders point of view.

1.3 Significance of the Study

The empirical results of this study will try to provide answers how port services can be benchmarked from a perspective of freight forwarders. First, it will explain whether determinants of port choice selected by freight forwarders in different regions have positive effect on container terminal efficiency. Second, depending on the size of the effects on terminal efficiency, it will outline whether port operators should focus on their improvement. Finally, this study could be useful to other port users included in the whole supply chain, as it will outline the factors that freight forwarders are paying attention in their port choice.

1.4 Organisation of the Dissertation

This dissertation consists of five chapters. Chapter 1 introduces research as a whole starting from background, outlining research problem and objectives and significance of the dissertation.

Chapter 2 provide an extensive literature review relevant to the subject of inquiry. This chapter describes the basics of port competitiveness, followed by outlining main decision makers and their main factors of port choice, port performance benchmarking methods, concluding with outlining the main hypotheses drawn to respond to the research question.

Chapter 3 outlines the research design and methodology adopted in this study, including such aspects as the formulation of the appropriate analytical models and techniques, the selection of the sampling frame, and the definition of the dataset and variables

Chapter 4 presents the detail discussion, results and findings of the analytical work. In particular, it starts questionnaire feedback analysis, followed by general discussion of the results from model application, tests of several hypotheses and concludes with productivity change analysis.

Chapter 5 concludes with research summary, main research findings and conclusions, followed by study limitations and recommendations for future research.

Chapter 2 - Literature Review

2.1 Port Competitiveness

Seaports are serious infrastructure resources and represent significant role in the transportation of people and freight. Over the history, seaports used to be a gateway to the rest of the World of their hinterlands. They were controlled and organised by public institutions that beside financial resources also provided regulatory and trade protection against other port competition (Bichou 2009). Ports are very different in their assets, roles, functions and institutional organisation. There are numerous definitions. Port can range from a small quay with one berth place to very large centre with numerous terminals and a cluster of industries and services (Bichou & Gray 2005).

Over the years, port competition became more and more intensified. There are several reasons for that, starting from growth and globalisation of international trade and liberalisation of transport market, through the development of cargo handling technologies to concentration increase in shipping industry. Nowadays, port markets are challenged by various ranges of competing ports and other logistic players, each offering alternative transport solution for shippers and shipping lines. This increase competition between global carriers which enhance the rivalry between seaports (Bichou 2009).

The nature and characteristics of competition depend upon the type of port involved and the commodity. In that sense the main focus on of competitive strategy lies on terminals, not ports itself (Heaver 1995). However, the nature of port competition has changed. Earlier, when global transport links were still inefficient and uncoordinated, port competition was driven by cost. More recently, with trade increase and globalisation and rise of emerging economies port competition depends not only on cost, but on trade-offs between cost and service quality (Bichou 2009). Besides that, port services are no longer provided in isolation, but they are part of the door-to-door supply chains (De Langen 2007).

There has always been rivalry among ports and terminals for traffic from hinterland regions. Huybrechts et al. (2002) and Bichou (2009) distinguish two different levels of competition:

1. Intra-port competition – within the port;
2. Inter-port competition – between different ports.

Intra-port competition takes place between terminal operators or service providers – stevedoring, warehousing or forwarding. For instance, competition can be focused on attracting major shipping lines and shippers to do their operations at the terminal, because usually shippers rather choose logistic chain and by that choose a port situated as a node in this chain[1].

Inter-port competition takes place at national or regional level between terminal operators from different ports (Huybrechts et al. 2002). Inter-port competition is also extended to the competition between intermodal systems, e.g. ports against inland transport system, or competition between port supply chains (Bichou 2009).

This has been the obvious case with container ports and modernisation of container ships in the last few decades. Moreover, containerisation enhanced, enlarged and extended this competition (Slack 1985).

2.1.1 Containerisation and Port Competition

Containerisation was a major technological innovation which caused significant level of service standardisation of port services. With containerisation, ports within the same region become exposed to competition from other ports and transport routes.

This trend was enhanced by two factors (OECD/ITF 2008):

1. Continuous development of container vessels implies less port calls are required for the same freight volume. With container vessel size increase intensifies competition of the ports over shipping lines choice for port of call on their route;
2. Port hinterland reach was extended by emergence of rail and inland waterway corridors. The extension of hinterland leads to overlap or ports' hinterland and stronger competition between ports.

Container ports cover certain range i.e. hinterland from/to where cargo flow comes/goes. Analyses of container port competition in various regions showed that ports compete not only with 'neighbours' but also with other ports located in the wider region (Notteboom & Yap 2012). In addition, Notteboom & Yap (2012) suggested that immediate hinterland serve as good base for inter-port rivalry.

As mentioned earlier, port competition is nowadays based on trade-off between cost and quality of port services. Slack (1985) argues that reliability, speed and quality of

[1] Authors perspective from his professional experience

service is more important than price. Increase in container cargo flows over years result in port congestion issues and not only within the port area but also in their hinterland transport networks. When a port or its hinterlands are strongly congested the quality of port's service becomes lower, reliability of such service declines and weakens its competitive position (OECD/ITF 2008). For instance, Slack (1985) outlined that several ports such as London and New York have poor reputation among shippers as being considered as centres of congestion, delay and labour problems. Such reputation definitely affects cargo flows.

Notteboom & Yap (2012) tried to explain complexity of port competition by showing that container port is more likely to be competitive if satisfy following conditions:

- Closeness of key production/consumption centres and major trade lines;
- Excellent hinterland connection and offers advanced connection to markets;
- It is able to reduce cost for users through higher productivity;
- Have strong bargaining power to attract carriers and shippers in relation to their cargo routing;
- Can meet demands for present and future capacity demand;
- Enables users to compete effectively with other transport modes;
- Can cope with challenges of new and changing logistics environment;
- Greater involvement of private sector at terminal operations level;
- Key driver of the local economy;
- Enjoys a long tradition, reputation and support from key stakeholders in the wider community.

2.2 Freight Forwarders' Role in International Shipping and Logistics

Freight forwarders play an important role in the international carriage of goods. Traditionally, the freight forwarder has been considered as a link between the owner of the cargo and the carrier, providing forwarding or clearing services (Saeed 2013). Previous researches tried to agree on definition, implying that freight forwarders play the role of the intermediary in international transport (Cateora & Keaveney 1987). In recent years, freight forwarders role got broader meaning. They are not only helping the parties to transport the cargo, but they are also transporting the cargo by their own means of transport truck, train or ship or making arrangements with other transport providers, and in this case they act as a principal rather than an agent.

Some of the functions included in the freight forwarders' activities are (Llanto & Navarro 2012):

- Acting on the customers' behalf to provide the most suitable combination of transport modes (Kokkinis et al. 2006);
- Arrange the cargo routing and offer the mode choice to the customer, together with secondary services such as custom clearance or packing, which involves higher level of expertise;
- Booking the necessary space with shipping company;
- Offer other services such as warehousing, customs clearance, packing and port agency;
- Arranging marine insurance for the shipments;
- Scrutinising and advising on ability to comply with letter of credit;
- Work closely with shippers in order to adapt and respond effectively to constantly changing needs of customers' requirement. In this sense freight forwarders slowly become third-party logistic providers (3PL).

However, as freight forwarders are trying to provide the whole logistic service to the customers, other players in the supply chain try to offer suitable services to their customers. Supply chain is a complex system in which members of different logistic channels can meet and interact (Bichou & Gray 2004). Bichou & Gray (2004) outlined that ports cannot only be considered as simple logistic node for cargo flow, but as an 'integrated channel management system' linking different cargo flows and channels with their members. In this sense, port and port operators can provide almost all services as freight forwarders and act as a freight forwarder in front of their customers. In addition, Rodrigue & Notteboom (2009) argued in their study that seaports and inland terminals are taking more active role in supply chain in order to increase throughput, optimise terminal capacity and make the best use of available land.

Beside port operators, shipping lines as being part of the whole supply chain and in order to satisfy their customer needs, also offer door-to-door service, including beside ocean also road, rail and inland shipping transport service.

However, many enterprises still outsource transportation tasks by assigning independent freight forwarding companies to their transportation activities (Saeed 2013). This means that the forwarding company is allowed to choose the mode of transport and this kind of companies will be the main subject of this dissertation.

2.3 Port Choice from a Perspective of Freight Forwarders

Increased competition and globalisation are key forces currently shaping development of the port sector. Ports act as interfaces between different actors, such as road, rail, inland waterway, logistic operators and shipping lines (Grosso & Monteiro 2008). In the time of intense port competition, it is imperative for port authorities, post managers and terminal operators to determine and to have a thorough understanding of the factors that influence users' port choice (Panayides & D. W. Song 2012).

The analysis of this section will be balanced between two parts. First of all, decision makers have to be outlined. Meersman et al. (2010) identified four major groups: shippers, forwarders, shipping companies and terminal operators. Some other authors also include port authorities and government agencies influence on port choice. They all have similar, but also different points of view when choosing the port for its business. Second, identification of their criteria for choice is required. A number of studies have examined the factors determining the choice of port. The knowledge of these factors can help a port improving its market share and growth. Efficiency gains, which are generated within the container port, will have a direct impact on the competitive advantage of its users and affect the economic potential of both origin and destination hinterlands (Grosso & Monteiro 2008). So, the analysis of port competitiveness will be mainly concentrated on port selection criteria.

2.3.1 Decision Makers

As mentioned in previous section four major groups of decision makers can be identified in port choice (Meersman et al. 2010). The studies can be classified according to the approach adopted in identifying the choice criteria. Authors seems to examine the factors that contribute to port competitiveness and on the basis of some criteria that is important to users some ports are preferred over the others. Most of the studies, examine the shippers perspective and to lower extent the determinants of port choice from perspective of freight forwarders or shipping lines. Tongzon (2009) justify this view with belief that shippers are people who actually make the decision to route the cargo through the port.

The main studies that examine port choice factors from shippers perspective include Foster (1978), Murphy et al. (1987), D'Este & Meyrick (1992), Murphy et al. (1992), Murphy & Daley (1994), Nir et al. (2003), Tiwari et al. (2003), Malchow & Kanafani (2001), Malchow & Kanafani (2004), Tongzon (2002), C. Ugboma et al. (2006) and De Langen (2007).

Several of the sources also evaluate shipping companies as port choice makers such as Murphy et al. (1992), Lirn et al. (2004), Ha (2003), D. Song & Yeo (2004), Chang et al. (2008) and Tongzon & Sawant (2007).

Shippers and shipping companies have been in focus of the researchers during the whole period from mid 80s till 2009. However, some of above mentioned authors beside shippers and shipping lines' perspective also evaluate freight forwarders' selection criteria. Freight forwarders' perspective together with other decision makers is more closely examined and in the works of Slack (1985), Murphy et al. (1987), Murphy et al. (1992), De Langen (2007) and Yuen et al. (2012). Sources that evaluate only freight forwarders as decision makers include Bird & Bland (1988), Tongzon (1995), Grosso & Monteiro (2008) and Tongzon (2009).

The choice of sources was not constrained by geographical considerations. The focus was on the decision makers' criteria that the authors identify as important and also on the methodology that they use.

In the 1980s, Slack (1985) surveyed port end – users i.e. shippers and freight forwarders engaged in Transatlantic container trade between America and North Europe to identify port selection criteria. Respondents were asked to choose different factors they considered important in port choice. Factors were based on four aspects: port selection criteria, port service criteria, liner characteristics and information sources. One of the significant findings was that decision makers are more affected by cost and quality of service offered by land and ocean carriers than by consideration of ports themselves. He also found, that although improvements in port facilities were often necessary, it did not have impact on changing the cargo flow to the other ports. This was because shippers are mostly conservative decision makers who are not very open to alternatives. At the end, he established that most important factors are the inland freight rates and the frequency of ship sailing concerning port choice. Regarding information criteria, Slack explained that shipping lines were mostly most important source of information on the ports themselves for other groups of decision makers.

Murphy et al. (1987) identified all the players involved in the use of ports and tried to investigate difference in their perception on port choice factor significance. They outlined that load – unload facilities, accommodation of large shipments, frequency, freight rate, equipment availability, pickup and delivery time, information availability, claim handling assistance and flexibility in meeting special handling requirements are one of the main factors. In addition, they concluded that decision makers perceive in different way importance of service quality and that port service providers should improve their customer communication.

Beside this study, Murphy, Daley and Dalenberg have done significant research on factors used by various decision makers that represent different interests and roles in global logistics, in their selection of international ports. Specifically these are the viewpoints of worldwide water ports (1988), carriers (1989), US based international shippers (1991, 1992), international freight forwarders (1992) and purchasing managers (1994). The analysis of the relative importance of selection factors showed a high degree of similarity between shippers and carries.

As mentioned above, Murphy et al. (1991) were analysing freight forwarders' perspective of port choice. They found that equipment availability was the most important factor, highlighting the necessity for ports to good maintenance of cargo handling equipment. Other important variables included low frequency of cargo loss and damage, large shipment capabilities and convenient pickup and delivery times. In contrast with their work from 1987, the found that ports information handling capabilities were relatively not important in decision making. They also indicated that ports' operational capabilities are more significant than its service capabilities. Still, the study showed that freight forwarders are willing to accept higher cost for improved service. This was confirmed later by study of D'Este & Meyrick (1992), who concluded that in the selection of a port, decision makers seem to value service characteristics more than price characteristics. Beside that they suggested that port selection shifted from shippers to carriers because shippers start requesting prices for door to door service rather than individual segments.

A following study by Murphy et al. (1992) investigated the variability in port selection factors between five major stakeholders: ports, carriers, freight forwarders and small and large US shippers. The work pointed out that ports consider carriers as their main customers and that there are differences among the groups in terms of factor importance, especially between shippers and ports. The study showed indicated that shippers perceive ports as service providers, as part of the whole supply chain, with paramount importance of information provided by ports. However, ports tend to consider themselves as good handlers of cargo rather than participants in the supply chain who provide variety of services to their customers.

Following this study, Murphy & Daley (1994) examined how purchasing managers view the port selection comparing to shippers and ports. Purchasing managers, like shippers in previous study from 1992, consider shipment information of vital importance. Another valuable factor is ports' loss and damage performance. The main conclusion of the study was that purchasing managers consider the value added services provided by ports more important than its physical operations. On the other hand, ports paid more attention to their physical operations. Consequently, both studies from 1992 and 1994 aim to demonstrate that ports should focus more on improving customer service and position themselves as service providers rather than cargo handlers.

Foster (1978) investigated the importance of qualitative factors of port choice by survey asking shippers to identify main port choice determinants. Based on feedback, he concluded that port charges i.e. monetary cost was the most important factor. This was supported by a more recent study conducted by Lirn et al. (2004) who were analysing liner transhipment port selection. In their work they were focusing on capturing the significance of subjective judgement affecting port selection. First they were outlining four main service criteria: physical and technical infrastructure, geographical location, management and administration and terminal cost which they divided it in sub-categories. From all sub-categories the authors revealed five most important ones: handling cost, proximity to main navigation routes, proximity to import/export areas, infrastructure condition and feeder network. While supporting the role of qualitative factors in port selection, at the end they argued that monetary cost remained the most significant factor in port choice.

Another study investigated by Ha (2003), contributed to this view. The author in his work investigated the quality of service offered by fifteen ports around the World regarding container handling and identified monetary cost, information, location, port turnaround time, facilities, management and customers' convenience as the major factors. Ha was questioning shipping lines to rank the importance of these factors and found that apart from monetary cost and time efficiency, ports should focus more on service quality and information flows. Another study of Ng (2006), who investigated container transhipment efficiency in Northern Europe, found that monetary cost is not the only component in port attractiveness. It also includes other factors as geographical location, service quality and time efficiency.

Beside port charges and monetary cost, some authors like Nir et al. (2003) identified that ports and freight forwarders indicated that a port's ability to handle large volume shipment is an important attribute. However, shipper's had the opposite view and stated that travel time or distance to the port as the most important factor. The authors were comparing how shippers' choice of port changes according to their previous experience with a port. Accordingly, the chosen port would minimise the cost incurred by travel time. By that, they were outlining distance i.e. port which is closest to import/export containers in order to keep lower transport costs. Factors such as port services, frequency and port infrastructure did not have strong impact on their decision. Moreover, the authors showed that shippers would choose a port that were already using before. On the other hand, ports and freight forwarders indicated that a port's ability to handle large volume shipment is an important attribute.

In similar way, Tiwari et al. (2003) also illustrated the importance of distance in port choice. He authors used China as case study and investigated shippers' behaviour in port selection. They concluded that the most important factors are the distance of the shipper from port, distance to destination and distance from origin. On top of this authors outlined port congestion and shipping line's fleet size as one of main contributors to overall port operational efficiency and smooth cargo flow.

A similar conclusion was made by Malchow & Kanafani (2001), who analysed the flow of four commodities in eight major US ports. The author's intention was to test significance of distance both ocean and inland, sailing frequency and average vessel size. In conclusion, the argued that ocean and inland distance were the most significant factors in carrier's choice of port, but not sailing frequency and vessel capacity. Specifically, inland distance proved to be more important in lower value shipments, whereas ocean distance was more significant for manufactured cargo, indicating the need to keep inventory cost down. The same authors in some years later, Malchow & Kanafani (2004), further examined if competition between ports would influence decision in port choice. The authors assumed that shippers' preference for a port is established by choosing a carrier providing a service through that port. Finding reveal that most critical factors were geographical location, port characteristics and vessel schedules, where port location was the most significant factor.

This point out another crucial factor in port choice: port location. Similarly as the study of Lirn et al. (2004), some other authors pointed out geographical location as one of the most important determinants in port choice. This view was confirmed by study of D. Song & Yeo (2004) who aimed at identifying the factors contributing to the overall competitiveness of Chinese main ports. They focused on geographical location and ports logistic and operational services. After conduction a survey with shipping companies, shippers, terminal operators and various researches they outlined five most important criteria for port competitiveness and choice: port location, port facilities, service level, cargo volume and port expenses.

On the other hand, Willingale (1984) and Murphy et al. (1991) found that port location was not as important in port choice decisions. The main reason for this view is that transportation system has become more advanced and more efficient, which lower the importance of geographical proximity between the ports and their customer choice in port choice decision making.

As one can see from above, port location and the distance to the consumer's markets play an important role in port choice, and consequently in the volume of port throughput. Tongzon (1995) determines that port throughput and cargo flow is dependent on three main factors. The first factor is the geographical location of the port. If port is located on easy accessible location and has good connection with different modalities, cargo flow is more likely to increase. The view of port accessibility was also confirmed later in the study Huybrechts et al. (2002), who evaluated the attractiveness of the port of Antwerp. He concluded that port accessibility was one of the major factors in port choice and that low accessibility, due to restrictions of River Scheldt, was the major obstacle in preventing Antwerp to become a market leader within North Europe. The second factor is the frequency of ship calls. The higher frequency of the ship calls, the higher port throughput. The third factor was terminal efficiency, which can be measured by looking at crane efficiency, the size of the vessels and cargo exchange and average number of container handled per hour. Tongzon (1995) in his study also included port charges in his model, but stated that contribution to the total costs were relatively small. In his later studies, Tongzon (2002) conducted a survey among shippers from Southeast Asia. He identified a few port choice determinants like port efficiency, shipping frequency, port infrastructure, port location, port charges, customer service and reputation to cargo damage. He found that, time efficiency, port infrastructure and geographical location were important determinants while port charges considered not important.

Chang et al. (2008) identified the factors that affect the port choice criteria of shipping companies, and also seek to identify differences on the basis of whether the shipping line operates a direct main trunk service (East Asia – Europe and transpacific) or is a feeder operator (intra – Asian feeder operations). The analysis showed that six variables were regarded as important in port choice decisions. They include local cargo volume, terminal handling charge, berth availability, port location, transhipment volume and feeder connection. Main - haul shipping lines were found to place added emphasis on value – added services and port costs. This confirmed the findings of Tongzon & Sawant (2007), who found port costs and range of port services to be the only significant factors in shipping lines' port choice.

As far as freight forwarders' point of view Bird & Bland (1988) studied the perceptions of European freight forwarders and showed that time on the route and labour problems at ports are their major concerns. Besides them, De Langen (2007) compared the port selection criteria of Austrian shippers and freight forwarders and has underlined the importance of analysing the port selection processes of forwarders by pointing to the growing supply chain power of third party logistics providers.

