ERASMUS UNIVERSITY ROTTERDAM

The Impact of Economic Crisis on Ports in Post-crisis Period

A study on cargo throughput in Hamburg-Le Havre range

Master Thesis

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Wang, Xiaolin

Student number: 369776

Supervisor: Dr. van Reeven, Peran

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Abstract

Port plays an important role in economic development in a region. The cargo throughput as an indicator of port development has been widely researched for investment, policy making and strategic planning. In order to illustrate the port development in the post crisis time, the cargo throughputs of ports of Antwerp, Hamburg and Rotterdam are estimated and forecasted in this study. The cargo throughput series are estimated and forecasted through linear regression models, time series models and VEC models. Among all models applied in this study, VEC models show best forecast among the models for the lowest prediction errors. The forecasted cargo throughputs from VEC models are used to illustrate the impact of economic crisis. The cargo throughput gap between Rotterdam and Antwerp is not significantly changing in the crisis period and in the post-crisis period, suggesting the benefits Rotterdam gained during economic crisis is able to last for relatively long time. Meanwhile, the cargo throughput gap between Rotterdam and Hamburg is significantly decreasing, suggesting port of Hamburg is recovering from the crisis, and the benefits Rotterdam had from crisis is diminishing.

Moreover, the research results show that GDP is an important determinant of cargo throughput of a port. The GDP from neighboring counties may also have impact on the cargo throughput of a port. The study finds that the cargo throughputs are dependent to each other. The impacts of other ports are found significant in both short run and long run. The results reveal a short run independent relationship between Rotterdam and Antwerp. Yet in the long run, Antwerp benefits from the development of both Rotterdam and Hamburg. Short run complement competition, long run substitutive competition is found between Rotterdam and Hamburg.

Key words: cargo throughput, forecast, impact of economic crisis, port of Rotterdam, Hamburg-Le Havre range

Chapter 1: Introduction

Port plays a key role for regional economic development. On one hand, it provides socio-economic opportunities such as direct employments and business earnings. On the other hand, port is important in facilitating of trades. About 90% of world trade is carried by shipping (ICS Shipping Facts, 2014). Scheduled shipping service of containerized cargo between ports and countries is considered as the most economical way of transporting large volumes of goods all over the world (Haralambides, 2007). As various of parties (such as purchasing, manufacturing, transportation and logistics, etc.) are involved in the trading activities in port region, the port management and strategic planning are able to make huge impact on the local economic development. Therefore, container throughput as one key indicator of port performance is of great value for both local business and port management.

In this study, the port throughput will be analyzed in order to illustrate port development in the post-crisis period. More specifically, port throughputs in three ports - Rotterdam, Antwerp and Hamburg will be studied.

Starting from the third quarter of 2008, freight handling in EU ports in general fell (EuroStat Statistics in focus, 2010). Port authorities were challenged to hit their targets in throughput and revenues to make sustainable growth. Although most of the ports suffered a throughput decline during the crisis, yet, the losses were not same for all ports. Comparing with the large freight handling declines in Antwerp (-17%) and Hamburg (-21.3%) , the port of Rotterdam is relatively less injured (-8.1%) by the impact of crisis. Some shipping companies changed their shipping lines to port of Rotterdam instead of Antwerp or Hamburg in crisis. Port of Rotterdam made itself a market share increase during crisis.

As time passes, the impact of financial crisis has been fading. It is interesting and important to know the impact of crisis on the port throughput and whether the ports have already recovered from the recession. Meanwhile, whether Rotterdam will keep the benefits in the current economy that is recovering from crisis is also much motivated to investigate. The port throughput in a time series and its forecasting should give a clue of answering these questions.

Additionally, many studies related to port throughput forecast are basing on ports located in the southeast Asia. The application of these studies may limited due to the differences in location, port development and economic environment. Given the value and importance of port throughput prediction to port management and business planning, it should be interesting to illustrate the impact of crisis on the most important ports in Hamburg- Le Havre range from a cargo throughput view.

Therefore, the research question is:

Does the impact of crisis make permanent changes on port throughput?

The research objectives will be attained by answering the following sub-questions. The sub-research questions are:

(1) What is the cargo throughput trend in selected ports?

(2) What are the key determinants of cargo throughput?

(3) What are the port cargo throughputs in the future?

(4) Does the cargo throughput gap decreasing comparing with that during the economic crisis?

In order to answer the research questions, certain research methods will be applied to analyze the cargo throughput. A theoretical research and data review will be applied to illustrate the trends in cargo throughput in Hamburg- Le Havre range in recent decade. Following by an intensive literature study, the possible determinants of port throughput will be identified. The cargo throughput of ports will be estimated and forecasted by applying different models such as linear regression models, time series models and multi-variate models. The models will be compared basing on the goodness of fit, information criteria and prediction error criteria. The forecast from best model will be used to illustrate throughput gap between Rotterdam and other ports. The answer to the question that that whether the impact of crisis on port throughput keeps in current situation of economic recovery is expected to get by analyzing the development of cargo throughput gaps.

The structure of this study is designed as follow: Chapter 2 presents problem definition, container throughput trends in Hamburg- Le Havre range and current research approaches in container throughput prediction. Chapter 3 reviews the related literatures in port throughput forecasting and develops the hypotheses basing on the theoretical study. Chapter 4 presents the research design, including the sample, models and measurements. Chapter 5 presents the results of empirical study. Chapters 6 discusses the results and conclude the study as well as a discussion for future research direction.

Chapter 2: Theoretic Framework

This chapter offers a review of theoretic framework that gives the detail definition and explanation to research question. The cargo throughput definition and value of port throughput forecast will be presented in Section 2.1. The trends of port throughput development in selected ports and Hamburg – Le Havre range will be reviewed in Section 2.2. At the end of this chapter, current research approaches on port throughput forecasting will be reviewed in Section 2.3.

2.1 Port Throughput and its forecast

In this section, the definition of cargo throughput for this study and the value of cargo throughput forecasting will be explained.

Port is an area of land and water, loading and unloading ships, providing storages for goods and has transport connections to hinterlands. The ports are important for logistic for its function in the flow of goods as well as the information and services in the supply chain management (Carbone and De Martino, 2003). In this study, the cargo transfers are considered from the port view. The cargo throughput of a port measures the flow of goods (including dry bulk, liquid bulk, containers and multipurpose cargo) from land to sea transport modes, and vice versa. The cargo throughput therefore includes short sea shipping and international journeys, both empty and loaded at a port in one year, measured in tons (EuroStat).

According to EuroStat definition, the cargo throughput consists:

Container throughput, measuring total number of containers loaded and unloaded in a port in a period of one year, expressed in twenty equivalent units (TEUs)

Dry bulk throughput, measuring total tonnage of dry bulk cargo loaded and unloaded in a port in one year,

Liquid bulk throughput, measuring total tonnage of liquid bulk cargo loaded and unloaded in a port in one year

Multipurpose throughput, measuring total tonnage of multipurpose cargo loaded and unloaded in a port in one year.

The port throughput is an important indicator of economic development in a region. The port throughput is closely related to the economic growth and provides information corresponding to other parts of the economy around the port, including infrastructure, transportation, international trade and logistics, etc. It has been long discussion that the relationship between cargo throughput and GDP among the scholars. GDP is traditionally considered as a pillar in port traffic forecast (Notteboom, 2013). Janssen, Meersman and van der Voorde (2003) states that the container throughput is largely boosted by international trade. Meanwhile, port throughput is able to provide information to various function areas in port development plan (De Langen, van Meijeren and Tavasszy, 2012). The port throughput and predicted throughput is largely used in infrastructure plans, financial investments and develop port strategies (Peng and Chu, 2009).

For the reasons stated above, forecasting cargo throughput is of great significant for port management and business plans in a region. In this study, the forecast of cargo throughput is specified in a short term. The cargo throughput development will be forecasted in order to illustrate the impact of economic crisis in a short future.

2.2 Cargo throughput trends in Hamburg- Le Havre range

In this section, the port development, specifically the cargo throughput trend will be reviewed. Rotterdam, Antwerp and Hamburg are selected as the represented ports in in Hamburg- Le Havre range. The development of cargo throughput in these ports, especially the port throughput during financial crisis are reviewed and compared. The sub-question with respected to the trends in container throughput will be answered with combination of previous studies and statistic figures.

2.2.1 The Hamburg- Le Havre range

Hamburg- Le Havre range is one of the busiest and most competitive container range in the world (Notteboom, 2007). Consisting of nine ports in Germany, the Netherlands, Belgium and France, the Hamburg- Le Havre range serves an expanding hinterland in North-West Europe with more than 350 million consumers (De Langen et al., 2012; HKTDC, 2014). Rotterdam, Antwerp and Hamburg are located within the Hamburg -Le Havre range, are the largest three container load centers within the range. Except the large gateway ports such as Rotterdam, Antwerp, Hamburg, Bremerhaven, and Le Havre, there are medium to small size ports are various in characteristics in terms of hinterland markets, commodities handled and location qualities (Notteboom, 2007).

Figure 1: Hamburg - Le Havre range

As shown in Table 1 and Table 2, Rotterdam, Hamburg and Antwerp are the leading ports not only in Hamburg- Le Havre range, but also the tops container load centers in Europe. In 2013, Port of Rotterdam took over one quarter of the container volume in Hamburg- Le Havre range. Rotterdam, Antwerp and Hamburg together took 78.2 percentage of total container throughput in Hamburg- Le Havre range in gross weight and over one third of total EU container throughput in TEUs.

Table 1: Total Throughput by commodity in the Hamburg- Le Havre range, 2013

Total throughput by commodity in the Hamburg - Le Havre range, 2013

2013	HAMBURG	BREMERHAVEN	WILHELMSHAVEN	AMSTERDAM	ROTTERDAM	ZEELAND SEAP.*)	ANTWERP	GHENT	ZEEBRUGGE	DUNKIRK	LE HAVRE
Iron ore and scrap	9.5	4.6	0.0	8.9	35.9	0.3	2.9	3.7	0.0	12.0	0.0
Coal	5.7	1.3	3.3	21.6	30.7	3.9	2.2	2.7	0.0	5.4	1.4
Agribulk	8.0	0.7	0.0	8.4	10.3	0.9	0.8	1.2	0.1	1.6	0.0
Other dry bulk	4.6	1.7	1.1	7.3	12.3	5.6	8.5	8.7	1.2	2.7	1.5
Subtotal dry bulk	**27.8**	**8.3**	**4.4**	**46.2**	**89.2**	**10.7**	**14.4**	**16.4**	**1.3**	**21.6**	**2.9**
Crude oil	2.5	0.0	18.2	0.0	91.1	0,0	4.7	0.0	0.0	0.0	23.7
Mineral oil products	9.5	1.6	0.0	38.7	81.6	9.6	43.1	1.2	3.2	5.2	12.3
LNG	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	3.3	0.0	0.0
Other liquid bulk	2.6	0.0	0.4	2.4	33.4	3.3	11.7	2.7	0.3	0.9	1.9
Subtotal liquid bulk	**14.5**	**1.6**	**19.5**	**41.1**	**206.8**	**12.9**	**59.5**	**3.9**	**6.9**	**6.1**	**37.9**
Total bulk	**42.3**	**9.9**	**23.9**	**87.3**	**296.0**	**23.5**	**73.9**	**20.2**	**8.2**	**27.7**	**40.9**
Containers	**94.8**	**61.0**	**0.6**	**0.8**	**121.3**	**0.2**	**102.3**	**0.6**	**20.4**	**2.7**	**24.8**
Roll on/Roll off	0.0	0.0	0.0	0.5	18.5	1.4	4.6	2.0	12.5	12.3	0.0
Other general cargo	1.9	7.9	0.0	7.3	4.7	7.9	10.1	3.2	1.7	0.9	1.5
Total breakbulk	**1.9**	**7.9**	**0.0**	**7.7**	**23.2**	**9.3**	**14.7**	**5.1**	**14.2**	**13.2**	**1.5**
Total throughput	**139.1**	**78.8**	**24.5**	**95.7**	**440.5**	**33.0**	**190.8**	**26.0**	**42.8**	**43.6**	**67.2**
Market share in %	***11.8***	***6.7***	***2.1***	***8.1***	***37.3***	***2.8***	***16.1***	***2.2***	***3.6***	***3.7***	***5.7***

Unit: Gross weight x 1 million metric tons
Hamburg, Bremerhaven and Le Havre: other general cargo including Roll-on/Roll-off; Zeebrugge: including bunker materials;
Le Havre: other dry bulk including iron ore and scrap; *) Zeeland Seaports: agribulk and other dry bulk breakdown of goods estimated.

Source: Port of Rotterdam Statistics (2014)

Table 2: Top 20 European container ports, 2013-2011

Top 20 European container ports, 2013 - 2011

		2013	2012	2011
Rotterdam	**Netherlands**	**11,621**	**11,866**	**11,877**
Hamburg	Germany	9,257	8,864	9,014
Antwerp	Belgium	8,578	8,635	8,664
Bremerhaven	Germany	5,831	6,115	5,916
Algeciras	Spain	4,343	4,112	3,063
Valencia	Spain	4,328	4,470	4,327
Felixstowe [1])	United Kingdom	3,500	3,327	3,249
Piraeus	Greece	3,163	2,734	1,679
Gioia Tauro	Italy	3,100	2,721	2,305
Ambarli/Istanbul *)	Turkey	2,750	2,600	2,686
St. Petersburg	Russia	2,578	2,520	2,197
Marsaxlokk *)	Malta	2,550	2,400	2,360
Le Havre	France	2,486	2,303	2,215
Zeebrugge	Belgium	2,027	1,953	2,206
Genoa	Italy	1,988	2,065	1,847
Southampton [1])	United Kingdom	1,800	1,651	1,500
Barcelona	Spain	1,720	1,759	2,035
La Spezia	Italy	1,300	1,247	1,307
Gdansk	Poland	1,178	929	686
Las Palmas	Spain	1,017	1,208	1,297

Unit: Number x 1,000 TEU (Twenty-Feet Equivalent Units)
[1]) 2013 Estimated based on Units, including Ro-Ro (Department of Transport);
*) 2013 Provisional figures

Source: Port Authorities

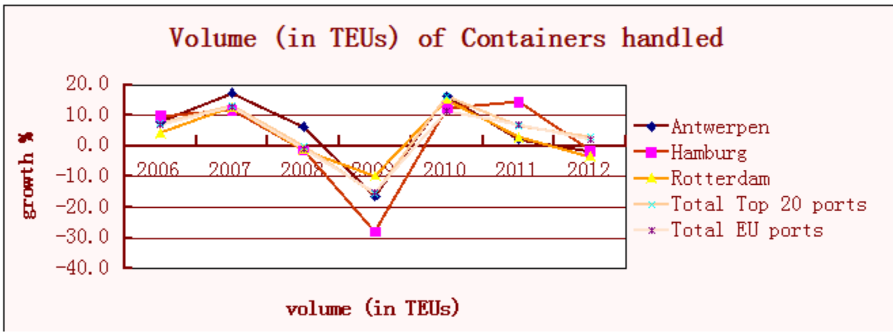
There is a long history of competition and cooperation among these three ports (Merk and Notteboom, 2013). As the logistic integration, emergence of global terminal operators and institutional environment differences, the competition and development among the largest ports are increasing complex (Notteboom, 2007).

2.2.2 The impact of financial crisis starting from 2008

The whole Europe experienced a strong growth in maritime transportation driven by the booming of container throughput in the pre-crisis period between 2000 and 2008. The average annual growth of European ports is 10.4 percent in 2005-2008 and 7.7 percent in the period 2000-2005 (Nottboom, 2013). The growth ended when the financial crisis started taking its full effect in late 2008. As the negative impact of economic crisis and the shirking of international trading, the maritime transportation consequently suffer a decline since the third quarter of 2008 (EuroStat, 2010).

As shown in Figure 2, the container handling in either selected ports or whole Europe maintained a negative growth in 2009. Total cargo volumes handled by European ports experienced a sharp decline of 12.2% in 2009, from 4.18 billion tons in 2008 to 3.67 billion tons in 2009 (Notteboom, 2013). The throughput in most ports decreased as the impact of world trading decline. Port authorities have been all challenged to maintain sustainable growth and hit their targets in term of both throughput and revenues.

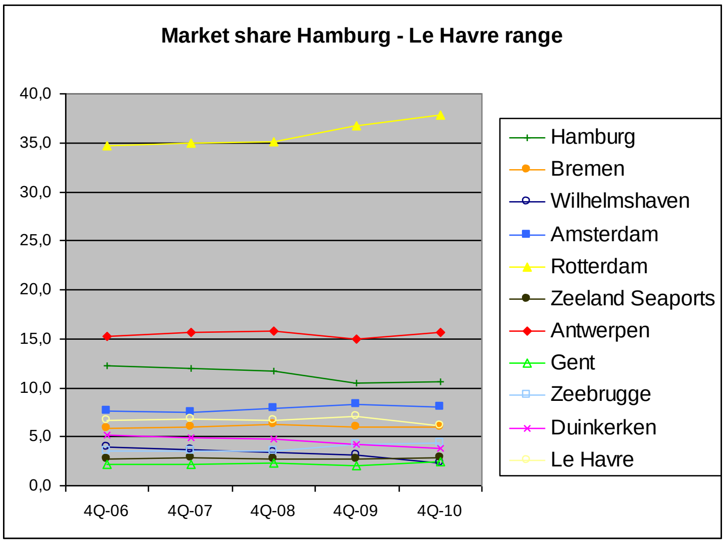
Figure 2: volume of containers handled (2006-2012)



Source: EuroStat

However, not all ports have been hit equally hard (Pallis and De Langen, 2010). The port of Rotterdam has performed better compared to most other ports, owing to its quick and proactive response to the crisis (OECD, 2010). The EuroStat data shows that Rotterdam suffered a freight decline of 8.1% during 2008 and 2009. Meanwhile the freight handling was suffering a decreased up to 17% in Antwerp and even worse condition (21% decline) in Hamburg. During the crisis, shipping lines combined services and deployed the biggest possible vessels to reduce costs. The location, depth, hinterland transport and port tariffs in Rotterdam tailored well to the changes in shipping lines and gain the benefits from this trend (OECD, 2010). Some shipping companies changed their route to Rotterdam for higher port efficiency under relatively lower costs. In addition, port of Rotterdam has diversified goods handling, which spread the risk in specific markets during crisis period (OECD, 2010). As shown in figure 3, port of Rotterdam managed its market share increase during this period while Antwerp and Hamburg were suffering the market shares loss.

Figure 3: Market share Hamburg- Le Havre range



In the post crisis period, the economic is gradually recovering. However, from the port throughput view, Europe has not yet reach the pre-crisis level (Notteboom, 2013). The throughput of Europe bounced back in 2010 to 3.83 billion tons, up 4.5% compared with 2009. But the figures from EuroStat suggests the growth slows in later years and the throughput failed to recovery back to pre-crisis level. Meanwhile, the Rotterdam, Antwerp and Hamburg showed different speeds of recovering. The port of Rotterdam firstly reached its pre-crisis level at fourth quarter of 2009. Then Antwerp was back pre-crisis level in early 2010. Hamburg recovered its previous level at last in late 2010. So far, it seems that Rotterdam has benefit from the economic crisis to keep its leadership in Europe and reach higher market share. The future trend of cargo throughput in Hamburg- Le Havre range will be discussed in later chapters.

2.3 Current situation of throughput forecasting

In this section, the common research methods for container throughput forecasting will be reviewed. The most commonly used research approach for forecasting container throughput are: linear regression, time series, multi-variate models, Grey theory and Genetic Programming.

2.3.1 Linear regression

Linear regression is a common statistical technique used in cargo throughput researches. It study the linear relation between response variable and predictor variables. The linear regression has been used for many years since it gives the elemental idea of models and illustrates the relations between variables in a transparent way that can be easily visualized on graphs (Verbeek, 2012). Furthermore, linear regression provides good and useful answers to many problems (Weisberg 2005).

The linear regression is used in port throughput studies for identify determinants of throughput and forecasting. Tongzon (1995) and Tongzon and Wu (2005) used linear regression to illustrate the causal relationship between the determinants and port performance. Chou et al. (2008) and Seabrooke et al. (2003) used the linear regression method for throughput forecasting of ports in Hong Kong and Taiwan.

2.3.2 Time Series

Time series analysis are the most used methods in estimating time series and forecasting. A time series is a sequence of data points, measured typically at successive points in time spaced at uniform time intervals. The time series predictions are usually used in forecasting the continuous pattern over time like growth in sale, stock market analysis or gross national product (Gosasang et al. 2010). The time series analysis emphasis the information in the historical values and used for forecasting the future behavior, distributions of future values, conditional on the past (Verbeek, 2012).

ARIMA and SARIMA are the most commonly used time series models for cargo throughput forecasting. It is used in Peng and Chu (2009), six univariate models including SARIMA are compared for forecasting the container throughput in three major ports in Taiwan. SARIMA is recognized as the most accurate method among six univariate models (Peng and Chu, 2009). In Rashed et al. (2013) SARIMA model is again used for forecast short term container throughput in Antwerp.

The ARMA model combines autoregressive and random effects as shown below:

$$Y_t = \phi_0 + \phi_1 Y_{t-1} + \ldots + \phi_p Y_{t-p} + a_t + \theta_1 a_{t-1} + \ldots + \theta_q a_{t-q}$$

As most of the economic series are non-stationary, the integration (differences) has to be applied till stationary, denoted as ARIMA (p, d, q) , stated as:

$$\Delta^d Y_t = \phi_0 + \Delta^d \phi_1 Y_{t-1} + \ldots + \Delta^d \phi_p Y_{t-p} + a_t + \theta_1 a_{t-1} + \ldots + \theta_q a_{t-q}$$

SARIMA (Seasonal Autoregressive Integrated moving average) is an extension of ARMA (Autoregressive moving average) for includes non-stationary in mean and seasonal component in the time series data. It can be formulated as

$$\Phi(B)\Delta^d X_t = \theta(B)\alpha_t$$

Where αt is such that

$${}_s\Phi(B^s)\Delta_s^D \alpha_t = {}_s\Theta(B^s)a_t$$

Hence

$$\Phi(B)_s\Phi(B^s)\Delta_s^D \Delta^d X_t = \theta(B)_s\Theta(B^s)\alpha_t$$

And Xt can be rewritten as

$$X_t \sim ARIMA(p,d,q) \times (P,D,Q)_s.$$

The idea is that the SARIMA is the ARIMA (p,d,q) models with the residuals t that are following ARIMA (P, D, Q). The operators in ARIMA are defined on Bs and successive powers (Verbeek, 2012).

2.3.3 Multi-variate models

As the increasing competition and cooperation among the ports, the performance of a port is usually affected by the other ports (Hui, et al., 2004; Yap and Lam, 2006). Therefore, the study of multiple ports in a range should incorporate the independency among the different ports. Vector autoregression (VAR) and Vector Error Correction (VEC) models are often used to forecast throughput for allowing more flexibility, eliminating the co-integration among time series data. Fung (2002) used VEC model to illustrate the container throughput in Hong Kong and Pearl River Delta region. VEC models and VAR models are used in Yap and Lam (2006) for illustrate the competition within a multiple ports region located in east Asia.

Vector Autoregression (VAR) model is an econometric model used to capture the linear interdependencies among multiple time series (Verbeek, 2005). The VAR is commonly used for forecasting systems of interrelated time series. The VAR model takes lagged values on each endogenous variable and includes all variables in a symmetric model. The VAR can be formulated as:

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + Bx_t + \epsilon_t$$

where y_t is a k vector of endogenous variables, x_t is a d vector of exogenous variables, A_1,..., A_p B are matrices of coefficients to be estimated, and ε_t is a vector of innovations that may be contemporaneously correlated with each other but are uncorrelated with their own lagged values and uncorrelated with all of the right-hand side variables.

Vector Error Correlation (VEC) model is another model that is often used in forecasting interdependencies among multiple time series. The VEC model is a restricted VAR model that including co-integrations and used for non-stationary series with co-integrations. An error correction representation may exist if a set of variables are co-integrated (Verbeerk, 2012). The VEC model restricts the long run behavior of endogenous variable by including the co-integrating equations. The short run dynamics are allowed without restrictions. The vector error correction model is a restricted VAR (VECM) design that can be represented as

$$\Delta y_t = \delta + \Pi y_{t-1} + \sum_{i=1}^{p-1} \phi_i \Delta y_{t-i} + Bx_t + \varepsilon_t$$

Where Δ is the differencing operator, y_t is a k vector of non-stationary variables.

2.3.4 Grey Theory

Grey Theory is a multidisciplinary theory which can be used under the situations that are lack of data and highly uncertain. It used the “white” system to illustrate the parts with all information known and “Black” as the parts without any information known. Therefore, the Grey is a partially known system. (Liu, 2007). The forecasting model based on Grey Theory is able to fit into the small samples with very little initial information (as little as 4 samples). Different types of Grey models exist and expressed as GM (m, n). Parameter ‘m’ stands for number of variables which are used for forecasting, whereas ‘n’ stands for order of differential equation (Shu. Huang and Nguyen, 2014).