Tongzon (2009) assessed the relative importance of port selection factors from a perspective of freight forwarders. He concluded that the key factors include high port efficiency, frequency of ship visits, good geographical location, low port charges, adequate infrastructure, wide range of port services, port reputation for cargo damage and connectivity to other ports. However, the most important criterion was found to be port efficiency, followed by shipping frequency, infrastructure, location and port charges. Tongzon's view was that freight forwarders' selection was not simple but complex process where ports are not considered in isolation, but together with other requirements associated with the movement of cargoes across the port-oriented supply chain. This view supports the evolving trend of ports as elements of supply chain and as main contributors of an efficient supply chain process. The author ended with conclusion that port operators and port authorities should focus more on attracting shipping lines to call their ports, since freight forwarders' practice is to choose shipping line first and then choose the port from those served by shipping lines. The importance of port location and hinterland connection for freight forwarders was also outlined as one of the main criteria in the most recent study of Yuen et al. (2012). Beside above two criteria, the authors indicated shipping services as one of the valuable factors, suggesting that forwarders would like to have more shipping liners to choose from and would like to receive better services from them.

Similarly to Tongzon (2009), the results of the study of C. Ugboma et al. (2006), who investigated the port choice criteria used by shippers, deemed efficiency the most important factor in shippers' port selection process, while frequency of ship visits and port infrastructure followed. Quick response to port users' needs proved to be insignificant to them.

In their case study of port of Genoa, Grosso & Monteiro (2008) identified which are the main factors and criteria influencing the decision of freight forwarders in choosing a port. The findings of this research show that the main elements affecting the decision of port choice are: connectivity of the port, cost and port productivity, electronic information and logistics of the container.

2.3.2 Concluding Remarks on Port Choice

From the existing literature so far reviewed, basic port selection criteria from a perspective of freight forwards are shown in Figure 1. Detailed explanation of each factor is presented in Appendix 1.

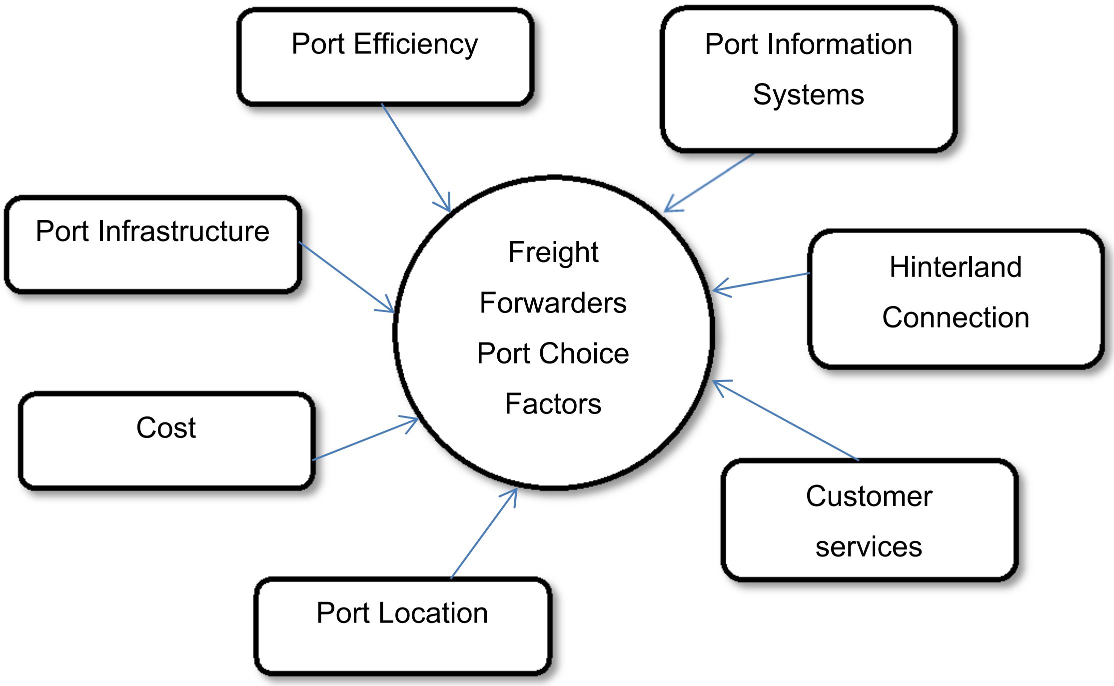

Figure 1: Factors influencing port choice from a perspective of freight forwarders

To conclude, the literature has given several potential determinants of port choice from perspective of freight forwarders. It gives qualitative analysis of the most important factors that influence their port choice. These determinants and factors will be used to quantitatively evaluate overall port performance and its efficiency in the whole supply chain (Tongzon 1995). In order to do this, it is essential to indicate port performance methods and indicators which will be used in analysis.

2.4 Port Performance Benchmarking

In the competitive environment, such as between container terminals, where option for physical expansion are limited and cargo shipments and ship sizes are increasing, ports are under huge pressure to increase their productivity, performance and operational efficiency (Bichou 2009). Gains in productivity in ocean transport over the past few decades have left ports as the last component of the logistic chain to improve efficiency (Demirel et al. 2012).

There are many ways of measuring port productivity and performance. Bichou (2006) outlined three broad categories of approaches:

1. Performance metrics and productivity index methods;
2. Frontier methods;
3. Process approaches.

2.4.1 Metric and Productivity Index Methods

A performance measure or metric is presented numerically to quantify one or many attributes of an object, product or process. One can distinguish input and output measures and ratio indices, usually presented as output – input ratios. Its objective is either to minimise latter or optimise former. Bichou (2012) drawn attention that port performance measures can be classified into three methods:

- Snapshot and composite measures;
- Single and partial productivity indices;
- Total factor productivity (TFP) indices.

2.4.1.1 Snapshot and Composite Measures

The typical snapshot measure that has been widely used to rank container ports and terminals is annual throughput in TEU. Other ways of snapshot measures have been used in evaluating port resources, facilities or operation. Sometimes, composite indicators are calculated to account for the relationship between two snapshot measures such as the number of TEUs per hour versus ship's size (Bichou 2012). One of the specific applications of snapshot measures are uses financial metrics for measuring port performance. These measures are most commonly used in the US public ports, but on the other hand these measures might not be suitable for benchmarking operational efficiency due to little correlation of financial performance and use of resources (Bichou 2012). For instance, Holmberg (2000) indicates that the main bias of financial techniques is that they show the results of past actions and that they are designed to meet external evaluators' needs and expectations. In overall, the main problem with snapshot and composite measures is that they only provide an activity measure rather than a performance measure.

2.4.1.2 Single and Partial Productivity Indexes

A single factor productivity index (SFP) compares the use of volume measures of output to an input. A single productivity index can be calculated to measure either the productivity over time for a single port or the productivity of one port relative to another's in the same period (Bichou 2012). Partial productivity indicator (PFP) has similar idea like SFP, with the difference that PFP compare a subset of outputs to subset of inputs when multiple inputs are involved. The objective is to construct performance measures that compare one or more outputs to one or more inputs (Bichou 2006). Bichou (2006) also indicated that in complex port operating and management system, SFP and PFP indicators are described as incomplete measures of performance. However, in the past literature several studies were done with use of SFP and TFP indicators, such as Fourgeaud 2000 or Talley (1988).

2.4.1.3 Total Factor Productivity (TFP) Indexes

The total factor productivity indices (TFP) include multiple inputs (M) and outputs (S) to measure productivity change over time or between firms. The TFP concept try to provide the total indication of productivity using a measure of total input/output quantity, but can be decomposed by introducing statistical effects of model decomposition (Bichou 2006). In the port benchmarking studies where output is often reduced to a single measure of the port throughput, TFP concept has been reduced to multi-factor productivity (MFP) measures linking one measure of output to a several inputs (Bichou 2012). In port studies the most commonly used TFP indexes are the Törnqvist index and the Malmquist productivity index (MPI).

The Törnqvist index is based on quantity data and market prices. The problem with this index can be unavailability of market prices or not appropriate weight aggregation. In general, cost shares are used as inputs and the revenue shares as outputs (Bichou 2006). However, this non-frontier approach to TFP measurement is usually unable to separate scale effects from efficiency differences. In order to improve that, researches use the Malmquist TFP index, which is constructed by estimating a distance frontier. The Malmquist productivity index (MPI) is defined as the measure of TFP change of two different time periods by calculating the ratio of the distances under specific technology (B. Liu et al. 2006).

There are several studies that used TFP approach for ports. The Törnqvist index was used by Lawrence & Richards (2004) to investigate the distribution of benefits from productivity improvements of an Australian container terminal. On the other hand, the application of the Malmquist index to port efficiency was used by Estache et al. (2004). They calculated productivity changes of port infrastructure in Mexico using a MPI index and this approach allowed them to assess the relative importance of the catching-up effects and the frontier shift effects resulting from reforms aimed at increasing competition between ports. Later, B. Liu et al. (2006) also applied the MPI to measure productivity change of several container terminals in China, by dividing MPI to technical efficiency change and technical change.

In overall, on the one hand the main advantage of TFP indices is that they reflect the joint impacts of the changes in combined inputs on total output, but on the other hand it is a non-statistical approach and does not allow for the evaluation of uncertainty associated with the results (Bichou 2012).

2.4.2 Frontier Approach

The frontier approach and concept indicates the lower and upper limit to a boundary efficiency range. Under this approach, a firm is defined as efficient if it operates on the frontier or inefficient when it operates away from it. Frontier functions can be either deterministic or stochastic. In the deterministic model, the frontier is estimated such that all deviations from the frontier are due to inefficiency. In deterministic model efficiency can be estimated in two ways, either using parametric techniques such as a corrected ordinary least squares (COLS) and stochastic frontier analysis (SFA), or non-parametric techniques such as data envelopment analysis (DEA) (Bichou 2009). On Figure 2 are presented the main frontier approaches and how efficiency calculations differ from an approach to another.

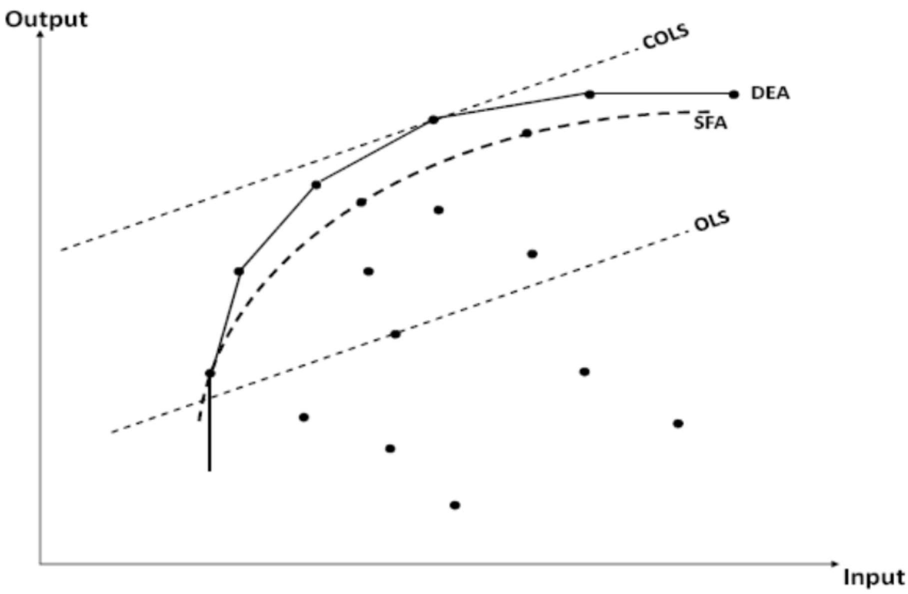

Figure 2: Graphical illustration of frontier methodologies

(Source: Bichou, 2012)

The literature in the port field distinguishes four main efficiencies technical efficiency, allocative efficiency, scale efficiency and total economic efficiency:

1. Technical efficiency (TE) or productive efficiency shows ability to produce maximum output from a given set of inputs or the ability to achieve a given level of output at minimum input use;

2. Allocative efficiency (AE) reveals a firm's ability to use inputs and outputs in optimal proportions given their respective prices and production technology;
3. Cost efficiency (EE) is calculated as the product of the TE and AE scores and an organisation can only be economically efficient if it is both technically and allocatively efficient;
4. Scale efficiency (SE) reflects the size and scale of the activity, such as in terms of constant returns (CRS) and variable returns (VRS) to scale technologies.

2.4.2.1 Parametric

Parametric methods involve a functional form where a set of observations of input and output can be statistically estimated. These models denote the estimation of a production or cost frontier function from the input/output data. Models could be either deterministic or stochastic, depending on whether or not certain assumptions are made regarding the data used. There are two main methods: corrected ordinary least squares (COLS) and stochastic frontier analysis (SFA).

COLS is a parametric approach to evaluate productive efficiency. It is a very useful function which tries to improve OLS method which fails to construct the frontier. It belongs to the regime of regression methods but differs from the OLS estimation method. The degree of efficiency of an individual unit can then be measured against this frontier (Bichou 2009).

The strengths of this approach are:

- It gives information about the production technique;
- Allows the measurement of relative efficiency.

The drawbacks of this approach are:

- It requires a priori specification of the production or cost function;
- It is not possible to measure error and other statistical noise.

SFA is a parametric and stochastic approach to estimate productive efficiency. The difference and major breakthrough of SFA compared to traditional regression analyses is that SFA calculates the inefficiency of economic agents based on distribution assumptions, so different individuals can have different inefficiencies (Bichou 2008). Comparing to COLS approach, the procedure to calculate frontier is different. SFA includes two random terms in order to take into account both inefficiency and normal statistical noise. Therefore, it acknowledges that each economic unit will exhibit its specific inefficiencies and the efficiency production/cost frontier is estimated without shifting or correcting a traditional regression line to a frontier. Then the degree of efficiency of individual economic units can be measured against this frontier.

The advantages of this approach are (Coelli et al. 1997; Lan & Erwin 2003):

- It doesn't assume that all firms are efficient in advance;
- SFA makes accommodation for statistical noise such as random variables of weather, luck, machine breakdown and other events beyond the control of firms, and measures error;
- It doesn't need to price information available;
- It is capable to hypothesis test;
- To estimate the best technical efficiencies of firm, rather than average technical efficiencies of firm.

The weaknesses of this approach are (Coelli et al. 1997; Lan & Erwin 2003):

- It needs to assume functional form and distribution type in advance;
- It needs enough samples to avoid lack of degree of freedom;
- The assumed distribution type is sensitive to assessing efficiency scores.

There have been numerous applications of SFA to the port industry. Z. Liu (1995) sets out to test the hypothesis that public sector ports are inherently less efficient than those in the private sector. A set of panel data relating to the outputs and inputs of 28 commercially important UK ports was collected for analysis. Notteboom et al. (2000) apply a Bayesian approach based on Monte-Carlo approximation to the estimation of a stochastic frontier model aimed at assessing the productive efficiency of a sample of 36 European container terminals located in the Hamburg-Le Havre range and in the Western Mediterranean. Coto-millan et al. (2010) applied a stochastic frontier model to estimate the economic efficiency of 27 Spanish ports, by using the Cobb–Douglas and Translog versions of the model. Cullinane & D. W. Song (2003) used SFA method for estimating productive efficiency levels, by applying it to both cross-sectional and panel data to UK against main South Korean ports. Cullinane et al. (2002) analysed the administrative and ownership structures of major container ports in Asia. The relative efficiency of these ports was then assessed using the cross-sectional and panel data versions of the stochastic frontier model. Cullinane et al. (2006) estimated an SFA model for panel data analysis of the efficiency of 50 terminals operators across Asia, Europe and North America.

2.4.2.2 Non-parametric

Non-parametric approaches do not require a pre-defined functional formulation but use linear programming techniques to determine rather than estimate the efficiency frontier. Most commonly used in research approach is data envelopment analysis (DEA). DEA tries to solve a series of linear programming problems and selecting the optimal solution that maximises the efficiency ratio of weighted output to weighted input for each decision-making unit (DMU) (Bichou 2006). Primarily, DEA seeks to measure technical efficiency (TE) without using price and cost data or specifying a functional formulation. However, when information about costs and prices is available, DEA allows for the calculation of allocative efficiency (AE) (Bichou 2009).

Based on how the relative productive efficiencies of DMU are assessed one can distinguish two types of DEA:

1. DEA-CCR which uses constant return to scale (CRS) concept
2. DEA-BCC which uses variable return to scale (VRS) concept.

Both models provide a valuable decision tool for the evaluation of the performance of DMUs and have been applied in various managing control and organisation diagnosis.

The main strengths of DEA method (Coelli et al. 1997; Lan & Erwin 2003):

- It doesn't assume that all firms are efficient in advance;
- It could handle with efficiency measurement of multiple inputs and multiple outputs;
- It doesn't need to price information available;
- It does not need to assume function type and distribution type;
- While sample size is small, it is compared with relative efficiency;
- Both the DEA-CCR and DEA-BCC models have nature of unit invariance.

The main disadvantages are (Coelli et al. 1997; Lan & Erwin 2003):

- It doesn't make accommodation for statistical noise such as measure error;
- It isn't capable to hypothesis test;
- When the newly added DMU is an outlier, it could affect the efficiency measurement.

In recent years, DEA has occasionally been used to analyse port production. In Martinez-Budria et al. (1999), 26 ports were divided into three groups high, medium and low complexity ports, where by using BCC models authors concluded that the ports of high complexity are associated with high efficiency, compared with the random mix of medium and low efficiency found in the other ports. J. Tongzon (2001) used both DEA-CCR and DEA-BCC models to study efficiency of 4 Australian and 12 other international container ports. Drawback of his study was poor data availability and a small sample size. At the same time Valentine & Gray (2001) applied the DEA-CCR model to 31 container ports out of the world's top 100 container ports for the year 1998 in order to determine relationship between port efficiency and particular types of ownership and organisational structures. As mentioned in the previous section Cullinane et al. (2006) besides SFA, applied DEA window analysis to panel data of the efficiency of 50 terminals operators across Asia, Europe and North America.

Contributing to above, while analysing port literature on both parametric and non-parametric approach, Bichou (2006) draw attention to following:

- In previous studies selection of variables was done based on subjective assessment;
- There is no consensus among port researches which method is the best that analyses port performance;
- There are inconsistent results when analysing the relationships between size and efficiency, ownership structure and efficiency, and locational/logistical status and efficiency;
- Most frontier applications in ports focus solely on sea access, which in fact is a common feature of much of the literature on port performance. The emphasis on quayside operations overlooks other processes of the port operating system and ignores the interests of other members of the port's supply chain network.

2.4.3 Process Approach

Process approaches rely on expert judgement, perception surveys and process benchmarking toolkits, but each of these requires a thorough investigation and may be very expensive and time consuming. Two different groups of methodologies may fall under the banner of process approaches (Bichou 2009):

- Expert judgement and perception survey approaches;
- Engineering and process benchmarking models.

Expert judgement is based on a thorough review to derive assessments of a firm's performance. On the other hand, perception surveys can be part of an expert judgement review, but they only report snapshot views of participants who may not necessarily have an expert understanding of the benchmarking process or the firm or industry under investigation. In both approaches, researchers may use statistical techniques for correlation and hypothesis testing (Bichou 2006).

The main weakness of expert judgements and perception surveys is that they depend on subjective analysis of port's performance. In order to reduce subjectivity, structured ranking methods, such as the analytical hierarchy process (AHP), are sometimes used along with expert judgements and perception surveys.

Engineering approaches use bottom-up techniques for modelling business processes such as costs, physical movements, information flows and management systems, to capture and improve current processes and ultimately build up a 'model' firm. Process benchmarking takes a strategic view of performance benchmarking such as in terms of a continuous process of measurement and improvement (Bichou 2009).

2.5 Conclusion of Literature Review

This chapter has reviewed the literature on several important aspects which will be used in benchmarking port services from a perspective of freight forwarders. Following remarks can be highlighted:

First, container ports and terminals are recognised as complex organisations which are in constant inter or intra competition in providing their services to different stakeholders. Containerisation made this competition even fiercer which caused that port services are no longer provided in isolation, but they have to be considered as a part of the door-to-door supply chains.

Second, in the time of very competitive market, ports have to fight for each user in order to survive on the market. Therefore, ports have to consider which factors are the most important for port users and adapt their development strategy. Since the main objective of this study is to analyse port choice factors from freight forwarders' point of view, the main studies and factors in the previous literature are outlined in

Table 1. These factors will later on in the dissertation serve as a basis for making a questionnaire.

Table 1: Literature review about port choice determinants from a freight forwarders' point of view

Author	Factors identified
Slack (1985)	Number of voyages, inland freight rate, port connection to Inland transport services, availability of container facilities
Murphy et al. (1987, 1991)	Large and odd-sized freight, large volume shipments, handling charge, loss and damage, equipment availability, pickup and delivery, shipment information, claims handling and special handling
De Langen (2007)	Frequency and quality of shipping services, connection to hinterland services, port location, port equipment, quality of terminal operating companies, port information services
Bird and Bland (1988)	Transit time, port labour problems
Tongzon (1995)	Port location, frequency of ship call, port charges, terminal efficiency
Grosso and Monteiro (2008)	Connectivity to the port, cost and port productivity, electronic information and logistics of the container
Tongzon (2009)	High port efficiency, frequency of ship visits, good geographical locations, low port charges, adequate infrastructure, wide range of port services, port reputation for cargo damage, connectivity to other ports
Yuen et al. (2012)	Port location, hinterland connection, number of shipping lines calling the port

Finally, the application of different benchmarking techniques to port efficiency measurement has provided reasonable way to make inter-port comparisons of their performance. Table 2 summarises these techniques:

Table 2: The main port benchmarking techniques

(Source: Adapted from Bichou 2011)

Classification of literature		Technique / Methodology	Disadavantages
Index methods	Snapshot indicators	Throughput in TEU, total turn-around time, service time, cargo dwell time, etc	Provide an activity measure rather than a performance measure.
	SFP	Single output / single input	Provide average productivity but does not capture overall productivity. Non-statistical approach
	PFP	Subsets of outputs / subsets of inputs	
	TFP	Törnqvist and Mamlquist indexes	Requires estimation of cost, production or distance function, otherwise unable to separate scale effects from efficiency differences. Non-statistical approach
Frontier analysis	Deterministic vs. Stochastic Parametric vs. Non-parametric	COLS - deterministic / parametric	Requires functional form and dominated by the position of the frontier firm
		SFA - stochastic/parametric	Requires functional form, specification of exact error terms and probability of their distribution
		DEA/FDH - deterministic / non-parametric	Sensitivity to choice of weights attached to input and output variables. No allowance for stochastic factors and measurement errors
Process approach	Bottom-up approaches	Engineering economic analysis (EEA)	Data intensive, relies on expert judgement and knowledge of the system.
	Benchmarking toolkits	Business process modelling (BPR)	Expensive to build and maintain.
	Expert judgements	Enterprise modelling (ERP)	
	Perception surveys	Process benchmarking (BSC, TQM)	Process approach, does not capture operational efficiency components and trends.

The study of container port and terminal efficiency and benchmarking of port services from a freight forwarders' point of view is still a relatively recent field of analysis with scarcity of literature. There is the need for further research to evaluate the economic performance within the context of our analysis. In contribution to this, port performance indicators are explained in more detail in Appendix 2.

Based on the literature review and theoretical background presented in this chapter, some hypotheses can be drawn. These hypothesis will rely on freight forwarders' perspective of port choice and their influence on overall port efficiency.

The first hypothesis investigates relation of port performance on container terminal efficiency. Any factor that contributes positively to port efficiency could be considered as contributing positively to the attractiveness of a particular sea port. As explained in previous section port performance can be expressed through various indicators of whom the most important one is port annual throughput. The annual terminal throughput among numerous factors depends on crane productivity which further influences vessel unloading/loading time, vessels operations in the port, delivery and total transit time. By increasing all these factors, container terminal efficiency should be increased and therefore, freight forwarder could benefit higher port performance indicators. This sets up the first hypothesis:

H1: Container terminal annual throughput is positively related to terminal efficiency.

Increase in shipping liner sailing or call frequency gives freight forwarders higher flexibility. If carriers decide to call the particular port more frequently they would be inclined to fill up the vessels space. For freight forwarders, this means more space availability, faster turnaround time and more alternatives which all could add to the attractiveness of a port. Frequency therefore, affects both the carrier's and the freight forwarders' choice of a port. Since freight forwarders' practice is to choose shipping line first and then choose the port from those served by shipping lines, port connectivity with different liner shipping companies plays very important role in port choice. So, next hypothesis is therefore:

H2: There is a positive correlation between port liner shipping connectivity and container terminal efficiency.

Next hypothesis can be drawn from the fact that poor infrastructure of container terminal, inefficient intermodal procedures and hinterland bottlenecks can lead to port congestion and inefficiency which can reject port users, such as freight forwarders. Port hinterland connection should be important as much as its shipside connection. This leads to the third hypothesis:

H3: Container terminal intermodal connection has positive impact on container terminal operational efficiency.

Besides port shipside and landside connection, port proximity to international trading centres has positive influence on regional economic development and attracts port users. That is why geographical location of the port and its regional efficiency of logistic services might have significant influence on port operational efficiency. It points out to next hypothesis:

H4: There is a significant differentiation between operating efficiency scores in different regions.

Introduction of information technology and information sharing systems would encourage greater integration, avoid duplication of documentation and improve the processing and treatment of data by all players in the supply chain. This affects information flow towards port customers and port efficiency of customer services. Ability to respond to customers request should be one of the priorities of port management in order to maintain port reputation. On this basis it can be hypothesised:

H5: The efficiency of the port customer service has positive relationship to terminal efficiency.

To conclude with, this chapter have identified the main issues presented in this literature and outline hypotheses that can be drawn to respond to the research question. Next chapter will provide a complete description of research methodology and approaches and describe the methods and sources of data collection.

Chapter 3 - Research Approach and Methodology

In previous chapter we have reviewed literature regarding port competition, followed by the most important factors that influence port choice from a freight forwarders' point of view and reviewed the most important benchmarking techniques applicable to port performance. At the end some most important operational hypotheses where formulated for further testing and evaluation.

This chapter will establish the methodology for the research problem, define the sampling frame and variable selection, and describe the methods and sources of data collection.

3.1 Research Design, Potential Methods and Procedure

The methods, research tools and techniques of analysis applicable to assess research questions are outlined as follows:

- Questionnaire technique based on 7 point Likert scale qualitatively determining the most important factors of freight forwarders' choice of a port;
- Analytical benchmarking for measuring and comparing container-port efficiency by using DEA technique;
- Productivity change analysis for assessing the impacts of port choice factors by using TFP Malmquist index.

In this study the following research procedure will be applied:

1. First phase of the research is to identify major factors for port choice form a perspective of freight forwarders. In order to do that and using the information from the literature review, 7 point Likert scale questionnaire will be developed, ranging from 1 (not relevant) to 7 (very relevant). Questionnaire will then be submitted to sample of freight forwarding companies operating in the United Kingdom and Balkan Peninsula. The interviewed will be asked to rank each of port choice factors. The data collected through this survey will be ranked by chosen importance and distinguished by region;
2. In this phase outcome of qualitative methods will be used for variable definition. This is then contrasted against the available information from the container-port sample to make up the final dataset of input and output variables;

3. This phase will apply DEA technique analyses to estimate and compare operational efficiency under constant technology;
4. In the final phase Malmquist productivity index will be calculated in order to assess total productivity growth.

The whole procedure and research framework is shown in the Figure 3.

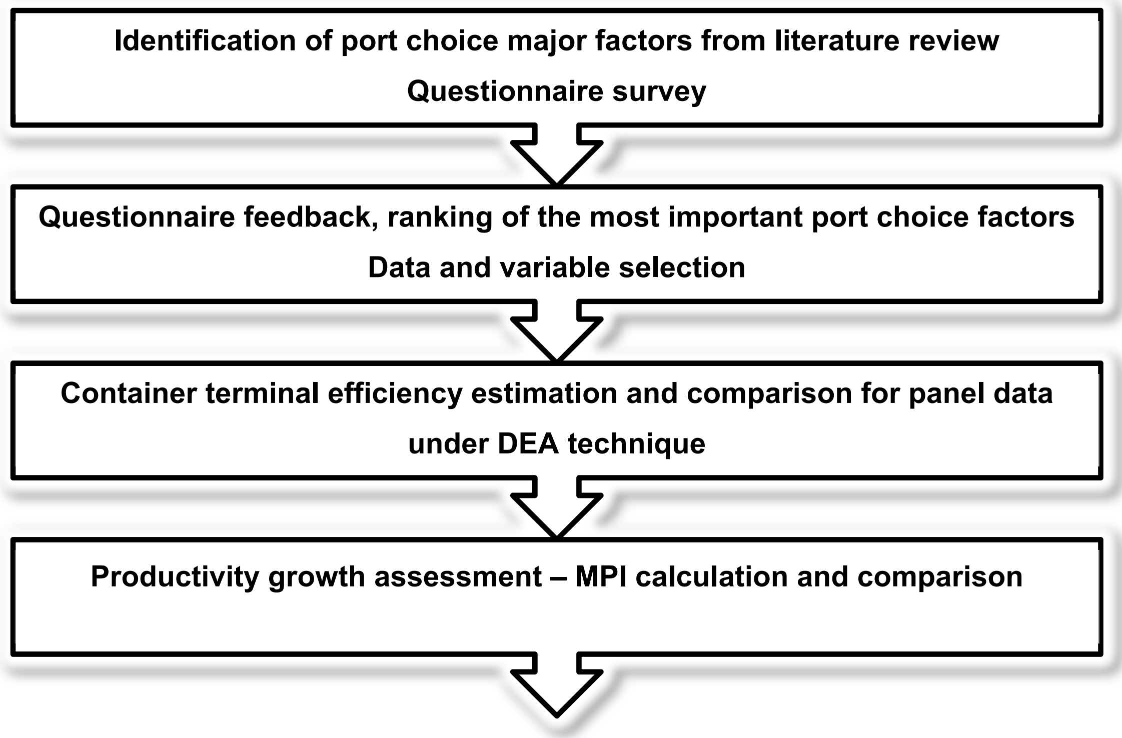

Figure 3: Research framework

3.1.1 Questionnaire Survey

Most qualitative studies are constructed on asking respondents questions or making observations in the field. First hand-data gathering collects data from primary sources for the first time as part of an experiment, survey, or personal observation (Beach & Alvager 1992).

Port attractiveness and determination of port choice here is assessed through literature review of previous researches and soliciting the opinions of freight forwarders that are the major and direct port users. A Likert-style questionnaire was distributed to the global freight forwarders from Balkan Peninsula, covering mainly Serbia, Montenegro, Croatia and Slovenia, and United Kingdom.

The questionnaire is consisted of three sections.

1. In the first section, respondents were asked to give some of the basic information about themselves;
2. In the second section, respondents were asked to give scores reflecting the significance of 20 factors affecting their port choice. These factors were identified with reference to existing literature (see Table 1) as well as in-depth discussions with significant players within the port and freight forwarding industry. The scale ranged from 7 to 1, from ‘very significant’ to ‘not relevant, respectively;
3. In the last section, respondents were given choice of four open questions, where they could express their free opinion about the subject matter.

The questionnaire is accompanied with a cover letter where respondents should be assured that they would receive a feedback when the study is completed, as a token of appreciation. The used questionnaire with accompanying cover letter is shown in Appendix 3 and Appendix 4, respectively.

3.1.2 DEA

As mentioned on previous chapter DEA can be defined as a non-parametric method of measuring the efficiency of a Decision Making Unit (DMU) with multiple inputs and/or multiple outputs. It is based on Farrell (1957) theory of using a non-parametric piece-wise-linear technology and combined with mathematical programming for efficiency rating.

The DEA efficiency theory can be traced back to Farrell (1957), and it was later developed by Charnes et al. (1978) and further expanded by Banker et al. (1984). It provides a valuable decision tool for the evaluation of the performance of DMUs and has been applied in various managing control and organization diagnosis. DEA takes advantage of the linear programming technique, without relying on the predetermined functional forms, to construct a piece-wise production frontier over the data. Assuming that linear combinations of the observed input-output bundle are feasible, the convex production set that connected by efficient DMUs enveloping around all the DMUs are estimated (B. Liu et al. 2006).

The DEA-CCR model assumes constant returns to scale (CRS) so that all observed production combinations can be scaled up or down proportionally. The DEA-BCC model, on the other hand, allows for variable returns to scale (VRS) and is graphically represented by a piecewise linear convex frontier.

Depending on orientation and objectives one can distinguish two orientations of DEA models:

- Input oriented models – minimise input while holding the output constant.
- Output oriented models - seeks to find the maximum produced output while remaining the input at its current level.

In the context of container-port operations, Bichou (2008) emphasised that the input oriented specification seems the most attractive because output levels in the short-run tend to be exogenously determined by the volume of demand and other locational factors.

When formulating DEA, since in this research operational efficiency will be investigated, input orientation will be used, as shown in (1).

Assuming a set of N $(n = 1,2,\ldots,N)$ DMUs in the sample, each observation, DMU_j $(j = 1,2,\ldots,n)$, uses m inputs x_{ij} $(i = 1,2,\ldots,m)$ to produce s outputs y_{rj} $(r = 1,2,\ldots,s)$. The efficiency ratio of DMU_j can be defined as the ratio of its weighted sum of outputs over its weighted sum of inputs:

$$E = Efficiency\ of DMU_j = \frac{\sum_{r=1}^{s} \lambda_j y_{rj}}{\sum_{i=1}^{m} \lambda_j x_{ij}} \quad \textbf{(1)}$$

Where: x_{ij} and y_{rj} are the amounts of i^{th} input and r^{th} output consumed and produced by DMU_j, respectively; and λ_j $(j = 1,2,\ldots,n)$ are non-negative scalars representing input and output weights such that $\sum_{j=1}^{n} \lambda_j = 1$.

An input orientation seeks to minimise input while holding the output constant. This is minimisation problem, which can be solved using linear programing. Equation (2) shows the DEA–CCR for the input oriented model:

$$Min \quad \theta - \varepsilon\left[\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right] \quad \textbf{(2)}$$

s.t.

$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta x_{ik}$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{rk}$$

$$\lambda_j \geq 0;\ s_r^+, s_i^- \geq 0;\ \forall i, r, j$$

$$r = 1,2,\ldots,s; i = 1,2,\ldots,m; j = 1,2,\ldots,n$$

Where :

θ – scalar;

λ_j – constant or weight of j^{th} DMU;

ε - small positive number;

s_i^- - slack variable of i^{th} input;

s_r^+ - slack variable of r^{th} output.

DEA BCC formulation uses the same form as in (2), but adds the convexity restriction $\sum_{j=1}^{n} \lambda_j = 1$.

The above model will be solved j times, and once of each DMU will obtain their respective θ value, which will be between 0 and 1. The optimal value of θ_0 is the measure of technical efficiency of DMU_0 under the variable return to scale. It is called pure technical efficiency (PTE). If the convexity constraint is not added in, the optimal value of θ_0 is the measure of technical efficiency of DMU_0 under the constant return to scale. It is called overall technical efficiency (OTE). The ratio of OTE to PTE is the measure of scale efficiency (SE). The value of unity indicates a point on the frontier which means that DMU is efficient (Farrell 1957). Whereas the value is less than 1, the DMU is not efficient.

The value of θ means the upper limit possible proportion that the inputs vector x_i can be contracted. λ_j with a positive value for DMU_0 indicates the benchmarks that the firms can learn from. Hence now it will be possible to rank the DMU_s according to their output and input data given by θ_0. Technical efficiency can be decomposed later into pure technical and scale perspectives to future identify the cause of inefficiency (B. Liu et al. 2006).

Above mentioned three efficiencies will be discussed in this dissertation and can be explained more detailed (Merk & Dang 2012):

1. Overall efficiency - derived from a model assuming constant returns to scale (CRS), provides a measure of overall port efficiency. It assumes that all observed production combinations could be scaled up and down proportionally. Varying production sizes or scales are considered to have no

effect on efficiency scoring, which means that small or large ports can equally operate in an efficient way;

2. Technical efficiency - pure technical efficiency is estimated by relaxing the constraint on scale efficiency, allowing output to vary disproportionally more or less with a marginal increase in inputs. It is derived from a model assuming varying returns to scale (VRS), and recognises that smaller ports may face disadvantages caused by production scale effects (Cheon et al. 2010);
3. Scale efficiency - scale inefficiencies arise when the scale of production is inappropriate, being above or below optimal levels and generating production wastes. Formally, they are identified when a difference appears between efficiency achieved at technical and overall levels, as measured by the following ratio (Färe et al. 1994): SE=CRS/VRS and where SE<1.

When SE<1, ports face scale inefficiency, driving higher overall inefficiency compared to pure technical inefficiency. By contrast, when SE=1, ports are operating at efficient scales, producing at the optimal level for which they were designed. 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). For ports operating at IRS (output rises proportionally more than the increase in inputs), production level should be expanded. This is usually 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. By contrast, when ports operate at DRS (output rises proportionally less than the increase in inputs) they should scale down their production toward lower optimal levels to limit inefficiencies lead, for example, by bottlenecks. In a long-run perspective, however, the alternative of raising the optimal level of production through investing in higher port infrastructure capacity should also be considered (Merk & Dang 2012).

3.1.3 TFP Malmquist DEA

In previous chapter it was mentioned that one of the most commonly used benchmarking technique is application of Malmquist productivity index.

The concept of the Malmquist productivity index was first introduced by Malmquist (1953) and Caves et al. (1982) applied it in a non-parametric framework. In order to avoid deciding on which period to define as the reference technology, Färe et al.

(1994) proposes a geometric mean of two TFP indices evaluated between periods t+1 and t as the base and the reference technology periods. This allows input and output weights to be calculated directly, which eliminates the need for price data (Bichou 2008).

The Malmquist TFP index can be decomposed into catching-up in efficiency and the shift in frontier technology, which is shown in (3):

$$M(y_t, x_t, y_{t+1}, x_{t+1}) = \frac{d_i^t(y_t, x_t)}{d_i^{t+1}(y_{t+1}, x_{t+1})}\left[\frac{d_i^{t+1}(y_t, x_t)}{d_i^t(y_t, x_t)} \frac{d_i^{t+1}(y_{t+1}, x_{t+1})}{d_i^t(y_{t+1}, x_{t+1})}\right] \quad \textbf{(3)}$$

Where:

- MPI is defined by distance functions $d_i^t(y_t, x_t)$ which represents the distance from the period t observation to the period i technology;
- The ratio outside the square brackets measures the change in the input-oriented measure of technical efficiency change (TEC) representing the catching up effect;
- The remaining part of the index is a measure of technical change (TC), which represents the shift in frontier technology between these two periods.

A value of MPI greater than 1 indicates an improvement in TFP while a value lower than 1 indicates a fall in TFP. Similarly, if TEC is larger than 1, then the efficiency improvement has occurred within the two periods. However, if TEC is smaller than one, then it indicates that terminal efficiency has become worse than before. Similarly, if TC is larger than one, then the production technology is progressive within two periods. The technology level is depressive if the value of TC is smaller than one.

The main problem with this index is that to properly measure TFP change, constant returns to scale (CRS) distance functions are required, because DEA VRS model does not capture the impact of production scale on efficiency. That is why Färe et al. (1994) suggest a further decomposition of MPI in which the CRS technical efficiency change measure (TEC) can be decomposed, by introducing some VRS distance functions, into a pure technical efficiency change (PEC) component and a scale efficiency change (SEC) component and (3) can be written as (4) (Estache et al. 2004):

$$TPFC = PEC \ x \ SEC \ x \ TC, \quad \textbf{(4)}$$

Where, the product of TEC and SEC is also sometimes known as total technical efficiency (TTEC).

This property makes the Malmquist index a particularly attractive technique for measuring and decomposing changes in productivity.

Bichou (2008) emphasised several reasons of Malmquist DEA application:

- Under application of stepwise Malmquist DEA, panel data can be exploit for both efficiency measurement and analysis of TFP growth, which will provide sound basis for benchmarking container terminal efficiency with tracking the shifts in the frontier technology over time;
- It should indicate whether any convergence in port productivity rates has taken place over time,
- Ability to decompose MPI into various sources of efficiency.

In this study MPI will be employed to measure the impact of productivity change on the panel data. The approach which will be used in this adopted in this study is to apply a stepwise Malmquist DEA analysis, both on a year-by-year basis and on a period basis in order to measure effects of economic crisis.

3.2 Data

3.2.1 Sampling Frame

Due to scope of research and time limitation, sample size has been limited to main container terminals from Balkan Peninsula and the United Kingdom. Therefore, considering the main objectives of this research, freight forwarders from above mentioned area has been targeted with on-line questionnaire.

For the purpose of homogeneity and data cleaning, terminals with multipurpose facilities and those that also handle non-container cargo has been excluded from sampling frame. Ports and terminals that either have a shorter history than the study period or lack complete or reliable data have also been excluded. As a result, we ended up with a final sample of 15 container terminals belonging to 15 ports, the details of which are provided in Appendix 5.

3.2.2 Datasets

The dataset consists of annual observations of sampled container terminals with time stretch from 2005 to 2011. There are several reasons for choosing this time frame:

- It can catch competition effects of other ports across the Europe that have built new or improved existing port facilities;
- It can catch effects of the World economic crisis started in 2008 and will allow assessment of productivity changes before and during the crisis.

The collection of data observations over a 7-year time-period resulted in a panel data of 105 terminal-years. In a dynamic context, panel data prevail over times-series and cross-sectional data. On the one hand, because a DMU is observed only once in either the times-series or the cross-sectional analysis, its efficiency estimate would be subjected to a higher degree of randomness and, therefore, may be misleading. On the other hand, the increase of the sample size under panel data analysis (from 15 to 105) would reinforce analytical reliability and reduce statistical error. In a panel data analysis, a DMU is defined as a container terminal-year (Bichou 2008).