Grey Model is often used in the field of port forecasting such as Peng and Chu (2009) in forecasting cargo throughput in Taiwan. GM (1, 1) is used model for the previous studies, focusing on one variable and first order differential equation.

2.3.5 Genetic Programming

Genetic Programming is a computational optimization tool to derive best feasible model from time series data. The main operators in GP are reproduction, crossover, and mutation. Random elements of terminal and functions create the population like a tree structure, but the shape, size and the structure creates randomly. This means the GP model allows for more flexibility and scenarios in forecasting the developments in the future. The symbolic regressions are used in GP to search for the best fit combination in order to minimize the error (Chen and Chen, 2010).

Genetic Programming (GP) is used in Chen and Chen (2010) to forecast the container throughput in Taiwan. In Chen and Chen (2010), GP, SARIMA and decomposition approach (x-11) are compared. The results show that GP method gives 32-36% better prediction than decomposition approach (x-11) and SARIMA in Taiwan ports (Chen and Chen, 2010)

2.4 Summary

In this chapter, the theoretic framework is presented. The port throughput is defined as the cargo throughput which is the sum of all commodities, including dry bulks, liquid bulks, containers and multipurpose throughput. The cargo throughput is important for business and port since it is not only related to the port development and infrastructure constructions but also have large impact on the business activities around the port region.

The Hamburg- Le Havre range is selected to apply the research and investigate the impact of economic crisis. As shown in previous studies and graphs, the cargo throughput increases rapidly before the economic crisis attacked Europe in 2008. The ports were hurt yet not equally damaged from the impact of crisis. Comparing with Antwerp and Hamburg, Rotterdam experienced less decline in port throughput and gain more market share during the crisis. Whether Rotterdam is able to keep the benefits from crisis is one of the main questions that will be discussed in this study.

In order to illustrate the future development of port throughput, the cargo throughput of a port has to be predicted. The commonly used methods are linear regression, time series analysis, multi-variate models, Grey theory and genetic programming.

Chapter 3: Literature Review

In this section, the variables and methods in previous studies related to cargo throughput forecasting will be reviewed. The previous studies on cargo throughput forecasting are mainly focus on two approaches, one is forecasting cargo throughput basing on a model that illustrate the relationship between cargo throughput and external variables; the other approach is applying the time series analysis on the historical throughput data and make forecast to the future. Section 3.1 reviews the findings with respect to the variables affecting the cargo throughput performance. Section 3.2 presents the time series related models and methods used in previous studies. Basing on the finding in Section 3.1 and Section 3.2, the hypotheses of this study are developed and presented in Section 3.3.

3.1 Determinants of cargo throughput

GDP is the most commonly recognized determinant and widely used in the researches in port economics. There has been a long history discussing the relationship between GDP and port cargo throughput (Notteboom, 2013). Normally, the growth in port cargo throughput is high during the economy booms while the cargo throughput declines significantly during the economic crisis. Tongzon (1995) applied a regression model on the a sample of 23 international ports, the results indicated that GDP is a significant determinant for port throughput. Seabrooke et al. (2003) used GDP of Hong Kong and GDP of neighboring proveniences as independent variables in the regression analysis to illustrate the maritime traffic developments in Hong Kong and found significant relationship between GDP and traffic volume of a port. In Chou, Chu and Liang (2008), a set of variables related to GDP of Taiwan are examined with a sample of Taiwan ports. Among the GDP indicators including GDP, Agricultural GDP, Industrial GDP and service GDP, industrial GDP is used in the regression and port throughput forecasting, since it has highest correlation with other variables and perform best in the regressions. Van Dorsser et al. (2012) analyzed the relationship between GDP and cargo throughput in Hamburg Le-Havre range, finding GDP is related to port throughput significantly. However, as indicated in Notteboom (2013), the ratio between port throughput growth and GDP growth in Europe is not stable but increasing in recent years, due to the low growth in European economy.

International trading is another determinant that is recognized in previous studies. As the international shipments have taken the major part in commodities handling in the gateway ports, it is usually observed that the cargo throughput of a port is influenced by the volume of international trade. Seabrooke et al. (2003) illustrate the cargo growth with imports and exports values, and found the significant relationship between cargo throughput and the value of imports and exports.

Chou, et al. (2008) used the volumes of export and import containers to illustrate the facts related to international trading volume. However, the international trade indicators are not used in the final regression in Chou, et al. (2008) since the volume of export containers and the volume of import containers are so closely related to the GDP indicators, resulting correlation that is too high to apply both GDP and international trading in the same regression. De Lange et al. (2012) developed four scenarios for the international trading in the long term future, and forecast the long term cargo throughput development in Hamburg- Le Havre range basing on the scenarios. Frequency of ship calls is identified as a significant determinant in Tongzon (1995) can be seen as an indirect indicator of international trading. When the international trading increases, the frequency of ship calls increase consequently, and stimulate the port throughput growth.

The other variables such as population (Seabrooke et al., 2003; Chou et al., 2008), wholesale price (Chou et al., 2008), industrial production index (Chou et al., 2008) and GNP (Chou, et al., 2008), expenditure on building and construction (Seabrooke, et al., 2003), and electricity demand (Seabrooke et al., 2003), port efficiency (Tongzon, 1995) are identified in the previous studies. However, the variables identified in Chou et al., (2008) were proven to be highly correlated with other variables hence replaced by industrial GDP. The expenditure on building and construction and eccentricity demand were not significant in the regression models that were performed in Seabrooke et al. (2003). The port efficiency plays a key role in the port choice and port competition (Wiegmans, van der Hoest and Notteboom, 2008; Notteboom, 2010 and is proven to be a significant determinant for port throughput in Tongzon (1995). However, considering the port throughput development along the time, the changes in port efficiency between periods are very small. Therefore, port efficiency can be seen as constant in the models related to time series and short term forecast.

3.2 Forecast methods and models

As mentioned in Section 3.1, the regressions are used in previous studies to illustrate the causal relationship between the determinants and cargo throughput of a port. The linear regression (Seabrooke, et al., 2003; van Dorsser, et al. 2012), linear regression with modified factors (Chou et al., 2008) and two-stage linear regression (Tongzon, 1995) are used for the cargo throughput analysis and forecasts.

Time series related analysis is another pillar in the studies related to forecast. ARIMA and SARIMA models are the most commonly used time series model in previous researches (Peng and Chu, 2009; Chen and Chen, 2010; Rashed et al., 2013). Peng and Chu (2009) compared six univariate models and concluded the SARIMA model performed quite well in port throughput forecasting. The results from other researches additionally show the high validity of SARIMA model in port throughput forecasting.

VAR models and VEC models are the multi-variate models that were used in Fung (2002) and Yap and Lam (2006) to illustrate the competition between ports within the same multi-ports range. The forecast of VAR and VEC models incorporate the influence from the cargo throughput of other ports. The results in these research indicated that the cargo throughputs of other ports do have impact on the port. VEC model is able to capture this interdependence between ports and improve the existing port throughput forecasts.

Grey models is used in Peng and Chu (2009). It have the advantage of processing sample that is relatively small and with limited information. Yet the forecast outcomes from the Grey models presented in Peng and Chu (2009) is not as good as the other models with seasonal adjustments.

Genetic programming is only used in Chen and Chen (2010). The Genetic Programming methods involve a complex process of determining parameters and simulation, which is aiming at incorporate the information of developing paths in the future. The mean absolute percentage error calculated in Chen and Chen (2010) suggests that GP prediction is 32-36% better than those in decomposition model and SARIMA.

In terms of long term projection, the scenario discussions were introduced in Van Dorsser et al. (2012) and De Lange et al. (2012). The scenarios were developed basing on the causal relationship between cargo throughput and economic indicators (GDP, international trade), and the paths of port throughput development are predicted in each scenario.

3.3 Hypotheses

Basing on the findings from reviewing and comparing previous studies, the hypotheses are developed. The focus of hypotheses is on testing the effect of port throughput determinants and find out the differences in predicted cargo throughputs among selected ports. Specifically, the following questions are going to be tested (1) what factors influence the cargo throughput? And (2) will Rotterdam keeps its benefits from economic crisis into short term future?

Therefore, the hypotheses are stated as following:

H1: There is a positive association between GDP and cargo throughput of a port

H2: The cargo throughputs of ports within the same multi-ports range are dependent to each other.

In order to illustrate the interactions among the cargo throughput of ports, the Hypothesis 2 will be tested in two sub- hypotheses that revealing the long run relationship and short run relationship

H2a: The cargo throughput of one port is affected by the cargo throughputs of other ports in the long run.

H2b: The cargo throughput of one port is affected by the cargo throughput of other ports in the short run.

H3: The cargo throughput gaps among selected ports will be smaller in the post crisis period than that in crisis period.

In case of the cargo throughput gap narrows in post crisis period, the Hypothesis 3 derived into following sub- hypotheses:

H3a: The cargo throughput gap between Rotterdam and Antwerp is smaller in post crisis period than that in crisis period

H3b: The cargo throughput gap between Rotterdam and Hamburg is smaller in post crisis period than that in crisis period.

3.4 Summary

In this chapter, previous studies related to cargo throughput forecasting were reviewed. GDP and international trade are the two determinants that most frequently identified in previous studies to illustrate the causal relationship between economic activities and port throughput development. Among the forecasting models, ARIMA and SARIMA are the most popular models besides linear regression since it incorporate the changes along the time and adjusted for seasonality. The multi-variate models such as VAR and VEC models are used in some previous studies that illustrate the cargo throughput under the increasing competition between ports within same multi-ports range. The grey models and genetic programming is less used and more complicated than the other models.

Basing on the findings from previous studies, the hypotheses are developed. The hypotheses are aiming to address the questions that (1) what factors influence the cargo throughput? And (2) will Rotterdam keeps its benefits from economic crisis into short term future?

Chapter 4: Research Design

To test hypotheses which are drawn in Chapter 3, it is important to design the research in a proper way. The measurement of variables, research method and sample selection are closely related to the results of this study as well as the validity of findings. In this chapter, Section 4.1 presents the data and sample selection. Section 4.2 shows the descriptive statistics. Section 4.3 performs the research methodology. Section 4.4 presents the measurements of variables. Section 4.5 indicates the statistic methods of this study.

4.1 Sample and Data

In this study, in order to research the cooperation and competition within a multi-port region and illustrate the impact of economic crisis, the Hamburg- Le Havre range is selected at the start of the study. Hamburg- Le Havre range on one hand is one of the busiest multi-port regions in the world with large container load centers competing and cooperating for long time. On the other hand, the ports within the range are affected yet with uneven damage during the economic crisis from 2008. Within the Hamburg- Le Havre range, port of Rotterdam, port of Antwerp and port of Hamburg are selected as represented ports to continue the study. Rotterdam, Antwerp, and Hamburg are the largest gateway ports in the Hamburg- Le Havre range, geographically located close to each other, sharing the hinterlands, and all have large capacity and high service quality comparing with other ports in the range. Nevertheless, the ports have been competing and cooperating for long time and shown different impacts from the economic crisis. It would be helpful to minimize the external impacts, reduce the control variables, and focus on the main questions.

The historical cargo throughputs of port of Rotterdam, port of Antwerp and port of Hamburg are collected from EuroStat database, under the item “Maritime transport- Goods (gross weight)- Quarterly data-Main ports- by direction and type of traffic”. The data starts from the first quarter of 1997 and ends at the fourth quarter of 2013, measured in thousands of tons.

As stated in Section 3.1, the most efficient and widely used determinants on port throughput forecast are GDP and international trading. The other variables are proven not significant or irrelevant to the study in the previous chapter. Since GDP and international trades are highly correlated, GDP is chosen to use in this study as the indicator of economic activity. On one hand, GDP is the most commonly used economic indicator in previous studies. On the other hand, since the short future economic outlook data have to be included in the forecast models as input, GDP is more preferred for availability and reliable data sources. Comparing with the other economic indicators such as import volume and export volume, the economic outlook on GDP is researched for longer time. Meanwhile the GDP projection data with high accuracy is more easily to access from a reliable data source.

The quarterly GDP figures are collected from OECD StatExtracts database, from the first quarter of 1997 to the first quarter 2014. The predicting GDP growth figures from third quarter 2014 to the fourth quarter 2015 are collected from European Economic Forecast, Winter 2014. The quarterly GDP figures from 2014Q1 to 2015Q4 are calculated by applying the growth rate to GDP of previous quarter.