Regarding the data collection methods, both primary and secondary data sources were used.

3.2.2.1 Primary Data – Questionnaire

For the purpose of this study, primary data are obtained directly from the subjects involved in the subject matter, in this case, different freight forwarders, across Balkan Peninsula and United Kingdom, involved either directly or indirectly in port operations, through the use of on-line questionnaire.

Due to time constraint for this dissertation, questionnaire has been conducted only during the period from 15th April until 15th May 2013. A sample of around 200 major freight forwarders from Balkan Peninsula and United Kingdom was covered by a questionnaire survey. Questionnaires were first emailed to these randomly selected freight forwarders engaged in port selection process. Freight forwarders selected for questionnaire survey are mainly independent, which means that they have free choice in selecting the mode and rout of cargo transportation, For Balkan Peninsula, main freight forwarding representatives were chosen based on authors previous work experience as freight forwarding agent as well as through official websites of freight forwarding societies from different countries.

For United Kingdom, freight forwarders were randomly chosen from the list of freight forwarders questionnaires provided by British International Freight Association (BIFA) website (BIFA 2013).

After the first round of mailing the survey forms, a reminder was sent twice an email and in some cases the author called the company offices.

The final sample of Balkan Peninsula freight forwarders (who returned completed questionnaires) is 19 while the final sample of the United Kingdom freight forwarders is 24. Thus, the response rate was only about 33% (45 responses) but it provides a sufficiently large sample to draw some generalizations.

3.2.2.2 Secondary Data

Secondary data are data that have been collected previously and reported by some individual other than the researcher (Beach & Alvager 1992). This data are usually readily available to be accessed in the form of books, documents, reports, Internet source or other media. In this study the data were collected as follows:

- Previous researches about the related topic obtained through City University library sources and from various scientific search engines such as Science direct, Francis and Taylor, Elsevier, IEEE explorer. In addition, a complementary search was performed in the following Journals: European Journal of Operational Research; Maritime Economics and Logistics; International Journal of Maritime Economics; International Journal of Logistics: Review of Network Economics; Transportation Research Part A: Policy and Practice; Transportation, Transportation Policy, Journal of Transportation Economics and Policy; Transport Reviews; Transportation Planning and Technology and International Journal of Shipping and Transport Logistics.
- Official websites of the port from the sample with purpose to find necessary input data for the quantitative analysis.
- The numerical (quantitative) data about ports were collected from the websites and annual reports of ports in the sample and from databases of trade journals like Containerisation International yearbooks for the period

2004-2010, Containerisation International On-line website, and The World Bank website.

- Other relevant data about ports were obtained from National Government Department of Statistics of the United Kingdom, Slovenia, Croatia and Romania.

3.2.3 Data and Variables Selection and Definition

In previous section about research approach it was explained that first phase involves identification of major factors of port choice form a perspective of freight forwarders. The relative importance of the port choice factors identified was assessed by asking the sampled respondents based in the United Kingdom and Balkan Peninsula to rank them from 7 (most important) to 1 (least important). The results of the seven most important factors are aggregated to show the overall ranking from the perspective of freight forwarders and are shown in Table 3.

Table 3: Ranking of port choice factors: freight forwarders' perspective

Rank	Factor	Mean	Standard Deviation
1	Geographical location	6.34	0.85
2	The efficiency and reliability of port intermodal connection	6.12	0.98
3	The frequency of ship calling	6.07	0.91
4	Inland delivery cost	6.05	1.40
5	Accessibility of the port and connection to a multimodal interface	6.02	1.01
6	Flexibility in responding to freight forwarders' demands and requests	6.00	1.14
7	Port working hours	5.73	1.36

Table 3 shows the most important factors in port choice from a perspective of freight forwarders. For measuring port efficiency as input to DEA model, quantitative measures will be determined which in the best way represent the most important qualitative factors from Table 3.

Variables selected for benchmarking container terminal operations consist of one output, six inputs and two additional input measures of port performance for the period of 2005-2011. Selected variables will be used later in this dissertation for testing operational hypothesis, outlined in the conclusion of Chapter 2.

Suggested quantitative factors which will be used in further analysis for determining port efficiency are presented in Table 4. Reasoning for selecting below mentioned factors with their more detail explanation is presented in Appendix 6.

Table 4: Input and output variables for container terminal operations

Inputs				
Determinant	Variables		Unit	Description
Liner (Shipping) Connectivity	x1	LSCI	Index number	Liner Shipping Connectivity Index
	x2	Vessel frequency	vessels / year	Total annual number of container vessels visiting the port
Service	x3	Labour	Employees	Total number of port employees at the 31st of December of each year
	x4	Port working hours	hours / year	Total number of port working hours during 1 year
Multimodal service	x5	Number of gates	Number	Number of gates, gate lanes, and/or railway tracks at the gate
	x6	Train frequency	Trains / week	Total number of train departures from particular container terminal per week
Port infrastructure	x7	WEF	Index number	Quality of port infrastructure
Logistic performance	x8	LPI	Index number	Logistics performance index
Output				
Determinant	Variables		Unit	Description
Terminal throughput	y	Throughput	1000 TEU	Annual total throughput

The combination of 15 terminals, 8 variables, and a 7-year (2005-2011) timeframe has resulted into a container-terminal panel dataset of 105 DMUs and 840 data points.

Table 5 depicts a summary of descriptive statistics relative to the aggregate container terminal dataset:

Table 5: Descriptive Statistics of Inputs and Outputs Variables in the Analysis

Variable	Mean	Standard deviation	Min	Max	Count
LSCI Index	61.14	30.55	8.48	87.53	105
Vessel frequency (per year)	675.59	566.19	5.00	2679.00	105
Labour	1007.15	852.94	124.00	3342.82	105
Port working hours (per year)	6195.73	1764.57	3368.00	8736.00	105
Number of gates	3.80	2.05	2.00	10.00	105
Train frequency (per week)	74.65	54.12	5.00	156.00	20
WEF Index	4.89	0.82	2.80	5.60	75
LPI Index	3.62	0.48	2.71	3.99	45
Throughput (1000 TEU)	629.72	786.76	17.00	3415.00	105

3.2.4 Validation of Data

This section will try to provide justification and validation of dataset and variables used in performance benchmarking under DEA methods.

3.2.4.1 Data accuracy

Accuracy of data regarding DMU can have significant influence on efficiency estimates and this is why collected data for all DMU should be as accurate as possible. In this sense, various sources were used for data collection and its cross checking.

3.2.4.2 Number of DMUs

In DEA, the number of units in the dataset should be greater than the number of inputs and outputs combined to ensure sufficient degrees of freedom (Bichou 2008). Generally, it is suggested that three DMUs are needed for each input and output variable. In this case, when panel data are applied the number of DMUs is increased from 15 to 105 (15 terminals x 7 years) which sets a ration of DMUs to the number of variables, including additional input variables, to 13.1 (>3).

3.2.4.3 Data scaling

It is suggested, that whenever possible data should be scaled down to lover levels, so that input and output variables do not take large values. This is recommended in order to reduce potential round-off errors in solving DEA models (Bichou 2008). For instance, in this dissertation terminal throughput is recorded in 1000 TEUs. Other values of input measures are in the range of reasonable scale.

3.2.4.4 Positivity

Generally, the DEA formulation requires that the input and output variables be positive or greater than zero. In this dissertation, all input and output values are positive and no further treatment is necessary.

3.2.4.5 Isotonicity

To satisfy the isotonicity premise, a Pearson correlation test has been carried out. The results of the test are shown in Table 6.

Table 6: Correlation coefficients between input and output variables

Variable	**Terminal throughput**	
	r	p
LSCI	0.2607	0.007212
Vessel frequency	0.9060	1.2E-40
Labour	0.5768	1.12E-10
Port working hours	0.3420	0.000352
Number of gates	0.8960	1.86E-38
Train frequency	0.8852	1.01E-07
WEF	0.1806	0.045229
LPI	0.2479	0.010743

The correlation coefficients in Table 6 show a p-value of less than 0.05 across the all correlations, which satisfy the isotonicity requirement.

3.3 Conclusions

This chapter identified the main research design, methodology and techniques selected for this study.

It started first by overview of main research questions and procedure applied in this study. The procedure entails application of questionnaire to the sample of various freight forwarders in the United Kingdom and Balkan Peninsula, gathering feedback and ranking the most important factors in their decision of port choice, identification of input and output measures in order to apply benchmarking techniques for efficiency estimation.

It is then followed by explanation of questionnaire application and formulation of DEA model. Besides that, MPI techniques was specified and decomposed into three sources of efficiency: technical efficiency, scale efficiency, and technological change. In order to measure productivity change before and after the World economic crisis, a step-wise MPI in terms of year-by-year and regulatory-period basis was applied.

Besides that, sampling frame of 15 container terminals was defined and data sets in time frame (from 2005 till 2007) which has resulted into a panel dataset of 105 terminal-years or DMUs. After that sources of data were described and variable selection defined. At the end validation of data was performed, including such aspects as number of DMUs, data scaling, positivity, and isotonicity.

Chapter 4 - Data Interpretation and Results

This chapter will try first to outline questionnaire feedback results and discuss main differences in port choice of freight forwarders in different regions. It will be followed by analysis and comparison of efficiency estimates and results from DEA model and the productivity change analysis. After that, a range of hypothesis will be explored and tested previously outlined in conclusion of literature review chapter. The approach adopted in this chapter is to present and interpret the empirical results by type of analysis and research problem. The software DEAP 2.1 (Coelli 2005) is used throughout this study to solve DEA models and calculate MPI index.

4.1 Questionnaire Feedback Results Analysis

To see how the freight forwarders located in the industrial and logistics centre of Balkan Peninsula differ from those based in the United Kingdom in terms of how they rank the key port choice factors, Table 7 presents their respective arithmetic means and standard deviation for the selected factors.

Table 7: Ranking of port choice factors: United Kingdom vs. Balkan Peninsula

Factor	United Kingdom		Balkan Peninsula	
	Mean	Rank	Mean	Rank
Geographical location	6.39	1	6.28	1
The efficiency and reliability of port intermodal connection	6.13	3	6.11	4
The frequency of ship calling	6.22	2	5.89	8
Inland delivery cost	5.87	7	6.28	2
Accessibility of the port and connection to a multimodal interface	5.96	5	6.11	5
Flexibility in responding to freight forwarders' demands and requests	5.83	8	6.22	3
Port working hours	6.04	4	5.89	9

From Table 7 it seem that the frequency of ship calling and port working hours have become more important to the freight forwarders in the UK, but geographical location has remained the most important port choice factor in both groups. In addition, it is interesting that inland delivery costs are ranked as seventh and hinterland connection and reliability as third out of twenty factors, which implies that freight forwarders in the UK might be willing to accept higher cost in return for highly reliable and more efficient container terminal and its connection with hinterland. This finding is opposite with De Langen (2007) findings, who conclude that freight forwards are highly price sensitive.

On the other hand, Balkan Peninsula freight forwarders ranking is in line with De Langen (2007) findings. From Table 7 it is clear that port choice of freight forwarders on the Balkan Peninsula has been mainly driven by costs i.e. inland delivery cost and how port handle their demands and requests. This implies that freight forwarders in this region more price elastic or price sensitive than the demand of freight forwarders in the UK. Moreover, freight forwarders from Balkan Peninsula consider that frequency of ship calling and port working hours have less influence in the their port choice.

4.2 Empirical Results and Efficiency Estimation under DEA Model

4.2.1 General Results of Efficiency Estimates

In order to derive efficiency estimates, both the DEA-CCR and DEA-BCC input orientation models are used to evaluate 15 container terminals in each year respectively under constant and variable returns to scale respectively. Estimates results of technical and scale efficiencies for both DEA models are presented in Appendix 7. Summary statistics for the derived efficiency estimates are exhibited in Table 8.

Table 8: Summary statistics for efficiency estimates

	DEA - CCR	DEA - BCC	Scale efficiency
mean	0.536	0.960	0.558
standard deviation	0.286	0.052	0.292
median	0.457	0.991	0.457
minimum	0.114	0.761	0.114
maximum	1.000	1.000	1.000
count	105	105	105

The results show that 8 DMU-years out of 105 in the sample are identified as efficient under the DEA-CCR model compared to 51 units identified as efficient under the DEA-BCC model. This result confirms that DEA-CCR models are more restrictive and produce lower efficiency scores (Bichou 2008). The mean efficiency score for the DEA-CCR model is 0.536 while the mean efficiency score for the DEA-BCC model is 0.960. The assumption of constant return to scale supported by DEA-CCR model, implies that efficiency estimates account for both technical and scale efficiency, while the variable return to scale identifies only technical efficiency. Therefore, it is only expected that DEA-BCC model will yield a higher level of mean efficiency. Besides that, average estimates of 0.960 and 0.558 for pure technical and scale efficiency, respectively, indicate both the utilisation of their existing resources and expansion on production scale terribly need to be improved.

In contrast to some previous applications of DEA to port efficiency estimation the correlation between the efficiency measures produced by the DEA-CCR and DEA-BCC models is found to be actually quite weak at 0.121. Moreover, the Spearman's rank order correlation coefficient between the efficiency rankings derived from DEA-CCR and DEA-BCC models is 0.218, which indicates that the efficiency estimates do not follow the same pattern across the sampled terminals. However, this is likely due to the limited sample size and while the DEA-BCC model produced many estimates of full efficiency, equivalent paired DEA-CCR estimates are often far from full efficiency. It is invariably the case that, in previous studies where a high correlation has been found between the estimates produced by the two models, sample size has been significantly larger.

It can be seen that container terminals such as Felixstowe, Southampton, London and Constantza, are identified as the most efficient terminals both in DEA-CCR and DEA-BCC perspectives, which is maintained throughout the whole time span of 2005-2011, with total average overall efficiency values of 0.973, 0.963, 0.860 and 0.834 respectively. It is not surprising since the proximity to the large shipping market and success in collaboration with foreign investment are the reasons behind their relative high efficiency scores. They are followed by container terminals in port of Liverpool and Medway with average efficiency values of 0.676 and 0.687 respectively. Overall efficiencies of all other container terminals do not exceed 50%. On the other hand their DEA-BCC values have high scores. This result indicates that these terminals are very busy in the handling operation, and the devotion of sufficient resources for future expansion is needed. In that sense, the lowest efficiency rating scored unit Ploče-2009 in the sample with a value of 0.114. In addition to this, 13 DMUs have scored lower than 20% efficiency rating in the DEA-

CCR model, consisted of basically three terminals Tees, Grimsby & Immingham and Ploče.

Contributing to this, the highest volatility and drop in the efficiency score has terminal in port of Ploče, which experienced significant drop in 2007. This can be explained, by the fact that although annual number of container vessels calling that port increases, port annual throughput remain at the same level.

Figure 4 shows average efficiency scores for each container terminal from the sample. The main observations emerging from the efficiency profile of container terminals are:

- Most efficient container ports operate at 70% to 90% of the maximum efficiency level. These ports are mostly located in the United Kingdom, with the exception of port of Constantza. However, they still operate under their optimal levels, suggesting that overall efficiency could be improved by 10% to 30% compared to their current levels.
- Among most efficient ports are some of the largest regional container ports: e.g. Felixstowe and Southampton (handling from 1 to 2 million TEU on annual basis), but also medium to small size ports such as London, Liverpool and Constantza (handling 0.5 to 1 million TEU per year). Further, when measuring the rank correlation between efficiency scores and output, as measured by TEU, the coefficient is 0.713, which indicates that there is a significant correlation between container terminal/port size and efficiency.

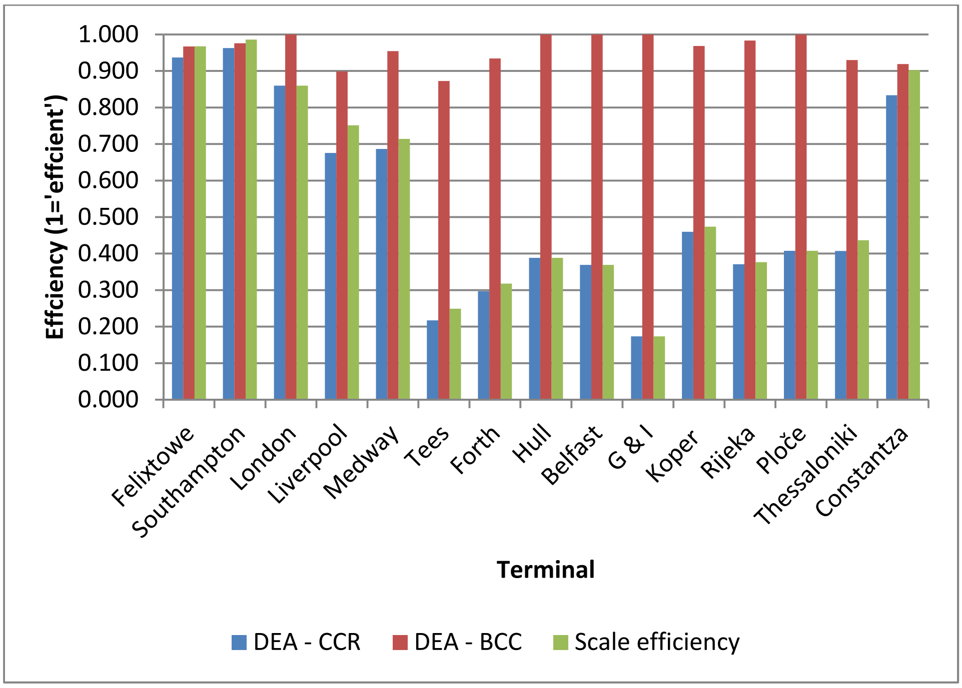

Figure 4: Average efficiency estimates for all years for each DMU in the sample

Figure 4 beside DEA-CCR and DEA-BCC values, shows scores of scale (in)efficiency (SE). It helps for identification of inefficiency sources. As previously stated, the DEA-CCR model assumes constant returns to scale. The DEA-CCR efficiency estimate is sometimes called overall technical efficiency, since it takes no account of the scale effect. The DEA-BCC model, on the other hand, assumes variable returns to scale, and the DEA-BCC efficiency estimate is sometimes called local pure technical efficiency. If a container terminal is fully efficient, with an efficiency estimate of 1 under both DEA-CCR and DEA-BCC models, it is said to be operating at its most productive scale. A container terminal that has full DEA-BCC efficiency but a low DEA-CCR score is said to be operating locally efficiently, but not globally efficiently because of the scale of the terminal's operations.

Figure 4 further depicts that almost all container terminals operate with high pure technical efficiency. Among these ports, two-third operates at lower overall efficiency levels, reflecting inefficiencies related to inappropriate production levels. For these terminals, the adjustments to limit production scale inefficiencies depend on whether ports are operating at increasing (IRS) or decreasing returns (DRS). Appendix 4 shows that the 97 out of 105 DMUs from the sample are all operating at increasing returns to scale, suggesting that DMUs are operating under their optimal levels and that production should be scaled up in order to reduce such inefficiencies.

4.2.2 Time Effects

Figure 5 depicts the development of the year-by-year average efficiency of all of the container ports in the sample using panel data analysis, assuming both the DEA-CCR and DEA-BCC model forms.

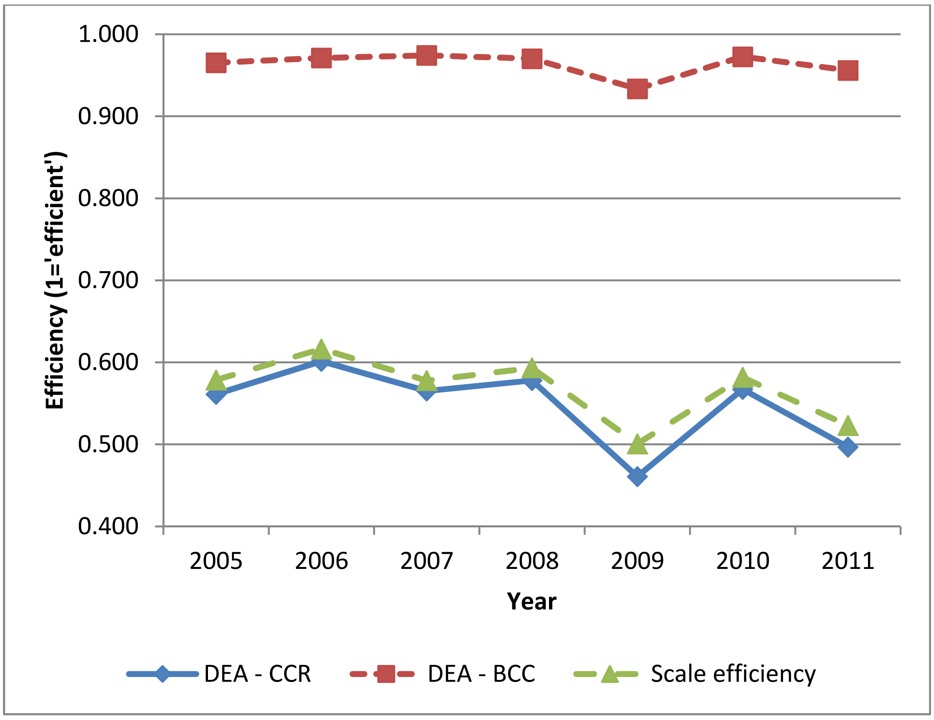

Figure 5: Year-by-year average efficiency for all container ports (2005-2011)

It shows a general steady trend for average efficiency estimates until 2008, followed by a sharp downward trend in 2009, continued back to the increase trend in 2010 and again returned to decrease trend in 2011. This volatility from the 2009 can be explained by negative impact of economic crisis in 2008, where immediate drop is felt in 2009 and attempt of recovery in 2010.