4.2 Descriptive statistics

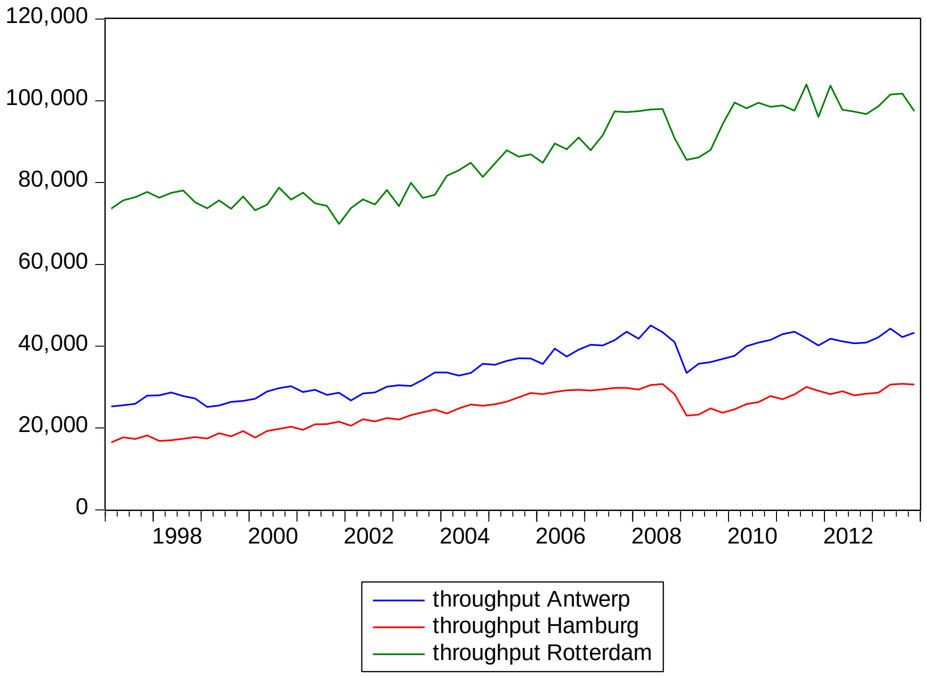
As shown in Table 3, the descriptive statistics of cargo throughputs of Antwerp, Hamburg and Rotterdam are presented. There are 68 observations in each series. From the first quarter of 1997 to the fourth quarter of 2013, the average weight of goods handled is 34.82 million tons per year in port of Antwerp, 24.41 million tons per year in port of Hamburg and 86.01 million tons per year in port of Rotterdam. Port of Rotterdam is the dominant market leader, which on average handled more goods than the sum of goods handled in port of Antwerp and port of Hamburg during the research period. Port of Hamburg has lowest standard deviation among the three ports, suggesting it may have smaller volatility on the cargo throughput. The skewness results are around zero, indicating the cargo throughputs are distributed in a symmetric way. The kurosis figures are around 1.5, indicating platykurtic distributions, which is flat in distribution comparing with normal distribution. Jarque-Bera statistics are significant at 5% level (throughput of Hamburg is slightly higher than 5%), suggesting the sample observations follow normal distribution.

Table 3: Descriptive Statistics of Cargo throughput

	ROTTERDAM	HAMBURG	ANTWERPEN
Mean	86009.44	24414.79	34816.12
Median	85196.00	24782.50	35663.50
Maximum	103993.0	30772.00	45032.00
Minimum	69848.00	16446.00	25132.00
Std. Dev.	10133.55	4563.048	6247.759
Skewness	0.206090	-0.262762	-0.038970
Kurtosis	1.553873	1.687285	1.532339
Jarque-Bera	6.406664	5.664952	6.120291
Probability	0.040627	0.058867	0.046881
Sum	5848642.	1660206.	2367496.
Sum Sq. Dev.	6.88E+09	1.40E+09	2.62E+09
Observations	68	68	68

Figure 4 shows the cargo throughput development in time. All three ports show an overall increasing trend before the economic crisis attacked in 2008. The increasing is rapid and stable especially between the first quarter of 2002 to the second quarter of 2008, due to the rapid growth in container handling (Notteboom, 2013). The economic crisis leads a jump down in cargo throughput at all ports during 2008 and 2009. The port cargo throughputs start recovering from 2010 and the growth slows in recent years.

Figure 4: Port cargo throughput in time



4.3 Models

In this section, the methods will be described. The linear regression will be used in order to view the causal relation between economic development and port throughput. In addition, the linear regression will also be used for forecasting the cargo throughput for it gives the simplest and efficient way of predicting which is used in many previous studies (Seabrooke, et al., 2003; Chou et al., 2008; Peg and Chu, 2009). Time series models are able to capture the stochastic process and seasonal effect in time, which are preferred in previous studies (Peng and Chu, 2009; Chen and Chen, 2010; Rashed et al., 2013). Time series models will also be used in this study for forecasting the cargo throughput. Furthermore, in order to detect the interaction between the ports within the same multi-ports range and incorporate the possible co-integrations, the error correction models will be applied. Previous studies (Fung, 2002; Hui, et al., 2004; Yap and Lam, 2006) suggest that the error correction models have advantages on estimating the impacts from other ports in the same region and give more accurate results than traditional methods. Grey model is also used in previous studies (Peng and Chu, 2009), yet it does not show much advantage in forecasting comparing with other models. Therefore, Grey model will not be used in the following part of this study. Genetic Programming will not be used in this research, for its less commonly used and too complicated in data collecting and processing.

For the reasons stated above, linear regression, time series models and error correction models will be performed and compared in this study with cargo throughput of selected ports.

The forecast models such as linear regression models, time series models and VEC models will be applied and fitted into the cargo throughput data. The cargo throughput data includes three series presenting the cargo throughput of Antwerp, Hamburg and Rotterdam. The quarterly cargo throughput data from 1997Q1 to 2013Q4 will be processed with GDP of port located country to estimate the models mentioned above. After estimation the model and check the residual and inverse causality, the forecast the cargo throughput will be made. The cargo throughput from 1997Q1 to 2015Q4 will be forecasted basing on the models for the port of Antwerp, Hamburg and Rotterdam. The forecast includes an in sample forecast from 1997Q1 to 2013Q4 and an out sample forecast from 2014Q1 to 2015Q4.

4.3.1 Linear regression

The linear regression model will be used to identify the causal relationship between cargo throughput and economic indicators, GDP. The regression is formulated as follows:

$$Y_i = \alpha_i + \beta_i GDP_i + \varepsilon_i$$

Y_i stands for the cargo throughput of a port, GDP_i stands for the GDP of the country that the port located in, and the ε is the error term.

4.3.2 Time series model

The time series models ARIMA and SARIMA as stated in Section 2.3.2, will be performed in this study. In this section, the forecasting will be accomplished in two phases: identification phase and estimation phase. In identification phase, the Augmented Dickey-Fuller unit root test (ADF) will be performed to determine the integration level d. Then Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) will be applied for choosing lag structure (p and q). In the estimation phase, after testing the goodness of fitness and residuals, the forecast will be made. Mean absolute error (MAE), mean absolute percentage error (MAPE) and root mean square error (RMSE) will be recorded for model comparison.

4.3.3 VAR and Error Correction models

As shown in Table 4, the correlations on cargo throughput between ports are quite high. Therefore, it is reasonable to assume that the cargo throughputs of ports are interdependent. Performance of a port may be affected by the performance of the other ports. The error correction models are applied to incorporate the dependence between ports. The model can be stated as follows:

$$\Delta Y_t = \delta + \Pi Y_{t-1} + \sum_{i=1}^{p-1} \phi_i \Delta Y_{t-i} + BGDP_t + \varepsilon_t$$

ΔY_t presents the cargo through at time t from port of Rotterdam, port of Antwerp and port of Hamburg. ΠY_{t-1} indicates the co-integration terms, $\sum_{i=1}^{p-1} \phi_i \Delta Y_{t-i}$ presents the sum of lag variables, GDP_t is a vector of GDP in all selected countries, δ is the constant.

Table 4: Correlation matrix of port cargo throughput

	ROTTERDAM	ANTWERPEN	HAMBURG
ROTTERDAM	1.000000	0.944461	0.851384
ANTWERPEN	0.944461	1.000000	0.944705
HAMBURG	0.851384	0.944705	1.000000

As in time series analysis, the unit root and co-integration has to be tested at the early stage. The lags will be selected basing on the analysis on unrestricted VAR. Further, the Johansen co-integration test will be performed to identify the existence of co-integration. The restricted

VAR model, which is known as VEC model will be established basing on the test result of Johansen co-integration test. The long term and short term relationship between ports will be identified by applying the VEC model. The forecast will be made and recorded for the later parts of this study.

4.4 Measurements

4.4.1 Measurement of variables

The cargo throughput is measured by the gross weight of good handled at the port. The total volume will be used including loaded and empty, measured in thousands of tons.

The quarterly GDP collected from OECD database is calculated basing on the expenditure approach and measured in euro. The GDP growth in Netherlands, Belgium and Germany is calculated basing on previous quarter.

Aiming at making choice between original series and transformed (natural logarithm) series, the likelihood statistics are collected. Table 5 shows that the transformed series have higher log likelihood and lower AIC in all models (only AIC for transformed series in time series model of Hamburg is slightly higher than that of untransformed series). The higher log-likelihood and the lower AIC indicate that the model is better fitted in the data. Therefore, the natural logarithm of original series will be used for following model analysis.

Table 5: Likelihood statistics for model fit to untransformed series and transformed series

		Untransformed series		**Transformed series**	
		Log likelihood	AIC	Log likelihood	AIC
Linear regression	Antwerp	-608.0293	17.9420	102.1929	-2.9368
	Hamburg	-610.6035	18.0178	73.9050	-2.1149
	Rotterdam	-676.7150	19.9622	93.9998	-2.7059
Time series	Antwerp	-576.9310	17.3412	126.5047	-3.6819
	Hamburg	-543.5618	16.5928	120.8897	-3.7108
	Rotterdam	-628.4863	18.8802	133.4891	-3.8653
VECM		-1557.142	52.4293	425.6041	-11.5034

4.4.2 Measurement of model performance

By using sample period from the first quarter 1997 to the fourth quarter of 2013, the forecast period starts from 1997Q1 and ends at 2015Q4. In this case, there are 17 years of forecast within the sample and two years out of the sample forecast. It is helpful to illustrate the performance of forecast by comparing the in-sample forecast and the true figures of port throughput.

The log-likelihood and information criteria will be recorded from each model and used for evaluate the models. Moreover, the mean absolute error (MAE), mean absolute percentage error (MAPE) and root mean square error (RMSE) will be recorded aiming at comparing the forecast results from different models. Besides, the forecast will be performed with both in the sample forecast and out of sample forecast. The forecast outcome will be recorded and plotted in order to visualize and compare the forecast performance from different models.

4.5 Statistic methods

During the analysis, the tests and forecasts will be processed through the models that stated in previous sections. All hypotheses are tested at 95% confidence level. The 95% confidence level means the probability to make type I error can be limited below 5%. It means that with 95% of the cases, the revealed relationship from the tests hold for true in whole population. There is only at most 5% possibility the right answer is rejected. All data and models will be processed by using EViews 8.

For H1, the relationship between GDP and port cargo throughput will be tested by examining the coefficient in the regression models. The sign of the coefficient on GDP suggests the positive or negative relationship between GDP of the country which the port is located and cargo throughput of the port. The significance suggests the relationship between cargo throughput and GDP is whether effective or not. If null hypothesis is not rejected at 5% level, it suggests that the GDP do not have significant effect on predicting cargo throughput of a port.

Hypothesis 2 stating the cargo throughputs of selected ports have impact on each other. It will be tested through the VECM model.

H2(a) will be processed through testing the significance and sign of the coefficient of co-integrating equations. The significance of co-integrating equations will give the information of long run causal relationship between ports. The sign of the coefficients of co-integrating equations will indicate the cargo throughput form other ports will benefit or hurt the cargo throughput at a specific port. If the coefficients are not significant, then there is no clear long run relationship in cargo throughput among the selected ports.

H2(b) will be processed through testing the jointly significance of all lagged variables from each endogenous variable. The jointly significance of the lag variables indicates the existence of short run causality from one port to another. For example, the coefficients on lag cargo throughput of Rotterdam are jointly significant when estimating cargo throughput of Hamburg. It indicates that the cargo throughput of Rotterdam is able to influence the cargo throughput in Hamburg in the short run. In case that the coefficients are not jointly significant, it is reasonable to accept there is no short run causal relationship between the ports.