The exact values of efficiencies year-by-year are presented in Table 9. From the Table 9 it can be seen that the mean efficiency obtained from applying DEA-CCR model is 0.578 for 2008, but reduces in to 0.461 in 2009. Almost the same pattern happened in 2010 and 2011. This observed decrease in mean efficiency may be attributable to the decline in container throughput experienced in some ports as the result of a downturn in the global economy and reduced international trade.

Table 9: Average efficiency estimates for each year in the sample

	DEA - CCR	DEA - BCC	Scale efficiency
2005	0.561	0.965	0.578
2006	0.601	0.971	0.616
2007	0.565	0.974	0.578
2008	0.578	0.970	0.593
2009	0.461	0.933	0.501
2010	0.567	0.973	0.582
2011	0.497	0.956	0.523
Total mean efficiency	**0.547**	**0.963**	**0.567**

This change will be more deeply discussed after the estimation of a TFP index for assessing productivity change before and after the economic crisis in 2008.

4.2.3 Region Specific Efficiency Estimates

Table 10 shows average efficiency in separate regions which are subjects of this study. Efficiency of the container terminals within the United Kingdom are presented in two parts, with annual throughput above and below 500.000 TEU. It is done in this way since annual throughput of Balkan Peninsula ports are not exceeding 500.000 TEU except in case of port of Constantza, which is very near this value.

Table 10: Average efficiency estimates for each year in the sample per region

	UK top 5 CCR	UK top 5 BCC	UK rest 5 CCR	UK rest 5 BCC	Balkan CCR	Balkan BCC
2005	0.839	0.965	0.285	0.960	0.559	0.971
2006	0.863	0.963	0.317	0.963	0.624	0.988
2007	0.842	0.961	0.300	0.963	0.553	0.998
2008	0.896	0.975	0.298	0.962	0.540	0.974
2009	0.739	0.935	0.281	0.963	0.362	0.902
2010	0.801	0.957	0.269	0.962	0.405	0.935
2011	0.789	0.960	0.273	0.956	0.428	0.953
Total mean efficiency	**0.824**	**0.959**	**0.289**	**0.961**	**0.496**	**0.960**

The average efficiency levels of containers terminals located in different regions fount to be significantly different from each other. As can be seen form the Table 10, the average efficiency of the top five United Kingdom terminals is found to be 0.824 and 0.959 for DEA-CCR and DEA-BCC models respectively. These ports are found to be more efficient terminals then the smaller ports inside the United Kingdom and representative ports from Balkan Peninsula.

Figure 6 depicts efficiency estimates under DEA-CCR model of all three groups of container terminals explained in the Table 11. Efficiency trends of the top five container terminals in the United Kingdom and container terminals from Balkan Peninsula are following the same pattern, with higher volatility expressed in the Balkan area. Both of these groups are experienced higher impact of economic crisis in 2008, comparing to smaller ports in the United Kingdom.

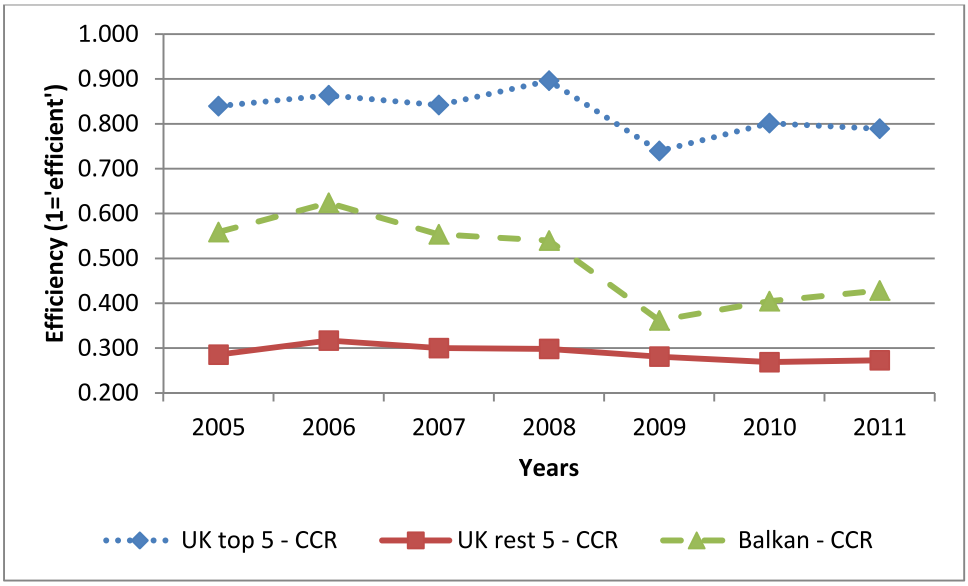

Figure 6: Average efficiency estimates for each year in the sample per region

Smaller container terminals in the United Kingdom are found to have the lowest efficiency in the selected time frame.

Efficiency estimates of container terminals from Balkan Peninsula are lower by almost double comparing to the top five United Kingdom container terminals. The reason of such a low mean value could be in lower market share, lower annual throughput and quality of port and hinterland infrastructure. Another, reason for this is could be that the market share covered by these ports and region contains countries outside European Union and its future candidates, which makes import/export procedures more complicated. To this also, contribute negative effects of the civil war that happened in ex-Yugoslavia during 1990s. It should be recognised, that not all the container terminals from Balkan Peninsula are included in the sample analysed.

4.3 Testing Operational Hypotheses

This section will try to use the results of DEA in order to test certain hypotheses drawn from literature review and pointed in conclusion of Chapter 2.

4.3.1 Analysis of Relationship between Overall Efficiency and Scale (Throughput)

The relationship of the port performance measures, such as annual throughput and operational efficiency can be concluded directly from Figure 7.

Figure 7 shows the relationship between container terminal annual throughput and their overall efficiency scores.

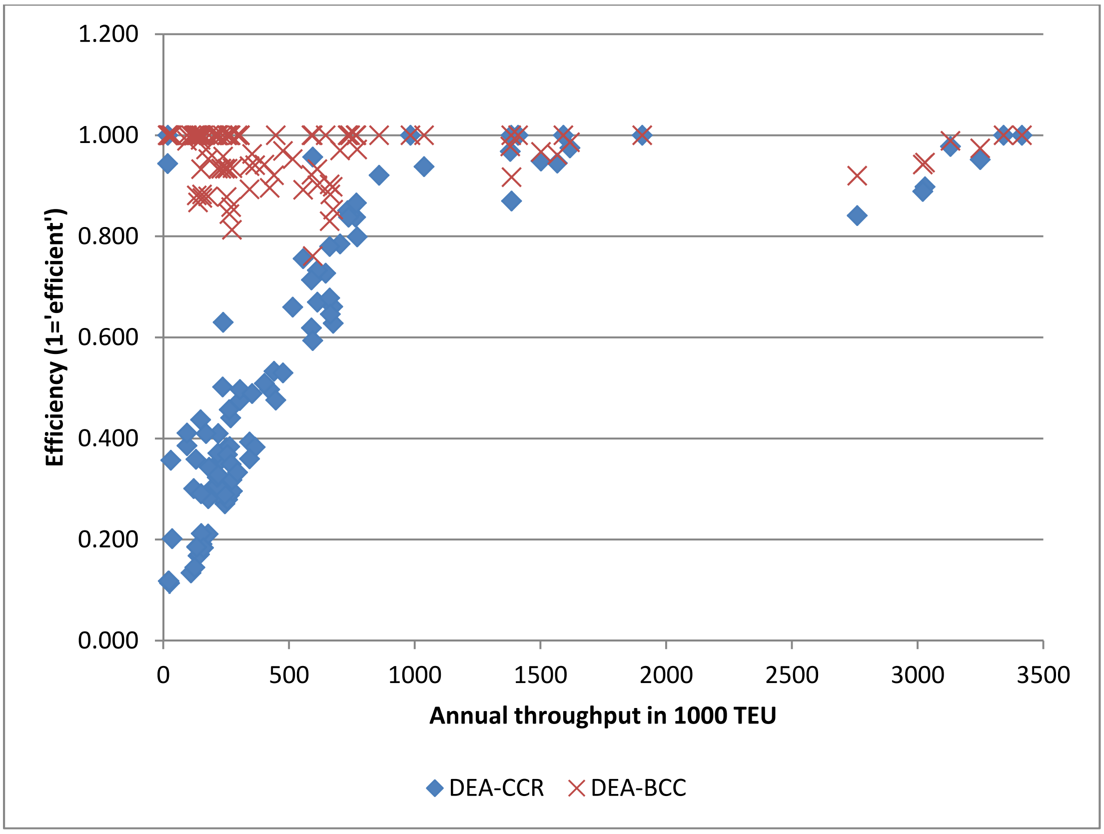

Figure 7: Relationship between annual throughput and mean overall efficiency

It is very clear that terminals with an annual throughput over 500.000 TEU are associated with high level of estimated efficiency. Other terminals with an annual throughput lower than 500.000 TEU do not exceed 50% of overall efficiency.

Further analysis, as presented in Table 11, on the relationship between throughput and efficiency shows positive coefficients relative to both the Pearson correlation and the Spearman’s rank order correlation, which indicates that the size of port production in terms of container throughput is positively correlated with efficiency scores. However, the values of both coefficients seem to indicate that this positive correlation is highly significant only applying DEA-CCR model.

Table 11: Correlation between throughput and efficiency

	DEA-CCR	DEA-BCC
Pearson correlation	0.713	0.051
Spearman's rank order correlation	0.819	0.218

From above it can be concluded that the hypothesis of positive relationship between efficiency of container terminal and its scale of production, cannot be rejected, which implies that economies of scale exist in container port sector. These findings are in line with the results of previous port literature (Bichou 2008; Bichou 2012; Cullinane et al. 2006).

4.3.2 Influence of Container Terminal Liner Connection on its Operating Efficiency

Influence of container terminal liner connection can be seen throughout two input variables ‘LSCI’ and ‘Vessel frequency’. Figure 8 shows both relationship between new liner variable (equal to product between LSCI and Vessel frequency) and overall efficiency. In addition, this figure also shows mean value overall efficiency scores depending on sailing frequency range.

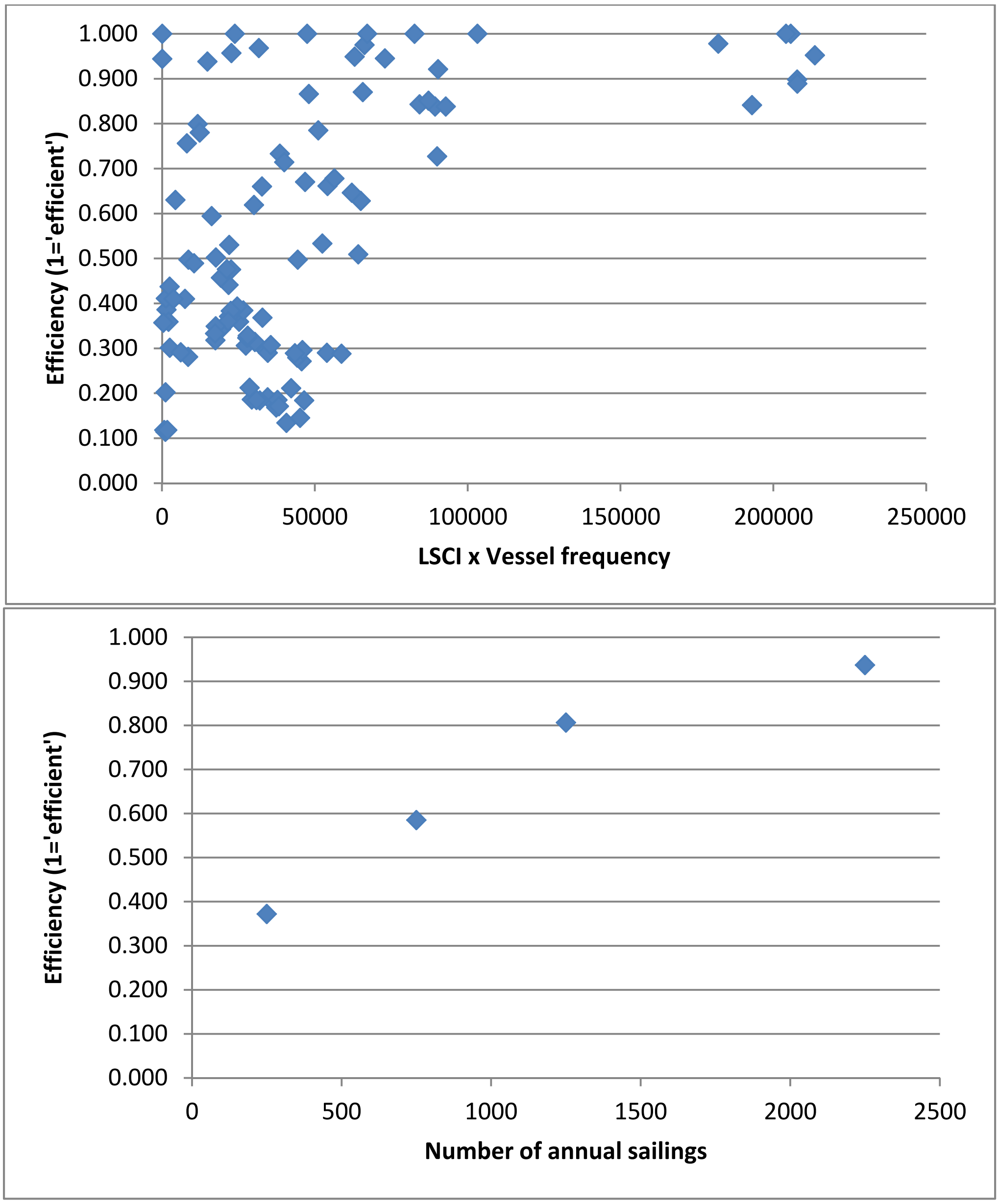

Figure 8: Relationship between average efficiency and terminal liner connectivity variables

It can be seen that, mean efficiency scores depict values of 37.2 %, 58.5 %, 80.6 % and 93.7 % for each range starting from 0-500, respectively. One exception is value for range between 2000 and 2500, since there are no container terminals with sailing frequency in that range. It is very clear that container terminals with higher sailing frequency tend to have higher mean overall efficiency.

4.3.3 Relationship between Port Intermodal Connection and Operating Efficiency

This section is intended for the examination of the relationship between the level of container terminal intermodal connection and its operational efficiency. In order to examine that, a new set of panel data will be run, with difference that the variable 'train frequency' will be included. In this way, sensitivity analysis will be done i.e. whether inclusion of this variable is likely to affect efficiency scores of terminal DMUs. Due to unavailability of data for all container terminals throughout selected time frame, new set of panel data was established, containing 20 DMUs from four container terminals throughout time frame 2007-2011. The comparative results between efficiencies with and without input variable 'train frequency' under DEA-CCR model are depicted in Figure 9. Full results of efficiencies for new panel data are reported in Appendix 8.

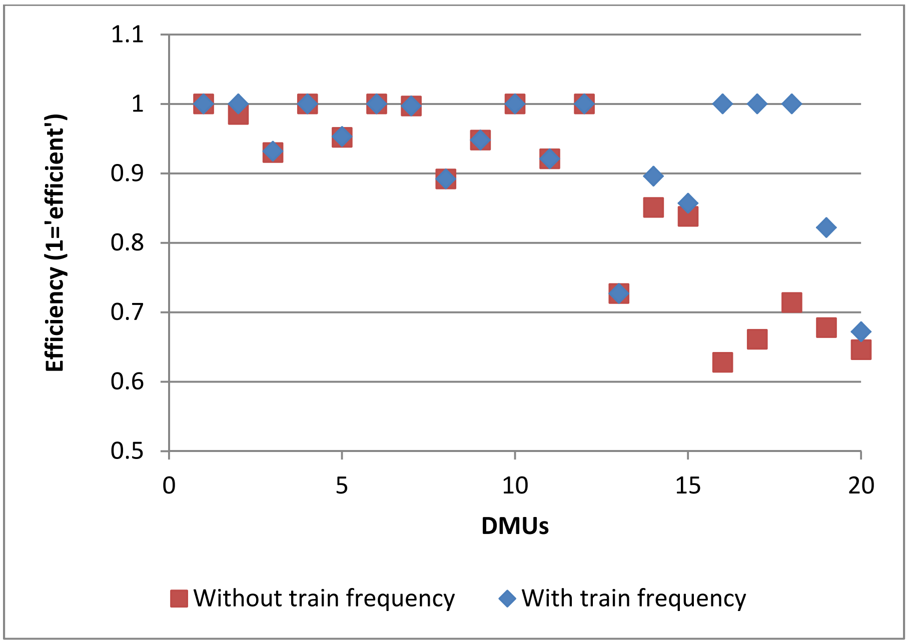

Figure 9: Comparison of efficiencies with and without input 'train frequency' under DEA-CCR model

From Figure 9, similar trend can be detected in both cases, but there are minor changes in efficiency scores. Comparing two set of efficiency scores from Appendix 5, the inclusion of the input variable 'train frequency' leads to a generalised increase of technical efficiency scores for 10 terminals DMUs (out of 20), from which 6 experienced an increase in their efficiency rating by less than 10 %, and 4 of them experienced an increase by 15-37 %. This means that on average, that use of train connection on container terminal improve its operational efficiency. This can be also seen from Table 12 where mean overall efficiency scores with and without input variable ‘train frequency’ depict value of 93.1 % and 86.8 %, respectively.

Table 12: Average efficiency estimates with and without intermodal connection variable

	DEA - CCR	DEA - BCC	Scale efficiency
With input 'train frequency'	0.931	0.997	0.933
Without input 'train frequency'	0.868	0.997	0.871

Furthermore, for some DMUs, just inclusion of train connection improves efficiency by more than 20 %, which is the case with Liverpool-2007, 2008 and 2009 with only 5 trains per week service. This means that it can be expected that midsize terminals can improve its efficiency, just by establishing basic intermodal connection service.

4.3.4 Geographical Location of the Terminal

To understand the difference of container terminal operating efficiency scores in different geographical location (United Kingdom vs. Balkan Peninsula), the opposite hypothesis will be tested: There is no significant differentiation between operating efficiency scores of the United Kingdom and Balkan Peninsula container terminals.

Among the 15 container terminals, there are 10 terminals from the United Kingdom. The other 5 terminals are on Balkan Peninsula.

Table 13 presents the p-values of the Mann-Whitney-U test for DEA model are larger than 0.05 significant and hence the null assumption cannot be rejected. It means that the two groups have no significant correlation with each other i.e. there is no significant differentiation between operating efficiency scores of United Kingdom vs. Balkan Peninsula container terminals, which is opposite to our first hypothesis. The reasoning might be that the professional management skills adopted by most container terminals are standard in the international market. Also, the stevedoring companies, global terminal operators, ocean carries involved in the terminal operation tend to push the port administrative authority to enhance port operating efficiency under the resource restrictions of container yard and terminal infrastructures. Therefore, the operating efficiencies in different ports seem to grow in the same direction and make no significant differentiation for United Kingdom vs. Balkan Peninsula container terminals.

Table 13: United Kingdom vs. Balkan Peninsula

Model	Mann-Whitney-U test	Z - test	p - value
DEA-CCR	1140	-0.5778	0.5634
DEA-BCC	1248	0.1529	0.8784

4.3.5 Importance of Port Customer Services on Terminal Operational Efficiency

In this section, influence of customer service on overall terminal efficiency will be examined. Customer service can be the best explained by input variable 'labour' expressed by employee number. Examination will be done throughout sensitivity analysis where efficiency scores with and without input variable 'labour', will be compared. Full results are reported in Appendix 9.

The mean average efficiencies scores with and without input variable 'labour' depict value of 0.536 and 0.523 respectively. It is clear that the exclusion of the input variable 'labour' leads to a generalised decrease of overall efficiency scores. In total 30 terminals DMUs (out of 105), experienced overall efficiency decrease from which only two, Koper-2009 and Koper-2010, experienced a decrease in their efficiency rating by more than 10 %.

In addition to this, Figure 10 presents relationship between number of employees and efficiency scores under DEA-CCR model. It is clear that ports up to 1500 employees depict various levels of efficiency where the only 5 are efficient. Despite that, ports with employee number above 1500 depict values above 60 % of overall efficiency.

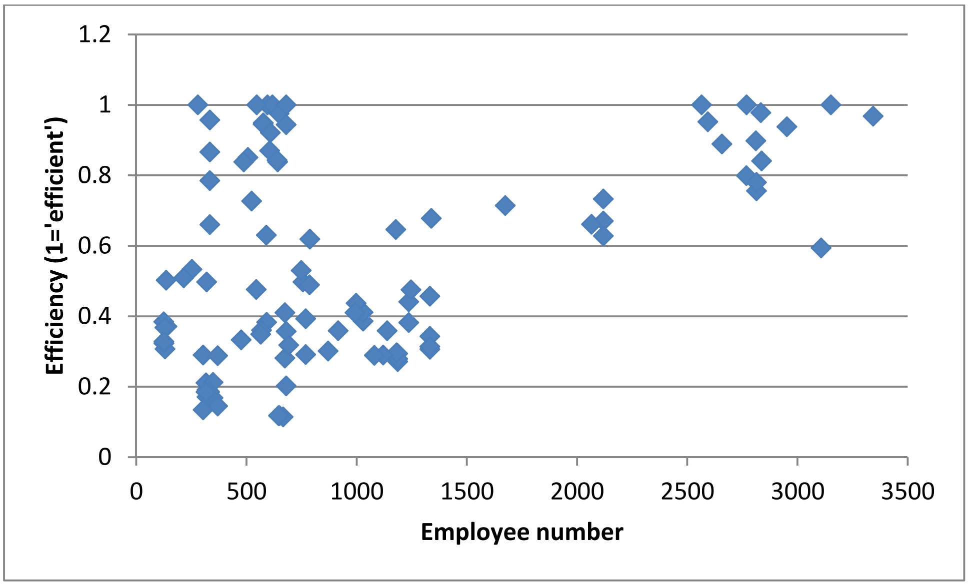

Figure 10: Relationship between number of employees and overall efficiency under DEA-CCR model

4.4 Productivity Change Analysis – The Malmquist Productivity Index

4.4.1 Multi-Year TFP Analysis

Results of the multiyear TFP analysis are reported in Appendix 10. In overall, the results show that on a year-by-year basis, 46 DMUs have achieved a productivity gain, 44 DMUs have experienced a productivity loss. There are no DMUs with any change in total factor productivity. Table 14 shows the descriptive statistics of year-by-year changes in MPI and its sub-categories.

Table 14: Descriptive statistics of the year-by-year MPI and its sub-categories

		Index decomposition			
		PEC	SEC	TC	MPI
Period	N	15	15	15	15
2005-06	Mean	0.961	1.054	1.051	1.062
	Median	1.000	1.000	1.049	1.020
	Minimum	0.839	0.866	0.933	0.895
	Maximum	1.000	1.334	1.221	1.470
	Standard deviation	0.068	0.115	0.071	0.145
2006-07	Mean	1.006	0.938	1.062	1.011
	Median	1.000	1.000	1.115	1.034
	Minimum	0.883	0.498	0.630	0.314
	Maximum	1.346	1.154	1.176	1.321
	Standard deviation	0.101	0.176	0.144	0.246
2007-08	Mean	1.022	1.063	0.958	1.033
	Median	1.000	1.017	0.946	0.981
	Minimum	0.943	0.505	0.808	0.543
	Maximum	1.175	1.590	1.140	1.560
	Standard deviation	0.060	0.238	0.084	0.223
2008-09	Mean	1.111	0.840	0.878	0.817
	Median	1.000	0.861	0.891	0.829
	Minimum	0.738	0.534	0.697	0.484
	Maximum	1.632	1.005	0.944	1.264
	Standard deviation	0.272	0.151	0.067	0.237
2009-10	Mean	0.947	1.012	1.119	1.062
	Median	1.000	1.000	1.122	1.085
	Minimum	0.514	0.773	1.051	0.757
	Maximum	1.102	1.394	1.190	1.436
	Standard deviation	0.151	0.169	0.036	0.216
2010-11	Mean	1.040	0.933	1.115	1.036
	Median	1.000	0.998	1.010	1.004
	Minimum	0.898	0.525	0.936	0.873
	Maximum	1.713	1.221	1.942	1.479
	Standard deviation	0.191	0.171	0.268	0.146
Total mean		1.015	0.973	1.030	1.003

The results from Table 14 show that TFP in selected ports rose by an average of 0.3% a year in 2005-2011. Among sub-category of the index, the pure technical efficiency change (PEC) is 1.015, scale efficiency change (SEC) 0.973 and the technical change index (TC) is 1.030 on average during 2005-2011. Regarding MPI year-by-year basis, on average a productivity gain has been recorded in all observation period, except in year-pair of 2008-2009 where loss in TFP was recorded. Regarding PEC, container terminals in the sample have experienced minor changes with small volatility in efficiency. Other sub-categories such as SEC and TC showed also volatility in their year to year efficiency scores with the highest drop in 2008-2009.

Figure 11 present variation of all indexes in year-by-year period. It is clear that efficiency changes of MPI and its sub-categories do not all follow similar productivity trends. The figure shows increasing trend in PEC until 2008-2009, followed by drop in 2009-2010 and recovery to productivity gain in 2010-2011. Totally opposite trend from PEC, can be noticed with TC. During year pairs 2005-2006 and 2006-2007 there has been increasing trend, it is followed by significant drop in 2007-2008 and 2008-2009, high recovery in 2009-2010 and slight drop, but still with value above 1 in 2010-2011. Both MPI and SEC follow the same pattern, changing trends in each year-pair.

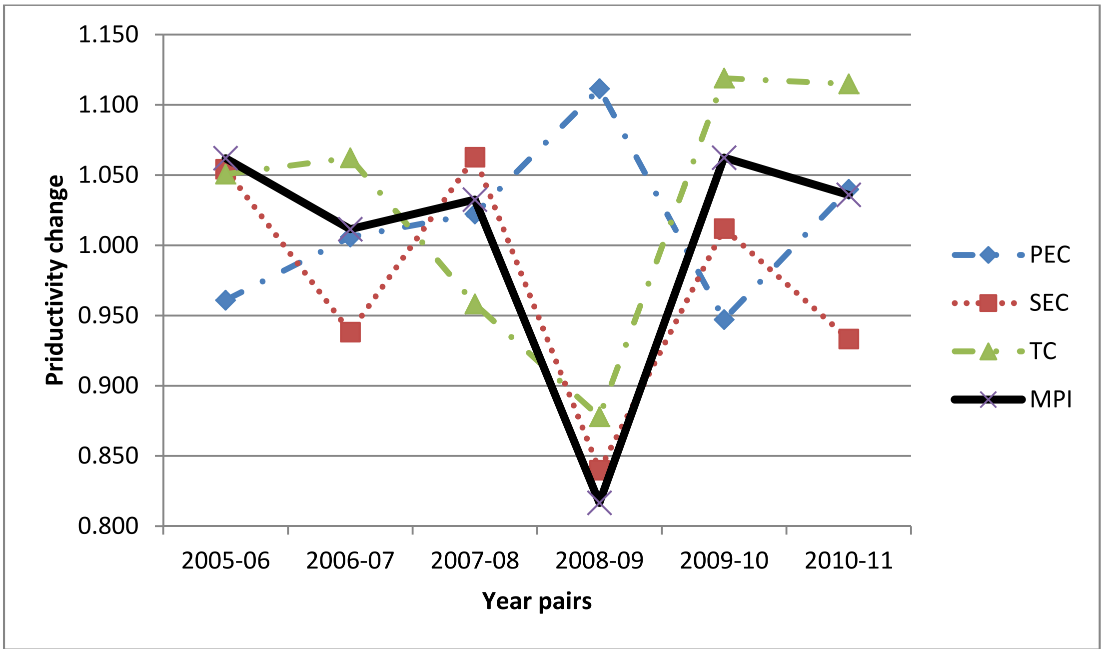

Figure 11: Average values of MPI and its sources of efficiency on a year-by year basis

Generally, from Appendix 7 it can be seen that the highest difference in MPI factors between the container terminals are during periods 2008-2009 and 2009-2010. For instance, in 2008-2009 all container terminals have MPI value below 1, except of terminals in Liverpool, Tees and Forth. The lowest MPI value in 2008-2009 have terminals in port of Ploče and Thessaloniki with MPI values of 0.487 and 0.484 respectively. The main reason for this is low TC index value. Cause of this could lie in sudden effects of world economic crisis and absence of improvement in technology change in port infrastructure. However, in the following year-pair 2009-2010 significant recovery can be seen where all terminals have TC index value above 1. The highest total MPI score can be notices in the terminals of port of Tees and Constantza with values of 1.436 and 1.411 respectively. In this sense, during year pairs of 2009-2010 and 2010-2011, shift (TC) dominates catching up effect (PEC) in almost all ports, while before the 2008 crisis, catching up effect was dominating the shift.

Table 15 depicts average values of MPI per year pair regarding the region. It can be seen that, container terminals in the United Kingdom were less affected with the crisis comparing to terminals on Balkan Peninsula which have higher volatility in MPI scores.

Table 15: Average values of MPI in different regions

	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
United Kingdom	1.013	1.013	1.057	0.904	1.032	1.046
Balkan Peninsula	1.161	1.008	0.985	0.641	1.123	1.016

Furthermore, the analysis of the relationship between the multiyear MPI and its sub-categories provides a statistical ground for explaining the changes in TFP through the various components of efficiency change. Results are shown in Table 16.

Table 16: Correlation of the multi-year MPI and its sources of efficiency change

	MPI decomposition		
Period	MPI-PEC	MPI-SEC	MPI-TC
2005-06	0.472	0.675	0.362
2006-07	0.032	0.876	0.869
2007-08	0.122	0.915	-0.046
2008-09	0.757	0.498	0.290
2009-10	0.652	0.410	0.277
2010-11	0.106	0.142	0.383

From Table 16, in the first 3 year pairs 2005-2006, 2006-2007 and 2007-2008 it can be seen that productivity gains from SEC has the strongest impact on the improvement of overall efficiency. The stronger impact of scale efficiency rather than the non-scale PEC indicates that the focus from the part of terminal operators was on achieving operational efficiency through terminal expansion rather than through the rationalisation of input use. This result is consistent with some previous results of Bichou (2008) and B. Liu et al. (2006). However, after being affected with economic crisis in 2008, PEC has the strongest impact in 2008-2009 and 2009-2010 pairs. As far as impact of TC is concerned, it also has significant impact on TFP. Still, the size of the impact is smaller than the one arising from adjustments in SEC.

4.4.2 Analysis of Economic Crisis Affected MPI

Although the stepwise multiyear MPI is useful for the analysis of short-term changes in productive efficiency, it does not provide a basis for the analysis of the productivity change influenced by economic crisis because its impacts are likely to take place over the medium and long-term horizons. In order to track TFP growth with a view of investigating the impacts of economic crisis, MPI and its sources of efficiency will be examined before and after 2008.

Appendix 11 shows the productivity growth of MPI and its sources of efficiency for the period of 2007-2011. Descriptive statistics for this period are depicted in Table 17 below.

Table 17: Descriptive statistics of the regulatory-run TFP and its sub-categories

		Index decomposition			
		PEC	SEC	TC	MPI
Period	N	15	15	15	15
2007-11	Mean	1.068	0.836	1.034	0.893
	Median	1.000	0.847	0.956	0.852
	Minimum	0.975	0.269	0.735	0.316
	Maximum	1.430	1.456	1.754	1.559
	Standard deviation	0.138	0.284	0.241	0.303

The results show that on average container terminals experienced productivity loss. However, minimum and maximum values of 0.316 and 1.559 respectively, points out that container terminals reacted in different way on the economic crisis, where smaller terminals showed productivity loss. Consequently, the same situation is with sub-categories, where SEC depicts the highest difference. The main outliner in this sense is terminal in port of Ploče with the lowest value of SEC and MPI, 0.269 and 0.316 respectively.

Table 18: Correlation of the crisis affected MPI and its sources of efficiency change

	MPI decomposition		
Period	MPI-PEC	MPI-SEC	MPI-TC
2007-11	**0.616**	**0.780**	**-0.095**

Table 17 and Table 18 suggest that TFP change has been driven mainly by adjustments in scale production and pure technical change. For the impact of technical change (TC) efficiencies, the results show that the size of the impact on TFP is smaller than that emanating from scale efficiency.

Chapter 5 - Conclusions and Recommendations

5.1 Research summary

In this section, main points from previous chapters will be summarised, highlighting a number of issues related to container terminal efficiency.

Chapter 1 presented general background and scope of the thesis, defined research problem and objectives of the study.

Chapter 2 provided a thorough review of the literature on the port competitiveness, port choice and port performance benchmarking. Port competitiveness section explained types of competition between the ports. The literature on the subject of port choice tried to group decision makers and their determinants of port choice, with special attention to freight forwarders point of view. The literature on the subject of port performance was grouped into three broad categories namely performance metric and productivity index methods, the frontier analysis and process approaches. For each category, main techniques have being reviewed. It was followed by explanation of main port performance indicators. The Chapter concluded outlining the main hypothesis drawn to respond to the research question.

Chapter 3 sets out a framework of viable research approach and methodology. The design of research methodology started by defining the main research questions and selecting and formalising the appropriate analytical technique for this study, namely questionnaire survey for determination of main factors that influence the port choice from a freight forwarders perspective, the data envelopment analysis (DEA) for efficiency measurement and performance benchmarking and the Malmquist productivity index (MPI) for productivity change analysis. Second part of the Chapter 3 defined the sampling frame and variables selection for this study and described the sources and methods of data collection.

In Chapter 4, the findings and results of the research are presented. The approach adopted in Chapter II was to present and interpret the empirical results by type of analysis and research problem in order to emphasise the findings from both the benchmarking exercise and the productivity change analysis. First of all, results from questionnaire feedback were presented depending on the region of freight forwarders. Second, the results of the benchmarking analysis under CRS using DEA model were presented. Assuming a stationary frontier, model provided a snapshot of productive efficiency under different dataset sizes and time observations. This was useful for testing five hypotheses that were implied from the operational assumptions discussed in previous chapters: the relationship between scale (throughput) and overall efficiency, the influence on container terminal liner connectivity on its operating efficiency, the relationship between the terminal landside connection and productive efficiency, significance between operational efficiencies between terminals in different geographical locations and importance of customer services and its impact on operational efficiency. Final part of the Chapter 4, presented the results of the productivity change analysis for multiyear year model and impact of economic crisis. Regarding multiyear model, the results of the year-by-year MPI analysis were tested and discussed with a view of tracking short term changes in productive efficiency both for total factor productivity (TFP) change and for its three main components or sources of efficiency, namely the pure technical efficiency change (PEC), the scale efficiency change (SEC), and the technical change (TC). Considering influence of economic crisis, the results before and after the crisis were tested and compared between the terminals.

This final Chapter, Chapter 5, provides a summary of the research findings and revisits both the assumptions and perspectives of the research in order to highlight the value and achievements of this dissertation as well as identify its gaps and limitations. The Chapter concludes with a series of recommendations on the way forward for future research.

5.2 Research Findings, Achievements and Limitations

5.2.1 Research Objectives and Propositions Revised

This research attempted to analyse and benchmark port services based on the factors and criteria most important to freight forwarders when choosing a port. The research problem was formulated as follows: *How can port services be benchmarked from a perspective of freight forwarders point of view?*

Having above in mind some most important research questions were drawn:

1. What are the main factors and criteria that influence freight forwarders choice of the port?
2. How can container port performance and efficiency be benchmarked based on these factors?
3. How can we measure and quantify the impact of these factors and criteria?

In trying to answer above questions, this study adopts an approach that incorporates framework of qualitatively data analysis, measures and techniques for benchmarking container terminal efficiency.

The main objectives of this dissertation are as follows:

1. To investigate the role of qualitative factors of port choice from a freight forwarders' perspective and outline the differences in the freight forwarders' view in port choice factor selection in terms of region they act and cover;
2. To apply an analytical model for measuring and benchmarking the operational efficiency of international container terminal operations,
3. To identify and incorporate the variations in container port operating sites and production technologies,
4. To provide appropriate platform for further research on port attractiveness, competitiveness and choice based on freight forwarders' decision.

5.2.2 Findings

The main purpose of this research was to analyse and benchmark port services based on the factors and criteria most important to freight forwarders when choosing a port. There was a scarcity of literature on this topic, and author tried, distinguishing from the previous researches, to benchmark container terminal performance based on input measured determined by the questionnaire feedback received from freight forwarders from the United Kingdom and Balkan Peninsula area. Following this analysis, the main research findings of this study can be summarised as follows:

1. Freight forwarders from different areas have slightly different priorities when choosing a port. Freight forwarders in the United Kingdom consider efficiency and reliability of port services as more decisive factor while forwarders on the Balkan Peninsula are mainly driven by cost issues. However, freight forwarders from both regions expressed that without any doubt geographical location is the most important factor in their port choice;
2. In overall, when looking to the total feedback of the questionnaire survey, it was showed that the main factors in selecting the port choice from a perspective of freight forwarders were geographical location, the efficiency and reliability of port intermodal connection, the frequency of ship calling, inland delivery cost, accessibility to the ports, flexibility in responding to freight forwarders' demands and requests, and port working hours. Based on these factors, port performance was assessed further under DEA model;

3. The number of container terminal DMUs identified as efficient accounts for 7.6% of the total when the DEA-CCR model is applied against 48.6% of the total when the DEA-BCC model is applied, respectively. This suggests that the sample is dominated by inefficient terminal DMUs;
4. During the whole time frame of 2005-2011 the most efficient container terminals are the largest terminals and operate at average of 70% to 90% of the maximum overall efficiency level. In this sense the best representatives are terminals in ports of Felixstowe and Southampton with average overall efficiency values of 0.937 and 0.963 respectively;
5. Container terminals showed different efficiency levels depending on the region where they are situated and size of the ports. The five biggest container terminals in the United Kingdom exhibit more than 80 % of its overall operational efficiency, followed by the Balkan Peninsula container terminals with efficiency range of 49% and the smaller size United Kingdom container terminals with 29% mean overall efficiency;
6. The analysis of the relationship between scale of production and operational efficiency reveal that 92.4% of DMUs exhibit increasing returns to scale (IRS) properties, which point out that the container terminal industry in these regions clearly depicts a VRS production technology. Besides that, this analysis also showed that container terminals with annual throughput above 500.000 TEU are associated with high level of estimated efficiency, while terminals with annual throughput lower than 500.000 TEU do not exceed 50% efficiency level;
7. The container terminal liner connection has a direct effect on terminal efficiency. Terminals with high frequency of ship calling tend to yield higher efficiency scores than their other counterparts;
8. In similar vein, level of intermodal connection was also found to have an influence on productive efficiency. In particular, train frequency towards container terminal hinterland seems to have a direct impact on terminal efficiency. Furthermore, the case of container terminal in the Liverpool port showed that midsize terminal can significantly improve its efficiency by just providing basic intermodal connection service;
9. The analysis of influence of geographical location on operational efficiency showed that there is no significant differentiation between operating efficiency scores between the container terminals in different regions. The

reasoning might be that the professional management skills adopted by most container terminals are standard in the international market;

10. The sensitivity analysis proved that port customer service proved to have influence on container terminal efficiency scores. However, this influence could be considered significant since the change of efficiency scores were not exceeding 10% difference;
11. For the productivity change analysis, the stepwise multiyear Malmquist DEA shows almost equal level of productivity loss and increase, with 44 DMUs that experienced productivity loss out of a total of 105. However, the whole period can be explained by constant volatility in productivity change. Until 2008, average productivity gains can be noticed, with a significant drop and production loss during 2008 and 2009 and recovery to initial values in 2010. The year-by-year MPI has shown that on average container terminals in the sample have incurred productivity gains in all periods except 2008-2009 when almost all terminals experienced productivity loss;
12. The analysis of the efficiency changes in MPI sub-categories has revealed that all indexes follow volatility trend. Pure efficiency change (PEC) and scale efficiency change (SEC) have constantly different trends throughout the observation periods. Analysis of the relationship between MPI and its sub-categories shows a stronger impact of scale efficiency compared to pure technical efficiency. This suggests that terminal operators in order to achieve higher operational efficiency, tried to focus on terminal expansion rather than rationalisation of input use. However, after being affected with economic crisis in 2008, PEC has the strongest impact in 2008-2009 and 2009-2010 pairs. As far as impact of TC is concerned, it also has significant impact on TFP. However, the size of the impact is smaller than the one arising from adjustments in SEC;
13. When analysing impact of economic crisis on productivity change, the results show regression of total factor productivity (TFP) change for selected observation period of 2007-2011 (MPI=0.893). However, container terminals individually showed different reaction on economic crisis. Correlation between MPI and its sub-categories showed that TFP change has been driven mainly by adjustments in scale efficiency change and pure technical change.