In order to answer the main research question of this study, which stated in Hypothesis 3, the test will be processed in two phases. At the first phase, the cargo throughput in two years from the fourth quarter of 2013 will be forecasted. The forecasting outcome will be recorded and compared among different models. The optimal model will be selected basing on the selection criteria. The forecast from best model will be used to calculate the cargo throughput gap. The gap is defined as the difference in cargo throughput between two ports at time t, which is calculated as

$$Gap_{ij}=Y_{i,t}-Y_{j,t}$$

At the second phase, the calculated gaps in post crisis period (from 2010Q1 to 2015Q4) will be compared with the gaps in crisis period (from 2008Q4 to 2009Q4). The gaps between Rotterdam and Antwerp, Rotterdam and Hamburg will be compared. The gaps will be plotted to show the overall trend of gap changes along the time. After that, H3(a) and H3(b) will be tested through the significance of an indicator of economic crisis.

In order to test the significance of economic crisis indicator, a dummy variable is created indicating the period of economic crisis. The dummy equals to 1 for time period from the first quarter of 2010 to the fourth quarter of 2015, otherwise equals 0. The estimation sample period is limited from 2008Q4 to 2015Q4 in order to remove the possible disturbance from early data. Then a linear regression is applied between gap variables and dummy variable.

If the both coefficients on dummy variables are significant and negative, then the null hypotheses of H3(a) and H3(b) are rejected. It indicates that the impacts of crisis are not permanent. The benefits which port of Rotterdam gained from economic crisis are diminishing along the time. If both null hypotheses are not rejected, it suggests that Rotterdam will keep the advantage from economic crisis into the future. In the case that the two hypotheses have one reject and one accept, it means that port of Rotterdam partly keep the benefits. For the null hypothesis which is rejected, the port is recovering from the economic crisis. The impact of economic crisis will finally disappear in some day in the future. For the null hypothesis which is accepted, the impact of crisis is not gone in the post crisis period. The damage from crisis may be permanent. The advantages Rotterdam had during the economic crisis are able to last in long future. It also gives the information that the impact of crisis is permanent in some components of port development, and diminishing in some other parts. Unfortunately, this study failed to give the detailed information on which parts of port cargo throughput will recovery from economic crisis and which components are damaged permanently.

4.6 Summary

In this section, the research design is presented. In order to illustrate the cargo throughput development in a multi-port region, Hamburg – Le Havre range is selected. Port of Antwerp, port of Hamburg and port of Rotterdam within the Hamburg- Le Havre range is selected as the cases to apply the research. The cargo throughputs of Antwerp, Hamburg and Rotterdam are collected from 1997Q1 to 2013Q4, together with quarterly GDP in the Belgium, Germany and Netherlands.

The cargo throughputs in each port show a slightly increase trend along the whole sample period. The cargo throughput in all ports experienced a stable increase from 2002 to 2008Q3, and declined sharply in the fourth quarter 2008 and 2009. From 2010, the cargo throughputs have been recovering yet the growth slows in recent years.

In order to illustrate the future impact of economic crisis in 2008, the cargo throughput of each port is forecasted by using linear regression models, time series models, and multi-variates models. The forecast period starts from 1997Q1 and ends at 2015Q4, which is 8 periods ahead of the sample. GDP of each country are used in the models as independent variable explaining the cargo throughput and improving the validity of forecast model.

The forecast model will be estimated, tested for the significance, and determine the impact of GDP. The influence of cargo throughput from one port to the others will be detected in VEC models. The forecast result will be recorded and compared to choose the optimal model. The forecast from optimal model will be used to calculate the cargo throughput gap between two ports and investigate the impact of economic crisis on the ports.

Chapter 5: Results

In this chapter, the results from empirical analysis are presented. Section 5.1 performs the model analysis and forecasting. In section 5.3, forecasting models will be compared. Section 5.4 performs the test for Hypothesis 2 basing on the findings from previous sections.

5.1 Model Analysis

In this section, different models will be used to illustrate the causal relationship and make forecasts on cargo throughput of each port. The linear regression, time series and multi-variate models will be performed in the following parts.

5.1.1 Linear regression

A linear model is applied to illustrate the causal relationship between economic activities and cargo throughput. Hypothesis 1 is tested in this section. Stating in Section 4.3.1, the linear regressions are applied between cargo throughput and GDP of the country that port is located. However, the forecast can be reached only within the time period that is already known, since the future GDP has not occurred hence impossible to record. In order to forecast future using the linear regression, the future GDP has to be predicted. In Van Dorsser et al. (2012), the long term port throughput is forecasted by applying the relationship between GDP and port throughput from the regression. The future GDP is predicted from a decompositions model of GDP development and the discussion of possible scenarios. Yet, instead of predicting GDP in this section, the economic outlook data from European Economic Forecast Winter 2014 is used. By applying the quarterly GDP growth forecasted by the reliable institution, the quarterly GDP from 2014Q1 to 2015Q4 are obtained.

The regression is applied between the cargo throughput of Antwerp, Hamburg and Rotterdam and GDP of each country. The causal relationship between GDP and cargo throughput will be tested through the significance of coefficient on GDP variables. The regression results are summaries in Table 6:

Table 6: Summary of linear regressions

	Antwerp	Hamburg	Rotterdam
Regression			
Constant	-14.1545	-27.0340	1.2136
GDP	2.1685	2.8026	-2.9092
Model			
R^2	0.9127	0.8243	0.7280
Log likelihood	102.1929	73.905	93.9998
AIC	-2.9468	-2.1148	-2.7059
SC	-2.8816	-2.0496	-2.6406
Forecast			
Throughput in 2015Q4	45009.93	36001.94	94177.54
RMSE	1738.702	2020.929	5053.284
MAE	1455.980	1660.381	1203.603
MAPE	4.428892	6.703124	5.007794

Before forecasting the cargo throughput, residuals have to be checked to make sure the model is well constructed and fitted. The serial correlation, heteroskedasticity, and normality are tested. The Breusch-Godfrey serial correlation LM is aiming at testing the existence of serial correlation. The null hypothesis assumes there is no serial correlation within the residuals. The test is run at 5% level. If there is serial correlation, the probability that F-statistics is larger than critical value should be smaller than 0.05. The null hypothesis of Breusch –Godfrey heteroskedasticity assumes there is no heteroskadasticity within the residuals. If the p-value is larger than 5%, it is reasonable to accept the residuals are homoskadasticity. The normality is detected by checking the histogram and Jarque-Bera statistics. If Jarque-Bera staistics is significant at 5% level, the residuals follow normal distribution.

The residual diagnose as shown in Table7 indicates that the residuals have serial correlation problems in all three cases. The distributions of residuals are not normal distribution. The heteroskedasticity test show significant heteroskedasticity in the residuals series in Antwerp and Rotterdam cases. It will again reduce the validity of the linear regression model. The residual diagnose together suggests the outcomes from linear regression models will be limited since it fails the assumptions of linear regression that the error terms should be independent, identical distributed and no heteroskedasticity exists. In another word, the linear model should have space to improve by including more components in the regression.

Table 7: Residual Diagnose

	Antwerp	**Hamburg**	**Rotterdam**
Breusch-Godfrey serial correlation LM	29.249 *	117.338 *	62.857 *
Breusch-Godfrey Heteroskedasticity	12.646 *	0.238	7.477 *
Jarque-Bera statistics	0.605	5.110	1.2235

*significant at 5% level

The reverse causality between cargo throughput and GDP has also to be checked before forecasting cargo throughput. The Granger Causality tests are performed to detect the causality between cargo throughput and GDP of port located country. The null hypotheses in Granger Causality tests assume there is no causality from one variable to another. If the null hypothesis is rejected at 5%, the causality from one variable to another significantly exists. Granger causal tests are sensitive to the lag lengths, therefore the different lengths are taken. The tests results are as shown in Table 8:

Table 8: Granger Causality between cargo throughput and GDP

	Lags	F-statistics	Prob.
LGDPB does not Granger Cause LYA LYA does not Granger Cause LGDPB	2	14.5691 1.16464	7.E-06 0.3189
LGDPD does not Granger Cause LYH LYH does not Granger Cause LGDPD	2	5.11348 0.08252	0.0088 0.9209
LGDPN does not Granger Cause LYR LYR does not Granger Cause LGDPN	2	2.42349 2.73255	0.0971 0.0730
LGDPB does not Granger Cause LYA LYA does not Granger Cause LGDPB	4	7.90368 0.23314	4.E-05 0.9186
LGDPD does not Granger Cause LYH LYH does not Granger Cause LGDPD	4	2.97878 0.42779	0.0268 0.7879
LGDPN does not Granger Cause LYR LYR does not Granger Cause LGDPN	4	2.56144 1.41885	0.0485 0.2399

As shown in Table 8, at lag length equal to 2, the null hypotheses that indicate no causality from GDP to cargo throughput are rejected in Antwerp and Hamburg cases. It means that the causality from GDP to cargo throughput is significant. In other words, GDP changes are one of the reasons that make cargo throughput volatile. The null hypotheses that indicate no causality from cargo throughput to GDP are not rejected in Antwerp and Hamburg, indicating the changes in cargo throughput can hardly result changes in GDP. The results suggest that the inverse causality does not exist in Antwerp and Hamburg. As in Rotterdam case, the causalities in both directions are slightly insignificant, indicating the cargo throughput and GDP in Netherlands are actually independent. When the Granger causal tests are performed with 4 lags, the reverse causality is rejected in all cases. The causality relations are not sure in Rotterdam case.

In order to get a clear causality relationship between GDP of Netherlands and cargo throughput of Rotterdam, the causality will be testes in a VAR model. The VAR Granger causality/block exogeneity Wald tests detect whether the variables in the model can be excluded. As shown in Table9, the Wald tests show the coefficient on GDP and cargo throughput are again slightly insignificant in both directions. The VAR Granger causality/block exogeneity Wald tests indicate there are no significant short run causal relationships between GDP of Netherlands and cargo throughput of Rotterdam. Therefore, the independent short run relationship between cargo throughput of port of Rotterdam and the GDP of Netherlands is accepted.

Table 9: VAR Granger causality/block exogeneity Wald tests

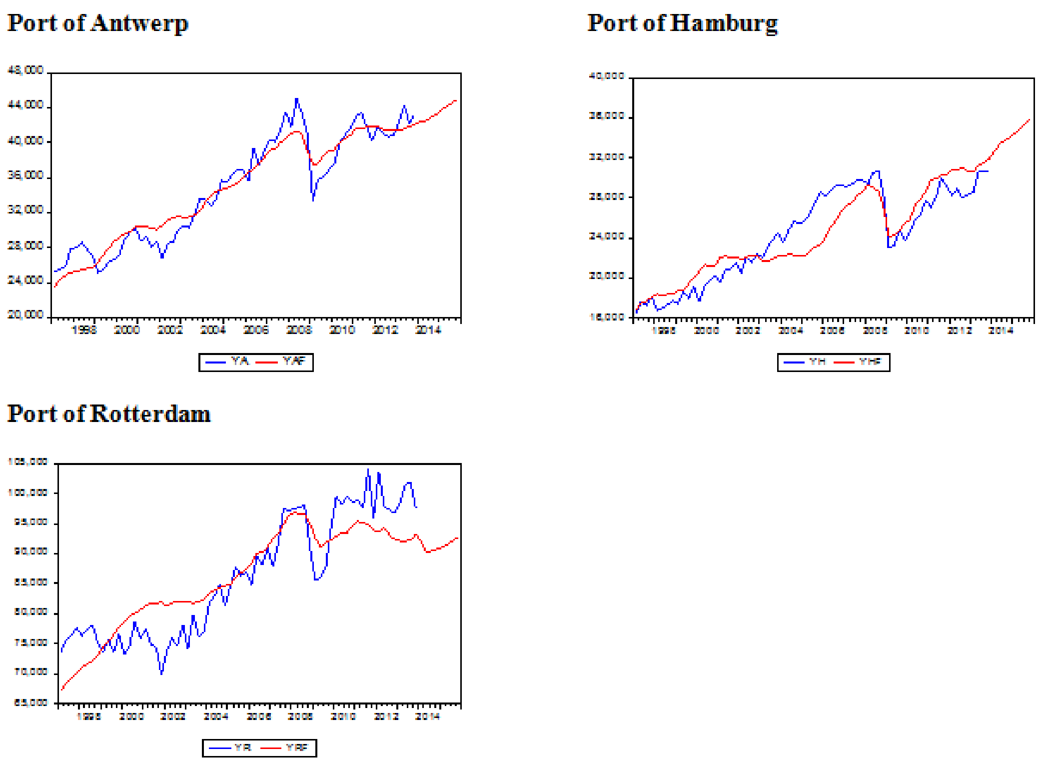
Dependent variable: LGDPN			
Excluded	Chi-sq	df	Prob.
LYR	5.465090	2	0.0651
All	5.465090	2	0.0651
Dependent variable: LYR			
Excluded	Chi-sq	df	Prob.
LGDPN	4.846987	2	0.0886
All	4.846987	2	0.0886

The results indicating there is no reverse causality in Antwerp and Hamburg cases. GDP growth is a driver of port throughput growth, the reverse is not. However, it may be not the case for port of Rotterdam, the causality between GDP and cargo throughput may not exist. Therefore the conclusion from linear regression models in Rotterdam case may limit due to the independent relationship between GDP of Netherlands and cargo throughput of Rotterdam.

The forecasts are made by applying the linear regression models using sample from 1997Q1 to

2013Q4. The forecast includes whole sample period plus two years (8 periods) in the future. The forecast (Red lines) and actual (Blue lines) cargo throughput of each port are shown in Figure 5.

Figure5: comparing original series to linear regression forecasts



The coefficient of GDP is positively significant in each port, suggesting the positive relationship between GDP and cargo throughput development. This result consists with Tonzon (1995) and Notteboom (2013). The forecast outcomes illustrate the development trends of port throughput which are largely reflecting the true trends. Yet the forecasted trends show less volatilities in the than real cargo throughput of ports. Besides, the forecast errors which are visualized as the differences between forecasted value and actual value sometimes can be large, which suggest the models are able to improve by capturing other factors that influence the cargo throughput.

5.1.2 Time series

In order to improve the linear regression model stated in 5.2.1, the cargo throughput changes over time are considered and incorporated in the model. Therefore, the effect of ARIMA and factor of GDP is considered in the same model. The advantage of this approach is that it incorporates the external effects from GDP.

At the start of applying ARIMA models, the residuals of linear regression 5.2.1 will be checked for stationary and level of integration. The Augmented Dickey-Fuller (ADF) unit root tests are applied to test the existence of unit roots. The null hypothesis of ADF is that the unit root exists. The ADF tests results are stated as in Table10.

Table 10: ADF test on residuals from regression

	Antwerp		**Hamburg**		**Rotterdam**	
	At level	1^{st} difference	At level	1^{st} difference	At level	1^{st} difference
ADF statistic	3.5562*		-1.3637	-12.1556 *	-2.0322	-12.1019 *
H_0	Reject		Accept	Reject	Accept	Reject

*significant at 5% level

Table 10 indicates that there is no unit root in the residuals series of Antwerp, the ARMA models is able to directly apply. However, the unit roots exist in the residuals series in Hamburg and Rotterdam cases. Both series are stationary at the first differences. Therefore, the integration 1 should be used for Hamburg and Rotterdam.

However, the inverted AR roots and MA roots are not significant in the AMMA models. It indicates that the non-stationary in the residual does not make large impact in the model estimations. Moreover, the ARMA models show higher log-likelihood and lower AIC than the models with one integration as shown in Table 11.

Table 11 comparing ARMA and ARIMA models for Hamburg and Rotterdam cases

	Hamburg		**Rotterdam**	
Model	SARIMA (1,0,0) (1,0,0)	SARIMA (1,1,0)(1,1,0)	ARMA (1,1)	ARIMA(1,1,1)
Inverted AR Roots	0.81	0.75	0.89	-0.50
Inverted MA roots	NA	NA	0.97	-0.11
Log-likelihood	120.8897	117.9795	133.4891	128.7330
AIC	-3.7108	-3.6768	-3.8653	-3.7798
SC	-3.5747	-3.3595	-3.7337	-3.6471

Therefore the ARMA model will be used for more accurate and less complicated than the ARIMA models. After applying ARMA models in cargo throughput of all three ports, the results are shown as in Table 12:

Table12: Summary of models

	Antwerp	Hamburg	Rotterdam
Regression			
Constant	-16.4740	-22.7885	-9.8702
GDP	2.3730	2.4834	1.803372
Time series			
AR(1)	-0.2521	0.788108	0.8887
AR(2)	0.7415		
MA(1)	0.9997		-0.3743
SAR(4)		0.4358	
Model			
R^2	0.9597	0.9601	0.9189
Log likelihood	126.5047	120.8897	133.4891
AIC	-3.6819	-3.7108	-3.8653
SC	-3.5161	-3.5747	-3.7337
Forecast			
Throughput in 2015Q4	46546.51	350009.02	93959.89
RMSE	1615.257	1475.760	4583.797
MAE	1320.348	1279.620	3707.776
MAPE	3.9943	4.4970	3.6789

The residual diagnose as shown in Table 13 indicates that there is no serial correlation or heteroskedasticity among the residuals of three models. The normality tests suggest the residuals from models for Antwerp and Hamburg follow normal distributions. The residual diagnose indicates that the model fits well in the Antwerp case and Hamburg case. The model for Rotterdam is fine, yet the accurate may be lower than the other two since the distribution of error terms is not normal distribution.

Table 13: Residual Diagnose

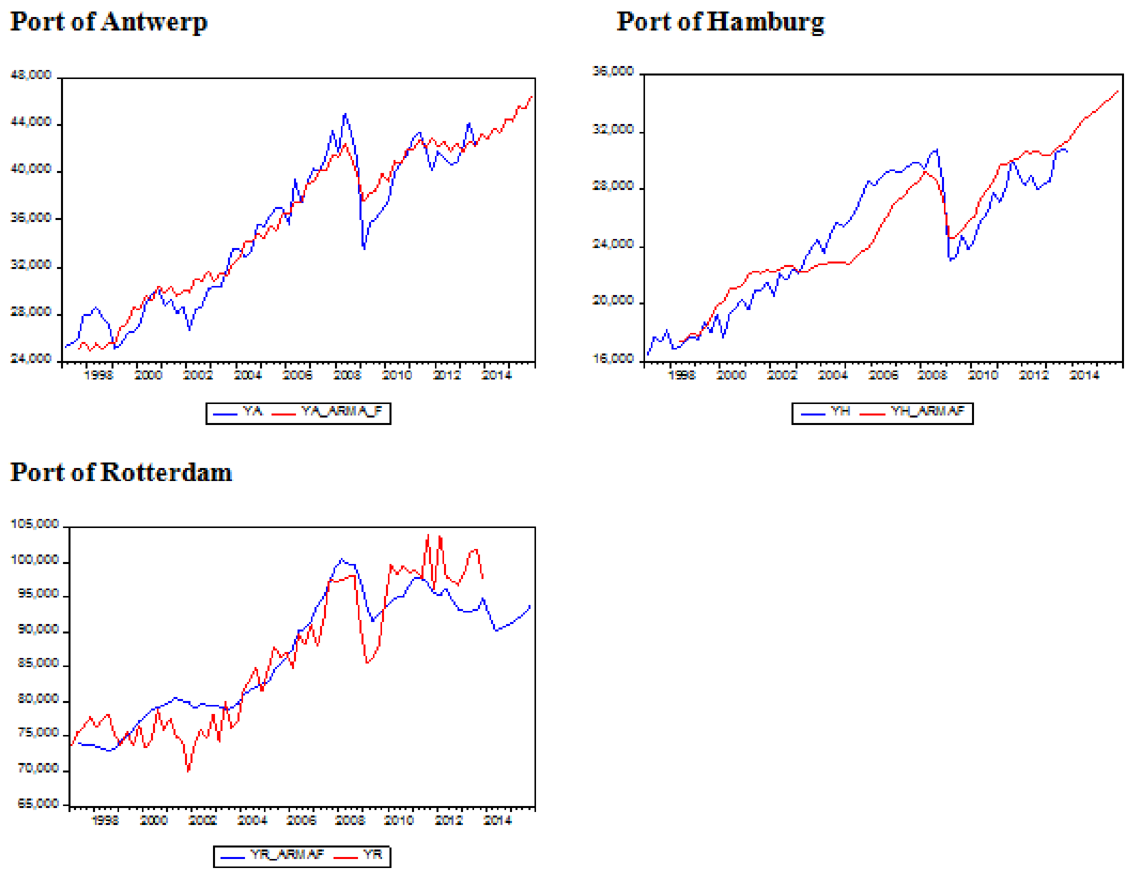
	Antwerp	**Hamburg**	**Rotterdam**
Breusch-Godfrey serial correlation LM	0.204	1.725	1.728
Breusch-Godfrey Heteroskedasticity	0.140	0.075	0.512
Jarque-Bera statistics	14.653 *	6.557*	0.784

*significant at 5% level

After the residual diagnose, the forecast is made by applying time series model with sample from 1997Q1 to 2013Q4. The forecast includes whole sample period plus two years (8 periods) in the future. The forecast (Red lines) and actual (Blue lines) cargo throughput of each port are shown in Figure 6.

The time series variables are applied to improve the forecasting models by incorporating both internal influences (cargo throughput growth) and external influence (GDP) on the cargo throughput. The significance in GDP and time parameters suggests both economic and internal growth play key roles in the cargo throughput development at a port. As shown in Figure 6, the time series models are able to capture the trends in cargo throughput development in all selected ports. In most cases, the time series models give forecasts that are close to the empirical records. Comparing with the linear regression models in Section 5.1.1, the increases in explanatory power R^2 and log-likelihood indicate increasing percentage of independent variable explained by the model. The lower AIC and SC and lower error criteria additionally suggest the time series models perform better than the linear regression models stated in Section 5.1.1.

Figure 6: comparing original series to time series forecasts



5.1.3 VAR and VEC models

In this section, the vector error correction models are used in order to incorporate the interactions among the ports. As stated in previous sections, the performance of one port may possibly make an impact on the other ports within the same multi-ports range. The correlation matrix shows that the correlations between each two ports are quite high and suggests the possibility that the ports are dependent. Therefore, the multi-variants models are used. GDP from previous sections is proven to be significant for cargo throughput development as an external factor revealing economic environment in a country. Therefore the GDP will be also included in the VAR and VECM models. In this case, the GDP of each country are assumed independent.

At the beginning, the number of lags has to be selected for testing of integration and constructing models. With GDP of each country as exogenous variables, the cargo throughputs of each port are modeled in an unrestricted Vector autoregressive (VAR) model. Then the VAR lag order selection criteria are applied to the unrestricted VAR model, the criteria are shown as below,

Table 14: VAR lag order selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	321.7920	NA	9.18e-09	-9.993292	-9.581588	-9.831647
1	376.6096	97.25688	2.10e-09	-11.47128	-10.75080*	-11.18840*
2	384.7117	13.59062	2.17e-09	-11.44231	-10.41305	-11.03820
3	389.5603	7.663964	2.51e-09	-11.30840	-9.970360	-10.78305
4	395.7528	9.188828	2.79e-09	-11.21783	-9.571017	-10.57125
5	419.6934	33.20797*	1.77e-09*	-11.69979*	-9.744195	-10.93197
6	426.9106	9.312512	1.94e-09	-11.64228	-9.377908	-10.75323

As shown in Table 14, the sequential modified LR test statistic, Final prediction error, Akaike information criterion, Schwarz information criterion and Hannan-Quinn information criterion are the information criterion which is used to compare the different models. The first three selection criteria select lag five as optimal, while Schwarz information criterion and Hannan-Quinn information criterion select lag 1. Since the information criteria are equally efficient on lag selection, therefore, the lag 5 is chosen for following tests and modelling for three out of five criteria select lag 5 as optimal.

As the co-integration exists between non-stationary series with same integration (Verbeek, 2012), prior to test the co-integration, integration of series has to be detected. As stated in Section 5.2.2, the Augmented Dickey-Fuller (ADF) unit root tests are used to test the stationary of series and determine the level of integration. The null hypothesis of ADF is that the unit root exists. The ADF tests results are stated as in Table 15

Table 15: ADF unit root test

	Antwerp		**Hamburg**		**Rotterdam**	
	At level	1st difference	At level	1st difference	At level	1st difference
ADF statistic	-1.2072	-8.9651*	0.6126	-8.4868 *	-0.8787	-11.0979 *
H_0	Accept	Reject	Accept	Reject	Accept	Reject

*significant at 5% level

Table 15 shows the unit root exists for cargo throughput series of Antwerp, Hamburg and Rotterdam at level, suggesting the original cargo throughput series are not stationary. After taking first differences, unit roots no longer exist. Therefore the cargo throughput series are stationary with integration equals one. It fits the pre-condition of Johansen co-integration test that the series have to be integrated at same level. Therefore, Johansen co-integration test is applied with lag 5 and country GDP as exogenous variables, the results are shown in Table 16.