5.2.3 Limitations

Limitations in this study include practical and analytical issues, including the research design and methodology. The limitations associated with this study are summarized herein:

- The time and size restrictions from the university guidelines for the construction of a Master of Science dissertation, which consequently affects the design of the research, particularly defining the scope and extent of the study;
- Unavailability to gather more detailed and reliable data from primary source, which prevented author from extending the sample size to more significant number of freight forwarders.
- Unavailability to gather container terminal specific data from secondary sources, which forced author to use other proxy variables which in the best way explain input measures.
- Possible theoretical gaps of the analytical techniques used in this study, related to DEA. In order to improve this gap, panel data were used and MPI stepwise analysis.

5.3 Directions for Future Research

The aim of this dissertation was to analyse how to port performance and services can be benchmarked from the freight forwarders' point of view. The results of this study can be used in further understanding of port performance assessment, since it takes into account factors not only important to shipping lines or shippers, but also freight forwarders and logistic companies that use the specific port in their door to door service. In view of the current global financial crisis and economic downturn, and the derived slowdown of global maritime and trade flows, author believe that container terminal operators will aim to achieve operational efficiency by shifting their focus to rationalisation of input use.

Other possible avenues of future research include:

- Expand this approach to different regions of the World, affected by different market situation. Their inclusion might lead to the emergence of different pattern of relative efficiencies. This would also remove any possibility that efficiency estimates within the region are somehow function of specific market conditions which prevailed during the period covered in this study;

- Expand the range of port outputs considered beyond just container handling;
- To account for the labour input more clearly, by accessing consistent and reliable sources of data;
- To validate the findings for the analysis by applying alternative methodologies, such as stochastic frontier analysis (SFA) to the same data set.

To conclude with, the study stands as a modest initiative for further research in the field of port performance and services benchmarking analysis.

Chapter 6 - References

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Appendix 1: Most Important Factors of Port Choice from Literature Review from a Perspective of Freight Forwarders

1. Port Efficiency

Port efficiency often means speed and reliability of port services (Tongzon 2009). In fast moving industries, where products must be delivered to the markets on time, ports as vital points in the supply chain must be in a position to guarantee very reliable and quick service to freight forwarders. Reliability is associated with service quality and a ports higher service quality will increase its competitive advantage (Notteboom & Winkelmans 2001). The ability of the port to offer its services without the delays that could arise from inefficiency practice, strikes, and weather conditions will affect the choice of freight forwarders and other port users. Tongzon & Ganesalingam (1994) outlined several factors of port efficiency and characterised them into two groups:

- Operational efficiency measures – deals with capital and labour productivity, such as crane rates, ship rates or TEUs per crane, and asset utilisation rates such as TEUs per berth metre, berth occupancy and TEUs per hectare of terminal area;
- Customer oriented measures – includes direct charges, ships waiting time and minimisation of delays in inland transport and reliability.

2. Port Infrastructure

Several authors outlined port facilities and infrastructure as important factors in port choice of freight forwarders' (Tongzon 2002; Tongzon 2009) and other port user's perspective (C. Ugboma et al. 2006). Infrastructure does not simply refer to number of container berths, cranes and size of terminal area, but also to their quality. If the volumes handled exceed the ports' cargo handling capacity, it will result in port congestion and inefficiency, which can turn off port users. So, by avoiding port congestion and ship waiting time with adequate infrastructure maritime transport cost can be reduced, allowing quicker and safer cargo flow. Besides that, high quality cargo handling equipment leads to high level of productivity and efficiency (Tongzon 2009).

3. Cost

Cost is important criterion in port choice. They represent a significant part of the total transportation cost and supply chain cost. Foster (1978) indicated port charges as most influential factor. However, Tongzon (1995) and Murphy et al. (1991,1992) suggested that service related factors are more important than price in port choice. There are different types of port charges and they are generally charged on the basis of port visits and cargo volume. Stevedoring and terminal handling charges are calculated depending on cargo type. For freight forwarders main charges concerned in port selection are container-handling charges. Some other types of cost which freight forwarders have to pay include secondary charges, mainly transferred from other port users', such as pilotage, towage, electricity, water and garbage disposal.

4. Shipping Lines Sailing Frequency

Increase of frequency of ship visits gives freight forwarders more choices in their shipping line selection and more competitive carrier costs. In addition it allows them higher flexibility and lower transit time. Therefore, more ship visits the port has, the more attractive is to freight forwarders as shown in Slack (1985), Bird & Bland (1988), de Langen (2007) and Tongzon (2009).

5. Port Location

Location of the port is important because it can have a positive effect not only on the port efficiency and performance, but for the whole supply chain process. Attractive location, closeness to major shipping lines and serving of important hinterlands could contribute to decrease of overall cost incurred and port attractiveness. As mentioned in previous section, Tiwari et al. (2003) showed importance of distance between the port and the port users and , Huybrechts et al. (2002) and Tongzon (2009) contributed to this view. On the other hand Murphy et al. (1991) found that location had a relatively low ranking.

6. Port Information Systems

The establishment and use of communication systems that facilitate efficient servicing of operations and achievement of the port's and its users' goals are important for the port as well as for the freight forwarders and other users. It has been found that information sharing leads to high levels of supply chain integration improving its reliability and speed (Zhao et al. 2002). Efficient information system has impact on whole supply chain efficiency in terms of cost and service level. Besides that, faster shipping notifications decreases lead time and speed up shipping transactions. For example, Carbone & De Martino (2003) found that essential parameters for facilitating the integration process between supply chain partners at the port of Le Havre included the presence of advance information and communication technologies.

Therefore, limited access to current information about shipment arrivals due to lack of adequate information system will slow the documentation process and thus the smooth functioning of a port (Tongzon 2009).

7. Intermodal and Hinterland Connection

Port competition has moved from competition between ports to between transport chains (De Langen et al. 2010). Hinterland connections are of vital importance for a port, because container ports are nowadays a link in a logistics chain (De Langen et al. 2010). This implies that the quality of the hinterland connections and the diversity of the modalities available determine the level of port throughput. Additionally, the costs of hinterland have become relatively important. Without adequate intermodal links, port users cannot easily move cargo to and from the port, which could lead to congestion, delays and higher costs (Tongzon 2009). A basic insight is that congestion in the port or in its hinterland increases costs and hence weakens a ports' competitive position (OECD/ITF 2008).

Meersman et al. (2010) in their study tried to tries to assess some of the effects that infrastructure pricing can have on the competitiveness of the seaports. They pointed out that the quality of hinterland connections is the second most important criterion for competitiveness of a port after the cost factor.

8. Customer Service

Customer service means all aspects regarding customer relation and the value of the proposition of the port to its users. It includes quality, reliability and responsiveness to user's needs and the flexibility to meet changing user's needs. This means that ports would have to constantly monitor and understand the needs of port users in order to find out the quickest way to respond. Tongzon (2009) suggest that it should be done with regular dialogues and social interactions between port's public relation staff and port users. Other studies of D'Este & Meyrick (1992), C. Ugboma et al. (2006) and De Langen (2007) have identified customer service as one of the factors considered by shippers and freight forwarders in their port selection decisions.

Appendix 2: Port Performance Indicators

The changing role of ports as becoming a part of the supply chain and the diversification of port activities beyond traditional logistics activities into value added logistics services (De Langen et al. 2007) broaden the scope of activities of ports. This makes the measurement of port performance hard to capture. Therefore, to give the stakeholders and the port management insights in the operations, different indicators can be analysed depending on the objectives of the port.

As a result of the diversification of port activities, the literature gives several classifications of indicators. Chung (1993) divided the indicators in operational performance indicators, asset performance indicators and financial performance indicators. De Langen et al. (2007) classify three types of port products, cargo handling product, logistics product and manufacturing product. For every port product, port performance indicators can be analysed to check how the port performs on this product, as indicated in Table 19.

Table 19: Port products and port performance indicators

(Source: Adapted from De Langen et al. (2007))

Product	Port Performance Indicator
Cargo handling Product	Port Throughput, Ship handling time
Logistics Product	Value added in logistics, m^2 logistics space
Manufacturing Product	Value added and investment level in port related manufacturing

The reason for so many different indicators is that seaports are complex service organisations and the port output can be multidimensional depending on the objective that ports want to achieve (Tongzon & Heng 2005).

The port performance indicators that focus on the cargo-handling product are very important to analyse. In Table 1, two possible indicators concerning cargo-handling products are given. From these two, port throughput is most commonly used in the port industry (De Langen et al. 2007). Besides that, port throughput is a determinant for the other port performance indicators. For instance, the size of the logistic space depends on port throughput volume. It port throughput is higher the logistic capacity has to increase. This also applies for the value added generated in the ports and the port related employment. Other potential indicators can be found in Chung's division of indicators. He stated that to evaluate the operational performance, the speed with which a vessel is unloaded is a good indicator (Chung 1993). The vessels' length of stay and speed depends on the volume of the cargo, the available facilities and the composition of the cargo. Chung furthermore states that the asset performance is influenced by the total port throughput: generally this is measured as total throughput divided by the meters of quay or number of berths. To make the financial performances comparable with other ports, they are stated relatively, meaning in ratio to the port throughput. In general, the other port indicators are (indirectly) determined by port throughput.

In addition to this, Talley (2007) states that performance indicators are choice variables for optimising the port's economic objective. Tongzon (1995) also states that using port throughput as port performance is based on the assumption that ports try to maximize throughput. Traditionally the performance of ports has been evaluated by comparing the actual throughput with its optimum throughput (Talley 2007).

Appendix 3: On-line Questionnaire sent to the Freight Forwarders

Dissertation topic: Benchmarking Analysis of Port Services from a Perspective of Freight Forwarders
Surveyor: Bojan Manic
MSc Student in Maritime Operation and Management
City University London, UK
Mobile no: +44 7449 663 966
Email: manicbojan@gmail.com; bojan.manic.1@city.ac.uk

PART 1 – GENERAL INFORMATION

Please write your answer below:

Name of the company:	
City:	
Country:	
Nature of activity / sector: - Freight forwarder (FF) - Manufacturer (M) - Logistic company (LC)	
Size (approximate number of employees):	
Name of the interviewee:	
Position in the company:	
Contact details:	

PART 2 – ELEMENTS INFLUENCING THE PORT CHOICE (LIKERT SCALE)

Please rate the following factors by the importance of your choice:

1 – Not relevant (the lowest rank)

7 – Very relevant (the highest rank)

Factor no	Criteria	Factor	Ranking (1-7)
1	Port facility	Geographical location	
2		The capacity of port container storage	
3	Efficiency	The terminal productivity	
4		The efficiency and reliability of port intermodal connection	
5		The average container dwell time	
6	Costs	Port handling charges	
7		Inland delivery cost	

8	Service	Presence of particular shipping line	
9		The frequency of ship calling	
10		Port working hours	
11		Custom working hours	
12		Customs efficiency and procedures (inspection, documentation)	
13		Flexibility in responding to freight forwarders' demands and requests	
14	Information	The use of modern IT and electronic information systems by the port	
15		The cargo tracing information services	
16	Multimodal services	Accessibility of the port and connection to a multimodal interface	
17		Capacity to handle transferring from one mode to another	
18		Warehousing services (consolidation, packing, labelling, stuffing, inventory management)	
19	Other	Strikes	
20		Reputation of the port within the region	

PART 3 – OPEN QUESTIONS (OPTIONAL):

1. Which port do you most frequently use?

2. Would you like to add any other factor that you think it is valuable in choosing a port, and it is not outlined in the questionnaire above?

3. Is there anything else that you find important or you would like to add to this questionnaire regarding dissertation topic?

4. Would you like to receive summary copy of this study?

When you finish your rating, please save the document and return it to the sender.
If it is possible, we would like to have your feedback no later than May 8th 2013.
Thank you for your participation!

Appendix 4: Questionnaire Cover Letter

Dear Sir / Madam,

My name is Bojan Manic and I am an MSc student at City University London. For my final dissertation project, I am examining the main factors and criteria influencing the freight forwarders decision in choosing a port, under supervision of Professor Dr Khalid Bichou. Since you are considered as a one of the most important representatives of freight forwarders in your area, we are kindly inviting you to participate in this research study by completing the attached questionnaire.

The following questionnaire was developed to rank the main factors that can influence your port choice. It is our hope that this information can help to determine the most important factors that freight forwarders from United Kingdom and Balkan area pay attention while choosing a port.

This questionnaire will take approximately 10 minutes to complete. There are no identified risks from participating in this research and all information provided will remain confidential. Copies of the project will be filed in the City University library which can be accessed only with individual login and password. If you choose to participate in this project, please answer all questions as honestly as possible and return the completed questionnaire promptly to my email address. Participation is voluntary and you may refuse to participate at any time.

Thank you for taking the time to assist me in my educational endeavours. The data collected will provide useful information regarding the analysis of port choice determinants from a freight forwarders point of view. If you would like a summary copy of this study please answer 'yes' under the relevant answer field at the bottom of the questionnaire. The completion and return of the questionnaire will indicate your willingness to participate in this study.

If you require additional information or have any questions, please feel free to contact me at the number listed below.

I am looking forward to your feedback.

Sincerely,

Bojan Manic
MSc Student in Maritime Operation and Management
City University London, UK
Mobile no: +44 7449 663 966
Email: manicbojan@gmail.com ; bojan.manic.1@city.ac.uk.

Appendix 5: Container Ports and Terminals in the Sample

DMU	Country	Port	Terminal
1	United Kingdom	Felixstowe	Trinity and Landguard Container Terminal
2	United Kingdom	Southampton	Southampton Container Terminal
3	United Kingdom	London	London Container Terminal
4	United Kingdom	Liverpool	Royal Seaforth Container Terminal
5	United Kingdom	Medway	Sheerness
6	United Kingdom	Tees	Teesport Container Terminal 1
7	United Kingdom	Forth	Grangemouth Container Terminal
8	United Kingdom	Hull	Hull Container Terminal
9	United Kingdom	Belfast	Belfast Container Terminal
10	United Kingdom	Grimsby & Immingham	Immingham Container Terminal and DFDS Seaways' Nordic Terminal
11	Slovenia	Koper	Koper Container Terminal
12	Croatia	Rijeka	Brajdica Container Terminal
13	Croatia	Ploče	Ploce Container Terminal
14	Greece	Thessaloniki	Pier 6
15	Romania	Constantza	Constanța South Container Terminal

Appendix 6: Explanation of output and input variables for DEA model and MPI analysis

The output variable is terminal throughput in TEU. This output relates to the need for cargo-related facilities and services. Another reason for selecting this particular output is it is considered to be the most important and widely accepted indicator for comparing the ports and terminals and also the container is basic handling unit in the operation. Another consideration is that container throughput is the most appropriate and analytically tractable indicator of the effectiveness of the production of a port (Cullinane et al. 2006).

To produce the above output and to facilitate port operations, a variety of inputs are required. As mentioned before in this section, input measures are selected to best represent the major qualitative determinants selected by freight forwarders from United Kingdom and Balkan Peninsula.

The most important factor was port location and terminal connectivity with other ports. Input measure selected to represent this factor is Liner Shipping Connectivity Index (LSCI). It is computed by the United Nations Conference on Trade and Development (UNCTAD) based on five components of the maritime transport sector (Hoffman 2012):

1. Containership deployment or number of ships - Concerns the number of ships that are calling the ports of a country, which can either involve imports, exports or transhipment activity;
2. Container carrying capacity - total capacity of services enables to link port calls with the related physical capacity. The higher the capacity, the greater the potential to trade on global markets. However, it does not necessarily mean that the capacity is available for imports or exports;
3. Number of companies that deploy container ships in a country's ports - relates to how many shipping companies are servicing the country;
4. Number of liner services - relates to how many scheduled services are offered from each country;
5. Average and maximum vessel size - a proxy to the available economies of scale since they convey lower shipping costs per TEU. A limited number of countries/ports are able to accommodate ships higher than 8,000 TEU. Those who can thus have a higher connectivity.

Above explained main components are the main reasons for selection of this measure because it captures county's level of integration into the shipping trade and its connectivity to maritime shipping.

Since LSCI index is measured per country, and sample of this study capture ports form the same country, it is important to include input measures that are different per port. In this sense frequency of container vessel per port is selected as the second input. Another reason for selection of this input is that frequency of ship calls is on 3rd position of freight forwarders major determinants of port choice.

Further on, freight forwarders outlined that port customer service is very important which can be seen by high rank position of factors such as: flexibility in responding to freight forwarders' demands and requests and port working hours. Port working hours tells by itself that annual port landside working hours per year can be used as input and flexibility in responding to request and demands is connected with port customer services and can be represented with total number of port employees.

To continue with, freight forwarders outlined importance of multimodal services through determinant - Accessibility of the port and connection to a multimodal interface. Bottlenecks and congestion are very important in port and whole supply chain efficiency. In this sense appropriate input measure of total number of gates, which include both truck gates and number of railway tracks, is selected as one of the inputs. Besides that, in order to better incorporate intermodal connectivity to the port hinterland additional input of train departures has been selected.

Selection of above inputs is in line with some of the choices of previous researches for their studies of benchmarking port performance. For instance, Tongzon (2001) outlined that based on the production framework, port inputs can be generalised as land, labour and capital. As far as labour input is concerned the most fundamental factor is the number of stevedoring labour. However, due to a lack of information on this particular variable, a proxy variable is used represented by the number of port authority employees for the respective ports.

The major capital inputs in port operations are the number of berths, cranes and tugs. With respect to the land input, the study uses the terminal area of the ports. These inputs are most commonly used to measure container terminal efficiency in previous studies. However, since neither of these factors were not selected as major criteria of port selection, and in order to satisfy the labour and capital input, additional proxy input is selected. In this case World Bank index for measuring port infrastructure quality will be used. This index measures business executives' perceptions of their country's port facilities. The index rating ranges from 1 to 7, with a higher score indicating better development of port infrastructure (The World Bank 2013).

Beside port infrastructure quality index, one more additional input will be used to contribute to productivity analysis. It is World Bank's Logistic Productivity Index (LPI). Logistics Performance Index includes several other sub-indexes and in overall score reflects perceptions of a country's logistics based on efficiency of following (The World Bank 2013):

- Customs clearance process;
- Quality of trade and transport-related infrastructure;
- Ease of arranging competitively priced shipments;
- Quality of logistics services;
- Ability to track and trace consignments;
- Frequency with which shipments reach the consignee within the scheduled time.

The index ranges from 1 to 5, with a higher score representing better performance. This index can contribute the effects of the port and the whole supply chain efficiency, which was determined by freight forwarder selection of criteria: The efficiency and reliability of port intermodal connection. Since this index is measured only on particular years, in this case 2001 and 2011, it can be used for productivity analysis before and after the 2008 economic crisis.

Due to the extreme difficulty of obtaining confidential data the respective prices of inland charges are not taken into account in the empirical analysis contained herein.