Table 16: Johansen co-integration test

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.516920	77.46059	29.79707	0.0000
At most 1 *	0.380996	32.35100	15.49471	0.0001
At most 2	0.041270	2.613065	3.841466	0.1060

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.516920	45.10959	21.13162	0.0000
At most 1 *	0.380996	29.73794	14.26460	0.0001
At most 2	0.041270	2.613065	3.841466	0.1060

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

The Johansen co-integration test is aiming at to test the number of co-integrating equations. The null hypotheses as stated in the Table 16 are none, at most 1 and at most 2 co-integrating equations exist in the system. The test is run at 0.05 level, which make sure the type I error is limited within 5%, indicating the result is correct in 95% of the cases. The p-value is smaller than 0.05 in the first two hypotheses, indicating there are more than 1 co-integrating equations existing. The co-integration rank tests using either trace or maximum eigenvalue cannot reject null hypothesis that there are at most two co-integrating equations, indicating that 2 co-integrating equations are existed at 0.05 level. Referring Verbeek (2012), the error correction term exists if co-integration equation exists. Therefore, the VEC model is developed by adding the restrictions (co-integrating equations) into the VAR model. The VEC model is constructed with GDP of each country as exogenous variables, the cargo throughput of each port as endogenous variables, combined with two co-integration models and lag 5. In this case, the unrestricted VAR which has same input as VEC model yet without restrictions on co-integration equations will also be performed for comparison.

To test the causal relationship, the coefficient of the model is analyzed, as shown in Table17.

Table 17: VECM and VAR results

		VECM			Unrestricted VAR		
		Antwerp	Hamburg	Rotterdam	Antwerp	Hamburg	Rotterdam
CE 1		-1.577 *	0.577	0.659	NA	NA	NA
CE 2		0.446 *	-0.447	-0.457 *	NA	NA	NA
Coefficients w.r.t. Antwerp	L_1	0.685	-0.353	-0.341	0.311	0.232	0.361*
	L-2	0.625 *	-0.421	-0.106	0.037	-0.085	0.224
	L_3	0.446	-0.301	-0.300	-0.1767	0.117	-0.243
	L-4	0.572 *	0.103	-0.157	0.061	0.360	0.108
	L-5	0.198	-0.049	-0.068	-0.479*	-0.294	0.0473
Coefficients w.r.t. Hamburg	L-1	-0.555 *	-0.246	0.108	-0.090	0.412*	-0.339*
	L- 2	-0.425 *	0.029	0.027	0.122	0.229	-0.049
	L-3	-0.500 *	-0.123	0.195	-0.116.	-0.165	0.179
	L-4	-0.167 *	-0.038	-0.115	0.237	0.169	-0.213
	L-5	-0.129	-0.060	-0.044	0.218	-0.0632	0.059
Coefficients w.r.t Rotterdam	L- 1	-0.096	1.309 *	0.331	0.463*	0.154	0.244
	L-2	-0.129	0.784 *	0.489	-0.071	-0.523*	0.171
	L-3	-0.039	0.649 *	0.156	0.236	-0.019	-0.275
	L- 4	0.330	0.663 *	0.177	0.186	-0.068	-0.049
	L-5	0.345 *	0.427 *	0.305 *	-0.159	-0.259	0.071
constant		-18.331*	-15.543 *	-12.40 *	-10.887*	-5.891*	-2.097
GDP_be		1.813*	1.840 *	2.078*	1.518*	1.865*	1.873*
GDP_de		0.224	0.999 *	0.112	0.042	0.534	-0.036
GDP_nl		-0.4440	-1.581 *	-1.077 *	-0.332	-1.143*	-0.910*

Log likelihood	425.604	423.307
AIC	-11.504	-11.629
SC	-9.136	-9.690

*significant at 5% level

The coefficients on co-integrating equation 1 and 2 indicate the long run causal relationships between the selected ports. If the coefficient is significant, the long run causal relationship is recognized between the ports. The coefficients of GDP factors indicate the relationships between GDP of a country and the cargo throughput. Referring the findings in 5.1.1, the GDP of port located should be significant for the cargo throughput of the port. The significance of GDP in other countries means not only the home country but the economic development of neighboring country will also have impact on the port throughput.

The jointly significance of coefficients with respect to one port indicate the short run causal relationship between two ports. The Wald test is applied to test the jointly significance of coefficients with respect to one port. The null hypothesis of Wald test is all coefficients related to one port are equal to 0. If the null hypothesis is rejected, it is reasonable to accept the cargo throughput of a port can be in short term affected by the cargo throughput of another port. The results of Wald Tests are shown in Table 18.

Table 18: Wald Test of jointly significant of short run relationship

VECM

	Antwerp		**Hamburg**		**Rotterdam**	
	F-statistic	Chi-square	F-statistic	Chi-square	F-statistic	Chi-square
Coefficient Antwerp	1.6990	8.4948	1.2265	6.1327	0.6964	3.4820
Coefficient Hamburg	2.3919	11.9596 *	0.7194	3.5969	1.0659	5.3292
Coefficient Rotterdam	1.5135	7.5674	2.5709 *	12.8547 *	1.2139	6.0694

*significant at 5% level

Unrestricted VAR

	Antwerp		**Hamburg**		**Rotterdam**	
	F-statistic	Chi-square	F-statistic	Chi-square	F-statistic	Chi-square
Coefficient Antwerp	4.2496 *	21.2482 *	2.172 *	10.8596 *	1.9886	99.9431
Coefficient Hamburg	1.7793	8.8962	4.0172 *	20.0858 *	1.9277	9.6386
Coefficient Rotterdam	2.9673 *	14.8367 *	2.9974 *	14.9871 *	2.9974*	14.9871 *

*significant at 5% level

For port of Antwerp, both coefficients on CEs are significant, which suggest the significant influence from the cargo throughput of other ports in the long run. The negative coefficient of CE 1 indicates a negative relationship in the long run between cargo throughputs of Antwerp with previous performance of Rotterdam. The significant positive coefficient of CE 2 indicates that the cargo throughput at time t is positively related to the performance of Hamburg and Rotterdam together in the long run. Combining the effect of Rotterdam in co-integrating equation 1 and co-integrating equation 2, a positive effect of cargo throughput of Rotterdam on the cargo throughput of Antwerp can be found. The results suggest that the cargo throughput of Antwerp in the long run is positive related to the cargo throughput of Hamburg and Rotterdam. The jointly significant is found between Hamburg and Antwerp using Chi-square statistics. It suggests that the performance of port of Hamburg have slight impact on the cargo throughput of Antwerp. Since there is only one of the two statistics is significant, the short run causality from Hamburg to Antwerp is very slight. Meanwhile the cargo throughputs of Rotterdam do not have impact on the cargo throughput of Antwerp in the short run. The GDP in Belgium is positively significant related to the cargo throughput of Antwerp, which consist with the findings from 5.2.1 and 5.2.3 that GDP of port located country have positive effect on the cargo throughput.

For port of Hamburg, CE 2 has a slightly insignificant ($p = 0.056$) negative coefficient, indicating the combined performance of port of Antwerp and port of Rotterdam may have a negative impact on the cargo throughput of Hamburg in the long run. The insignificant of CE1 suggests the cargo throughputs of Antwerp have no long run impact on the cargo throughput of port of Hamburg. The results on co-integrating equations suggest a long run substitutive competition among Hamburg with Antwerp and Rotterdam may exist, yet is not statistically significant. The coefficients with respect to lags in Rotterdam are jointly significant, suggesting the short term impact from cargo throughputs in Rotterdam to Hamburg. The positive coefficients indicate that an increase in cargo throughput of Rotterdam will benefit the cargo throughput at port Hamburg. All GDP factors are significant in Hamburg case, suggesting the cargo throughputs of Hamburg are affected by the GDP not only in Germany, but also in the neighboring countries. An increase in the GDP of Belgium will benefit the cargo throughput of Hamburg while the increase in GDP of Netherlands will lead the cargo throughput decline at port of Hamburg.

For port of Rotterdam, the CE1 is not significant, suggesting no significant long run causal relationship between the cargo throughput of port of Rotterdam and cargo throughput of port Antwerp. The slightly significant coefficient on CE 2 ($p=0.0496$) suggests there is a negative relationship on the cargo throughput between port of Hamburg and port of Rotterdam. This finding is consists with the finding in Hamburg case. Yet, it indicates that the cargo throughput of Rotterdam can significantly influence the cargo throughput in Hamburg, but the reverse effect is much less. It additionally supports the long run substitute competition between Hamburg and Rotterdam. The short run coefficients are not significant in Rotterdam case, suggesting the cargo throughput of other ports have no impact on cargo throughput of Rotterdam in the short run. GDP of Netherlands and Belgium are significant in Rotterdam case. However, the results illustrate a positive relationship between cargo throughput of Rotterdam to GDP of Belgium and a negative effect from GDP of Netherlands.

Similar to VEC model, VAR models give information about the influence of one port to the others. The lag variables of tested ports are significant in all ports, indicating the time series relationship that the previous cargo throughputs will project on the future cargo throughput. The variables related to cargo throughput of Hamburg are jointly significant in both Antwerp case and Rotterdam case, indicating that the cargo throughput of Hamburg may have influence on the cargo throughput of Antwerp and Rotterdam. The variables related to cargo throughput of Antwerp are jointly significant in Rotterdam case, which indicates the cargo throughput of Rotterdam may affected by the cargo throughput of Antwerp. The significance in coefficients of GDP variables indicates that in addition to the home country GDP, the GDP of neighboring country may also have influence on the cargo throughput performance of a port.

The residual diagnose as shown in Table 19 indicates there is no serial correlations among the residuals of models. The heteroskedasticity tests indicate that there is no heteroskedasticity among the residuals with all ports using VAR model. Only heteroskedasticity is found in Hamburg when using VEC model. Both criteria indicate the models fit well to the data. However, the all three models fail in the normality test, suggesting the validity of model may limit.

Table 19: Residual Diagnose

VECM

	Antwerp	**Hamburg**	**Rotterdam**
Breusch-Godfrey serial correlation LM	0.279	0.191	1.759
Breusch-Godfrey Heteroskedasticity	0.852	2.205 *	0.993
Jarque-Bera statistics	0.743	2.666	3.101

*significant at 5% level

VAR

	Antwerp	**Hamburg**	**Rotterdam**
Breusch-Godfrey serial correlation LM	1.017	0.448	0.475
Breusch-Godfrey Heteroskedasticity	1.615	1.687	1.092
Jarque-Bera statistics	4.038	0.989	3.215

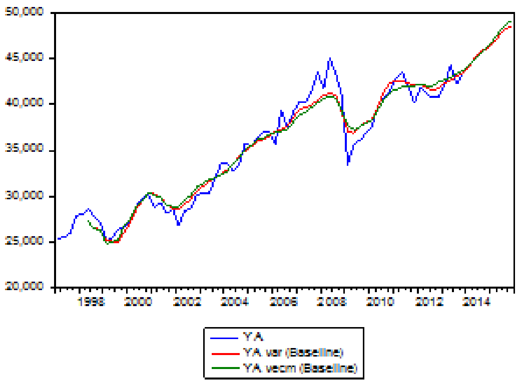
*significant at 5% level

Then the forecast is made by solving the models on the baseline scenarios, results as shown in Figure 7 and Table 20.

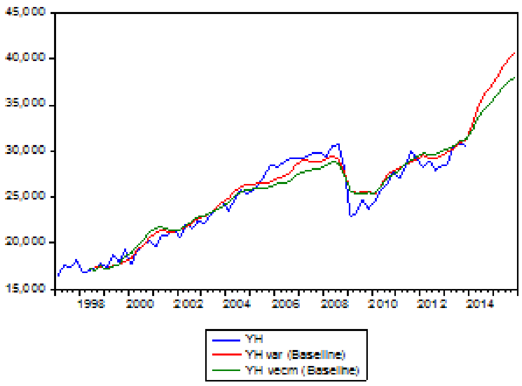
As shown in Figure 7, both VAR (Red lines) and VEC (Green lines) models are able to predict the trends of cargo throughput development (Blue lines) at the ports, although less volatilities are found in the predicted series. Comparing the three cases, VEC model perform better in Hamburg and Antwerp cases, while VAR model fits in Rotterdam case more than the others. In each case, both models make the predicted very similar cargo throughputs that close to the original value. However, the advantage of VEC and VAR models is allowing more flexibility. In this case, only baseline scenario is used in forecasting the cargo throughput, the benefits of allowing more flexibility are not seen.