Appendix 7: Terminal Efficiency for Panel Data under DEA Model

Terminal - year	DEA - CCR	DEA - BCC	Scale efficiency	Return to scale
Felixstowe - 2005	0.841	0.920	0.914	Increasing
Felixstowe - 2006	0.898	0.946	0.949	Increasing
Felixstowe - 2007	1.000	1.000	1.000	Constant
Felixstowe - 2008	0.978	0.989	0.989	Increasing
Felixstowe - 2009	0.889	0.942	0.945	Increasing
Felixstowe - 2010	1.000	1.000	1.000	Constant
Felixstowe - 2011	0.952	0.974	0.977	Increasing
Southampton - 2005	1.000	1.000	1.000	Constant
Southampton - 2006	0.949	0.967	0.981	Increasing
Southampton - 2007	1.000	1.000	1.000	Constant
Southampton - 2008	0.975	0.986	0.990	Increasing
Southampton - 2009	0.870	0.917	0.948	Increasing
Southampton - 2010	0.945	0.961	0.983	Increasing
Southampton - 2011	1.000	1.000	1.000	Constant
London - 2005	0.838	1.000	0.838	Increasing
London - 2006	0.843	1.000	0.843	Increasing
London - 2007	0.921	1.000	0.921	Increasing
London - 2008	1.000	1.000	1.000	Constant
London - 2009	0.727	1.000	0.727	Increasing
London - 2010	0.851	1.000	0.851	Increasing
London - 2011	0.838	1.000	0.838	Increasing
Liverpool - 2005	0.733	0.933	0.785	Increasing
Liverpool - 2006	0.670	0.901	0.744	Increasing
Liverpool - 2007	0.628	0.853	0.736	Increasing
Liverpool - 2008	0.661	0.898	0.736	Increasing
Liverpool - 2009	0.714	0.922	0.774	Increasing
Liverpool - 2010	0.678	0.903	0.751	Increasing
Liverpool - 2011	0.646	0.883	0.732	Increasing

Appendix 7 (Continued)

Terminal - year	DEA - CCR	DEA - BCC	Scale efficiency	Return to scale
Medway - 2005	0.785	0.970	0.809	Increasing
Medway - 2006	0.957	1.000	0.957	Increasing
Medway - 2007	0.660	0.953	0.693	Increasing
Medway - 2008	0.866	1.000	0.866	Increasing
Medway - 2009	0.497	0.896	0.555	Increasing
Medway - 2010	0.533	0.921	0.579	Increasing
Medway - 2011	0.509	0.942	0.540	Increasing
Tees - 2005	0.168	0.867	0.193	Increasing
Tees - 2006	0.186	0.881	0.211	Increasing
Tees - 2007	0.191	0.883	0.217	Increasing
Tees - 2008	0.185	0.876	0.212	Increasing
Tees - 2009	0.211	0.879	0.240	Increasing
Tees - 2010	0.290	0.878	0.330	Increasing
Tees - 2011	0.288	0.844	0.341	Increasing
Forth - 2005	0.294	0.934	0.315	Increasing
Forth - 2006	0.271	0.934	0.291	Increasing
Forth - 2007	0.279	0.934	0.299	Increasing
Forth - 2008	0.296	0.935	0.317	Increasing
Forth - 2009	0.359	0.934	0.384	Increasing
Forth - 2010	0.290	0.934	0.310	Increasing
Forth - 2011	0.289	0.934	0.309	Increasing
Hull - 2005	0.382	1.000	0.382	Increasing
Hull - 2006	0.441	1.000	0.441	Increasing
Hull - 2007	0.475	1.000	0.475	Increasing
Hull - 2008	0.457	1.000	0.457	Increasing
Hull - 2009	0.343	1.000	0.343	Increasing
Hull - 2010	0.306	1.000	0.306	Increasing
Hull - 2011	0.314	1.000	0.314	Increasing

Appendix 7 (Continued)

Terminal - year	DEA - CCR	DEA - BCC	Scale efficiency	Return to scale
Belfast - 2005	0.371	1.000	0.371	Increasing
Belfast - 2006	0.502	1.000	0.502	Increasing
Belfast - 2007	0.384	1.000	0.384	Increasing
Belfast - 2008	0.368	1.000	0.368	Increasing
Belfast - 2009	0.307	1.000	0.307	Increasing
Belfast - 2010	0.323	1.000	0.323	Increasing
Belfast - 2011	0.328	1.000	0.328	Increasing
Grimsby & Immingham - 2005	0.212	1.000	0.212	Increasing
Grimsby & Immingham - 2006	0.184	1.000	0.184	Increasing
Grimsby & Immingham - 2007	0.171	1.000	0.171	Increasing
Grimsby & Immingham - 2008	0.184	1.000	0.184	Increasing
Grimsby & Immingham - 2009	0.185	1.000	0.185	Increasing
Grimsby & Immingham - 2010	0.134	1.000	0.134	Increasing
Grimsby & Immingham - 2011	0.145	1.000	0.145	Increasing
Koper - 2005	0.281	0.953	0.295	Increasing
Koper - 2006	0.410	1.000	0.410	Increasing
Koper - 2007	0.497	1.000	0.497	Increasing
Koper - 2008	0.489	0.963	0.507	Increasing
Koper - 2009	0.393	0.893	0.441	Increasing
Koper - 2010	0.530	0.969	0.547	Increasing
Koper - 2011	0.619	1.000	0.619	Increasing
Rijeka - 2005	0.386	0.989	0.390	Increasing
Rijeka - 2006	0.411	1.000	0.411	Increasing
Rijeka - 2007	0.437	0.991	0.441	Increasing
Rijeka - 2008	0.410	0.972	0.422	Increasing
Rijeka - 2009	0.359	1.000	0.359	Increasing
Rijeka - 2010	0.301	0.999	0.301	Increasing
Rijeka - 2011	0.291	0.933	0.312	Increasing

Appendix 7 (Continued)

Terminal - year	DEA - CCR	DEA - BCC	Scale efficiency	Return to scale
Ploče - 2005	0.944	1.000	0.944	Increasing
Ploče - 2006	1.000	1.000	1.000	Constant
Ploče - 2007	0.357	1.000	0.357	Increasing
Ploče - 2008	0.202	1.000	0.202	Increasing
Ploče - 2009	0.114	1.000	0.114	Increasing
Ploče - 2010	0.118	1.000	0.118	Increasing
Ploče - 2011	0.118	1.000	0.118	Increasing
Thessaloniki - 2005	0.383	0.941	0.407	Increasing
Thessaloniki - 2006	0.360	0.939	0.383	Increasing
Thessaloniki - 2007	0.476	1.000	0.476	Increasing
Thessaloniki - 2008	0.630	0.958	0.658	Increasing
Thessaloniki - 2009	0.349	0.858	0.407	Increasing
Thessaloniki - 2010	0.318	0.813	0.391	Increasing
Thessaloniki - 2011	0.333	1.000	0.333	Increasing
Constantza - 2005	0.799	0.972	0.822	Increasing
Constantza - 2006	0.938	1.000	0.938	Increasing
Constantza - 2007	1.000	1.000	1.000	Constant
Constantza - 2008	0.968	0.978	0.990	Increasing
Constantza - 2009	0.594	0.761	0.780	Increasing
Constantza - 2010	0.756	0.892	0.847	Increasing
Constantza - 2011	0.780	0.830	0.939	Increasing

Appendix 8: Terminal Efficiency Estimates with and without Input Measure ‘Train Frequency’ for Panel Data under DEA Model

Efficiency estimates with ‘Train Frequency’ variable

Terminal - year	Train frequency	DEA - CCR	DEA - BCC	Scale efficiency	Return to scale
Felixstowe - 2007	141	1.000	1.000	1.000	Constant
Felixstowe - 2008	134	1.000	1.000	1.000	Constant
Felixstowe - 2009	146	0.932	0.994	0.938	Increasing
Felixstowe - 2010	156	1.000	1.000	1.000	Constant
Felixstowe - 2011	155	0.953	0.995	0.958	Increasing
Southampton - 2007	102	1.000	1.000	1.000	Constant
Southampton - 2008	124	0.997	1.000	0.997	Increasing
Southampton - 2009	102	0.892	1.000	0.892	Increasing
Southampton - 2010	89	0.948	0.996	0.951	Increasing
Southampton - 2011	85	1.000	1.000	1.000	Constant
London - 2007	35	0.921	1.000	0.921	Increasing
London - 2008	35	1.000	1.000	1.000	Constant
London - 2009	35	0.727	1.000	0.727	Increasing
London - 2010	30	0.896	1.000	0.896	Increasing
London - 2011	32	0.857	1.000	0.857	Increasing
Liverpool - 2007	5	1.000	1.000	1.000	Constant
Liverpool - 2008	5	1.000	1.000	1.000	Constant
Liverpool - 2009	15	1.000	1.000	1.000	Constant
Liverpool - 2010	25	0.822	0.979	0.840	Increasing
Liverpool - 2011	42	0.672	0.977	0.688	Increasing

Appendix 8 (Continued)

Efficiency estimates without 'Train Frequency' variable

Terminal - year	Train frequency	DEA - CCR	DEA - BCC	Scale efficiency	Return to scale
Felixstowe - 2007	141	1.000	1.000	1.000	Constant
Felixstowe - 2008	134	0.985	1.000	0.985	Increasing
Felixstowe - 2009	146	0.930	0.994	0.936	Increasing
Felixstowe - 2010	156	1.000	1.000	1.000	Constant
Felixstowe - 2011	155	0.952	0.995	0.957	Increasing
Southampton - 2007	102	1.000	1.000	1.000	Constant
Southampton - 2008	124	0.997	1.000	0.997	Increasing
Southampton - 2009	102	0.892	1.000	0.892	Increasing
Southampton - 2010	89	0.948	0.995	0.953	Increasing
Southampton - 2011	85	1.000	1.000	1.000	Constant
London - 2007	35	0.921	1.000	0.921	Increasing
London - 2008	35	1.000	1.000	1.000	Constant
London - 2009	35	0.727	1.000	0.727	Increasing
London - 2010	30	0.851	1.000	0.851	Increasing
London - 2011	32	0.838	1.000	0.838	Increasing
Liverpool - 2007	5	0.628	1.000	0.628	Increasing
Liverpool - 2008	5	0.661	1.000	0.661	Increasing
Liverpool - 2009	15	0.714	1.000	0.714	Increasing
Liverpool - 2010	25	0.678	0.979	0.693	Increasing
Liverpool - 2011	42	0.646	0.977	0.661	Increasing

Appendix 9: Terminal Efficiency Estimates with and without Input Measure ‘Labour’ for Panel Data under DEA-CCR Model

Terminal - year	Labour	With 'labour' input	Without 'labour' input	Difference
Felixstowe - 2005	2837	0.841	0.841	-
Felixstowe - 2006	2811	0.898	0.898	-
Felixstowe - 2007	2769	1.000	1.000	-
Felixstowe - 2008	2833	0.978	0.978	-
Felixstowe - 2009	2657	0.889	0.889	-
Felixstowe - 2010	2565	1.000	1.000	-
Felixstowe - 2011	2593	0.952	0.952	-
Southampton - 2005	595	1.000	1.000	-
Southampton - 2006	576	0.949	0.949	-
Southampton - 2007	617	1.000	1.000	-
Southampton - 2008	648	0.975	0.975	-
Southampton - 2009	605	0.870	0.870	-
Southampton - 2010	575	0.945	0.945	-
Southampton - 2011	279	1.000	1.000	-
London - 2005	641	0.838	0.838	-
London - 2006	638	0.843	0.843	-
London - 2007	608	0.921	0.921	-
London - 2008	546	1.000	1.000	-
London - 2009	523	0.727	0.725	0.002
London - 2010	506	0.851	0.844	0.007
London - 2011	487	0.838	0.827	0.011
Liverpool - 2005	2119	0.733	0.733	-
Liverpool - 2006	2119	0.670	0.670	-
Liverpool - 2007	2119	0.628	0.628	-
Liverpool - 2008	2065	0.661	0.661	-
Liverpool - 2009	1674	0.714	0.714	-
Liverpool - 2010	1338	0.678	0.678	-
Liverpool - 2011	1177	0.646	0.646	-

Appendix 9 (Continued)

Terminal - year	Labour	With 'labour' input	Without 'labour' input	Difference
Medway - 2005	333	0.785	0.722	0.063
Medway - 2006	333	0.957	0.957	-
Medway - 2007	333	0.660	0.660	-
Medway - 2008	333	0.866	0.807	0.059
Medway - 2009	319	0.497	0.486	0.011
Medway - 2010	252	0.533	0.470	0.063
Medway - 2011	215	0.509	0.388	0.121
Tees - 2005	348	0.168	0.168	-
Tees - 2006	332	0.186	0.186	-
Tees - 2007	320	0.191	0.191	-
Tees - 2008	330	0.185	0.185	-
Tees - 2009	316	0.211	0.210	0.001
Tees - 2010	303	0.290	0.265	0.025
Tees - 2011	369	0.288	0.263	0.025
Forth - 2005	1186	0.294	0.294	-
Forth - 2006	1186	0.271	0.271	-
Forth - 2007	1186	0.279	0.279	-
Forth - 2008	1181	0.296	0.296	-
Forth - 2009	1138	0.359	0.359	-
Forth - 2010	1120	0.290	0.290	-
Forth - 2011	1080	0.289	0.289	-
Hull - 2005	1236	0.382	0.382	-
Hull - 2006	1236	0.441	0.441	-
Hull - 2007	1246	0.475	0.475	-
Hull - 2008	1332	0.457	0.457	-
Hull - 2009	1332	0.343	0.343	-
Hull - 2010	1332	0.306	0.306	-
Hull - 2011	1332	0.314	0.314	-

Appendix 9 (Continued)

Terminal - year	Labour	With 'labour' input	Without 'labour' input	Difference
Belfast - 2005	139	0.371	0.352	0.019
Belfast - 2006	135	0.502	0.470	0.032
Belfast - 2007	124	0.384	0.377	0.007
Belfast - 2008	129	0.368	0.329	0.039
Belfast - 2009	130	0.307	0.275	0.032
Belfast - 2010	125	0.323	0.320	0.003
Belfast - 2011	125	0.328	0.326	0.002
Grimsby & Immingham - 2005	348	0.212	0.212	-
Grimsby & Immingham - 2006	332	0.184	0.184	-
Grimsby & Immingham - 2007	320	0.171	0.170	0.001
Grimsby & Immingham - 2008	330	0.184	0.171	0.013
Grimsby & Immingham - 2009	316	0.185	0.185	-
Grimsby & Immingham - 2010	303	0.134	0.134	-
Grimsby & Immingham - 2011	369	0.145	0.145	-
Koper - 2005	674	0.281	0.218	0.063
Koper - 2006	674	0.410	0.315	0.095
Koper - 2007	756	0.497	0.377	0.120
Koper - 2008	786	0.489	0.391	0.098
Koper - 2009	768	0.393	0.278	0.115
Koper - 2010	748	0.530	0.377	0.153
Koper - 2011	787	0.619	0.449	0.170
Rijeka - 2005	1029	0.386	0.386	-
Rijeka - 2006	1029	0.411	0.411	-
Rijeka - 2007	997	0.437	0.437	-
Rijeka - 2008	992	0.410	0.410	-
Rijeka - 2009	916	0.359	0.359	-
Rijeka - 2010	870	0.301	0.301	-
Rijeka - 2011	768	0.291	0.291	-

Appendix 9 (Continued)

Terminal - year	Labour	With 'labour' input	Without 'labour' input	Difference
Ploče - 2005	680	0.944	0.944	-
Ploče - 2006	680	1.000	1.000	-
Ploče - 2007	680	0.357	0.357	-
Ploče - 2008	680	0.202	0.202	-
Ploče - 2009	666	0.114	0.114	-
Ploče - 2010	649	0.118	0.118	-
Ploče - 2011	645	0.118	0.118	-
Thessaloniki - 2005	591	0.383	0.347	0.036
Thessaloniki - 2006	568	0.360	0.337	0.023
Thessaloniki - 2007	544	0.476	0.440	0.036
Thessaloniki - 2008	590	0.630	0.630	-
Thessaloniki - 2009	564	0.349	0.349	-
Thessaloniki - 2010	691	0.318	0.318	-
Thessaloniki - 2011	476	0.333	0.333	-
Constantza - 2005	2768	0.799	0.799	-
Constantza - 2006	2951	0.938	0.938	-
Constantza - 2007	3152	1.000	1.000	-
Constantza - 2008	3343	0.968	0.968	-
Constantza - 2009	3107	0.594	0.594	-
Constantza - 2010	2814	0.756	0.756	-
Constantza - 2011	2814	0.780	0.780	-

Appendix 10: Malmquist Productivity Index: Year-by-Year TFP Change

Port	2005-06				2006-07				2007-08			
	PEC	SEC	TC	MPI	PEC	SEC	TC	MPI	PEC	SEC	TC	MPI
Felixstowe	1.000	1.000	1.078	**1.078**	1.000	1.000	1.113	**1.113**	1.000	1.000	0.974	**0.974**
Southampton	1.000	1.000	0.976	**0.976**	1.000	1.000	1.088	**1.088**	1.000	1.000	0.932	**0.932**
London	1.000	1.000	0.988	**0.988**	1.000	1.000	1.144	**1.144**	1.000	1.000	1.140	**1.140**
Liverpool	0.839	1.063	1.049	**0.935**	0.883	0.930	1.139	**0.935**	1.116	1.017	0.949	**1.077**
Medway	1.000	1.000	0.990	**0.990**	1.000	0.683	0.952	**0.650**	1.000	1.455	0.929	**1.352**
Tees	0.850	1.152	1.042	**1.020**	1.346	0.714	1.054	**1.013**	0.943	1.129	0.916	**0.976**
Forth	0.884	1.044	1.044	**0.963**	0.921	0.990	1.133	**1.033**	1.100	1.022	0.946	**1.064**
Hull	1.000	1.246	0.933	**1.162**	1.000	1.154	0.896	**1.034**	1.000	0.954	1.076	**1.026**
Belfast	1.000	0.999	1.121	**1.120**	1.000	1.029	1.134	**1.167**	1.000	1.149	0.808	**0.928**
Grimsby & Immingham	0.840	1.015	1.050	**0.895**	0.938	0.913	1.115	**0.955**	1.175	1.061	0.879	**1.096**
Koper	1.000	1.334	1.102	**1.470**	1.000	1.043	1.160	**1.210**	1.000	1.080	0.908	**0.981**
Rijeka	1.000	1.093	0.988	**1.080**	1.000	0.995	1.027	**1.022**	1.000	0.979	0.958	**0.938**
Ploče	1.000	1.000	1.085	**1.085**	1.000	0.498	0.630	**0.314**	1.000	0.505	1.076	**0.543**
Thessaloniki	1.000	0.866	1.093	**0.947**	1.000	1.124	1.176	**1.321**	1.000	1.590	0.981	**1.560**
Constantza	1.000	1.000	1.221	**1.221**	1.000	1.000	1.173	**1.173**	1.000	1.000	0.901	**0.901**

Appendix 10 (Continued)

Port	2008-09				2009-10				2010-11			
	PEC	SEC	TC	MPI	PEC	SEC	TC	MPI	PEC	SEC	TC	MPI
Felixstowe	1.000	1.000	0.944	**0.944**	1.000	1.000	1.135	**1.135**	1.000	1.000	0.936	**0.936**
Southampton	1.000	1.000	0.885	**0.885**	1.000	1.000	1.119	**1.119**	1.000	1.000	1.479	**1.479**
London	1.000	1.000	0.697	**0.697**	1.000	1.000	1.146	**1.146**	1.000	1.000	1.010	**1.010**
Liverpool	1.209	0.963	0.922	**1.074**	0.996	0.819	1.141	**0.930**	0.959	1.055	0.938	**0.949**
Medway	1.000	0.669	0.841	**0.563**	1.000	0.979	1.161	**1.137**	0.975	0.847	1.208	**0.998**
Tees	1.585	0.861	0.850	**1.160**	1.065	1.173	1.149	**1.436**	0.898	1.012	1.085	**0.986**
Forth	1.632	0.831	0.932	**1.264**	0.738	0.952	1.078	**0.757**	0.943	1.059	1.006	**1.004**
Hull	1.000	0.801	0.940	**0.753**	1.000	0.773	1.051	**0.812**	1.000	0.918	1.084	**0.995**
Belfast	1.000	0.903	0.917	**0.829**	1.000	0.878	1.190	**1.045**	1.000	0.525	1.942	**1.020**
Grimsby & Immingham	1.601	0.625	0.875	**0.875**	0.514	1.394	1.122	**0.804**	1.109	0.916	1.063	**1.080**
Koper	1.000	0.906	0.864	**0.783**	1.000	1.218	1.095	**1.334**	1.000	1.221	0.952	**1.163**
Rijeka	1.000	1.005	0.891	**0.895**	1.000	0.803	1.095	**0.880**	1.000	0.893	0.980	**0.875**
Ploče	1.000	0.534	0.912	**0.487**	1.000	1.001	1.084	**1.085**	1.000	0.998	1.101	**1.099**
Thessaloniki	0.738	0.712	0.920	**0.484**	0.791	1.020	1.123	**0.905**	1.713	0.626	0.999	**1.071**
Constantza	0.907	0.788	0.779	**0.556**	1.102	1.169	1.095	**1.411**	1.000	0.929	0.940	**0.873**

Appendix 11: Malmquist Productivity Index: Economic Crisis TFP Change

Port	2007-11			
	PEC	SEC	TC	MPI
Felixstowe	1.000	1.000	0.944	**0.944**
Southampton	1.000	1.000	1.270	**1.270**
London	1.000	1.000	0.898	**0.898**
Liverpool	1.289	0.847	0.959	**1.046**
Medway	0.975	0.808	1.060	**0.834**
Tees	1.430	1.153	0.945	**1.559**
Forth	1.250	0.856	0.956	**1.023**
Hull	1.000	0.542	1.151	**0.624**
Belfast	1.000	0.478	1.754	**0.839**
Grimsby & Immingham	1.073	0.846	0.938	**0.852**
Koper	1.000	1.456	0.816	**1.188**
Rijeka	1.000	0.705	0.954	**0.673**
Ploče	1.000	0.269	1.172	**0.316**
Thessaloniki	1.000	0.724	0.960	**0.695**
Constantza	1.000	0.855	0.735	**0.628**