Figure 7: comparing original series to VECM forecasts

Port of Antwerp



Port of Hamburg



Port of Rotterdam

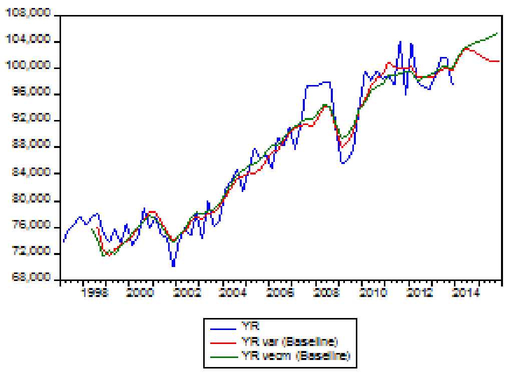


Table 20: Summary of Forecast

	VECM			VAR		
	Antwerp	Hamburg	Rotterdam	Antwerp	Hamburg	Rotterdam
Throughput in 2015Q4	48559.55	40276.52	101528.3	48568.56	40732.43	101177.8

RMSE	1055.360	860.2827	2346.027	1138.810	910.7955	2334.548
MAE	772.3850	646.6416	1928.666	790.4430	713.7767	1891.334
MAPE	2.1517	2.5752	2.2548	2.2083	2.8632	2.1762

5.2 Comparing model performance

In this section, the forecasting results from different models will be compared. As shown in Table 21,

Table 21: Model Comparison

		Linear regression	**Time series**	**VECM**	**Unrestricted VAR**
Antwerp	Log-likelihood	102.1929	126.5047	135.9218 *	132.05
	AIC	-2.9468	-3.6819	-3.7072 *	-3.5890
	SC	-2.8816	-3.5161 *	-2.9867	-2.9427
	RMSE	1738.702	1615.257	1055.360 *	1138.810
	MAE	1455.980	1320.348	772.3850 *	790.4430
	MAPE	4.4289	3.9943	2.1517 *	2.2083
Hamburg	Log-likelihood	73.905	120.8897	128.9045 *	128.5635
	AIC	-2.1148	-3.7108 *	-3.4808	-3.4782
	SC	-2.0496	-3.5747 *	-2.7603	-2.8319
	RMSE	2020.929	1475.76	860.2827 *	910.7955
	MAE	1660.381	1279.62	646.6416 *	713.7767
	MAPE	6.07031	4.4970	2.5752 *	2.8632
Rotterdam	Log-likelihood	93.9998	133.4891 *	-563.4845	142.8852
	AIC	-2.7059	-3.8653 *	18.8543	-3.9328

	SC	-2.6406	-3.7337 *	19.5748	-3.2865
	RMSE	5053.284	4583.797	2346.027	2334.548*
	MAE	1203.603	3707.776	1928.666	1891.334 *
	MAPE	5.008	3.6789	2.2548	2.1762*

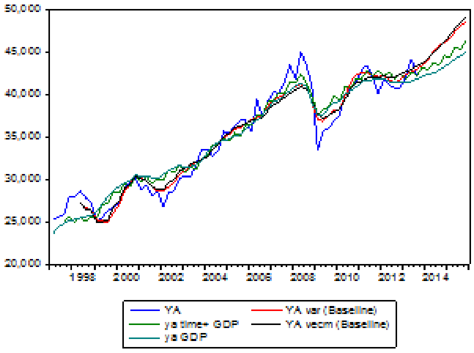
As shown in Table 21, all selection criteria except Schwarz information criterion indicate the highest performance in VEC model for port of Antwerp case. For the case of Port of Hamburg, the AIC and SIC suggest better model of time series, yet the other criteria show favor to VEC models. As in the port of Rotterdam, the log-likelihood, AIC and SC are in favor of time series while the VAR model has lower prediction errors.

It seems that there is no dominant optimal model for forecasting the cargo throughput in the selected ports. Yet, for forecasting the cargo throughput at a port, the prediction errors are the most concerned if goodness of fit does not differ much. Therefore, the VEC models and VAR are selected. The differences in forecast between VEC model and VAR model are very small, which can be also seen in Figure 7. VEC model is the best model choice in this study since it performs better in both Antwerp and Hamburg cases.

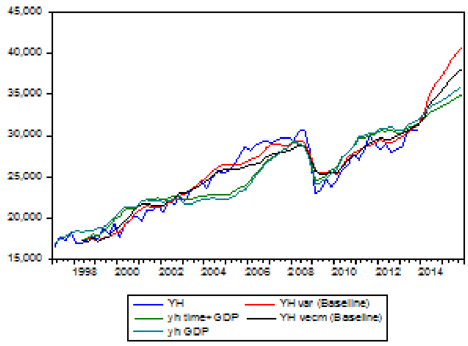
The forecasted cargo throughputs form models are compared with the empirical cargo throughput as shown in Figure 8. Figure 8 illustrates that all models are able to capture the overall trends of cargo throughput development in each ports in most of the time. The forecast of each model are quite close to each other in most time and show similar development paths. Among the models, the forecasts from VEC model (Red lines) show paths that closest to the path of original data (Blue lines) in all three cases. After VEC models, the time series model (Green lines) perform better in capture the changes in cargo throughput than linear regression model (Black lines). Therefore, the VEC models are considered as optimal in this study.

Figure 8: Comparing forecasts from models

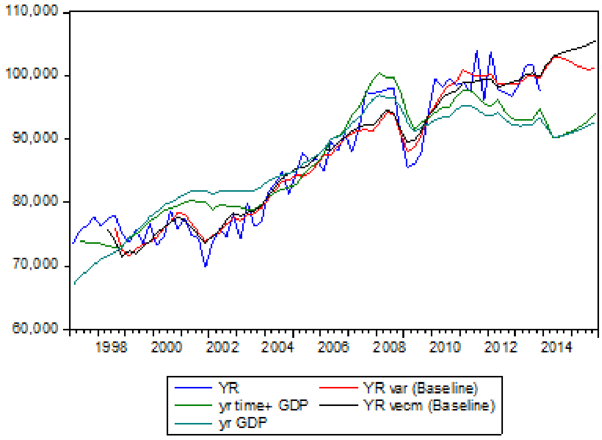
Port of Antwerp



Port of Hamburg



Port of Rotterdam



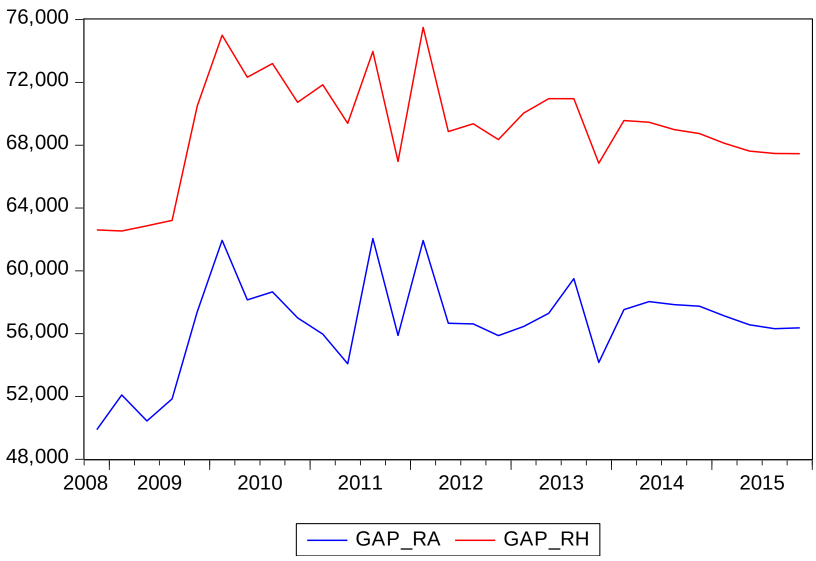
5.3 Test the impact of economic crisis

Basing on the conclusion of Section 5.3, the forecasted cargo throughputs from VEC models will be used in the tests in this section. As stated in the Section 4.4, the cargo throughput gap is calculated as

$$Gap_{ij} = Y_{i,t} - Y_{j,t}$$

Figure 9 shows the cargo throughput gaps from the fourth quarter of 2008 to two years later from the sample end. The gap increased during the financial crisis period (2008Q4 and 2009) and gradually decreases in recent years and stabilizes in the forecast period.

Figure 9: cargo throughput gap from 2008 Q4



As shown in Table 22, the tests for dummy variable indicating period of economic crisis are performed. Both coefficients on economic crisis dummy variable are negative, suggesting smaller gap between the cargo throughput in port of Rotterdam and other ports in the post crisis period. However, the coefficient is not significant for the gap between Rotterdam and Antwerp, indicating the cargo throughput gap between Rotterdam and Antwerp is not actually covering in the post-crisis period. Meanwhile, the coefficient for cargo throughput gap between Rotterdam and Hamburg is significant, which indicates that the cargo throughput gap is indeed reducing.

Table 22: Test for cargo throughput gap changes

	Coefficient	Std. error	t-statistic	Prob.
Gap _ra	-1428.352	909.4869	64.4589	0.1735
Gap _rh	-2823.849	1091.012	-2.5883	0.0164

5.4 Discussion

GDP is found significant in all models in this research. The results indicate that GDP is an important determinant of port throughput. The finding consists with Chou et al. (2008) and Tongzon (1995). However, the impact of GDP of port located country is not always positive. The positive relationship is found in linear regression models and time series models. Negative relationship is found when competitions between ports are introduced in the multi-variate models.

Not only the GDP of home country, but the GDP of neighboring countries are found having significant impacts on the port throughput at a port. For example, the port throughput in Hamburg is affected by GDP of Belgium, Netherlands, and Germany. Meanwhile, GDP in Netherlands shows a negative impact on the cargo throughput of Rotterdam while GDP of Belgium is promoting the cargo throughput in Rotterdam. One possible explanation for this is that as the development of hinterland transportations and international trades, the commodities that handled at a port are transferred from / to neighboring countries. The commodities for international trading which will not be consumed or produced in the port located country are taking the increasing percentage of port throughput and lead the different effects of GDP on cargo throughputs.

The multi-variates models (VAR and VEC) are applied in order to take the interactions between ports into consideration. Both unrestricted VAR and VEC models show the port performances are affected by each other. The results from VEC models indicate that there are long run causal relationships between cargo throughput of Antwerp and cargo throughput of other ports. The long run relationship is positive on the overall effect of Rotterdam and Hamburg, indicating Antwerp will benefit from growth of other ports and the development of the region in the long run. This finding provide empirical proof to the previous studies related to the competition between port of Antwerp and port of Rotterdam (Loyen, Buyst and Devos, 2002; Merk and Notteboom, 2013). The results from VEC model also indicate a positive long run relationship between Antwerp and Hamburg, a negative long run relationship between Hamburg and Rotterdam. It shows the substitutive competition between Rotterdam and Hamburg, while Hamburg and Antwerp are showing a complement competition. Both Antwerp and Hamburg are competition with port of Rotterdam in the long term and benefit each other when cargo throughput increases.

Meanwhile, the significant positive short run effect of cargo throughput of Rotterdam on cargo throughput of Hamburg is founded, which indicates that the cargo throughput in Rotterdam and Hamburg are reacting to the same direction in the short run. The short run relationship between port of Rotterdam and Hamburg is reacting as cooperation and benefits each other. The findings incorporate with the previous studies on port competition in Hamburg- Le Havre range (Merk and Notteboom, 2013, Meerseman et al., 2008). The similar findings are stated in the previous studies related to port development in East Asia. Both Fang (2002) and Yap and Lam (2006) conclude that the substitute competition and complement competition exist among the ports in a multi-port region.

The test for the impact of crisis shows the impact of the economic crisis benefits the cargo throughput in Rotterdam, yet is diminishing among the Rotterdam- Hamburg competition. The gap between Rotterdam and Antwerp is not covering, indicating the benefits Rotterdam had during crisis will last into future. The test results shows that the ports are partly recovering from the economic crisis yet some parts of the market and competition have been changed permanently.

Among the commodities handled in a port, container cargos are most sensitive to the economic crisis. The shipping lines increased ship sizes in pre-crisis period and reduced the number of services during the crisis for lower costs in the long distance transportation from Asia to Europe (Pills and De Lange, 2010). This trend in maritime transportation made more loss in the ports that have smaller number of calls. Comparing Rotterdam, Antwerp and Hamburg, both Rotterdam and Antwerp focus more on liquid bulk while Hamburg is very concentrated in container handling (Merk and Hesse, 2012). The container cargos experienced a dramatic decline up to 24% in Hamburg in 2009 while the container cargo decline at same time in Rotterdam is 12%. It enlarges the cargo throughput gap between Rotterdam and Hamburg during the crisis. However, as the economic recovers, the international trades and container cargos increases. As stated in Notteboom (2010), the container transportations are highly concentrated due to trade tradition. There has been long history of international trades between Hamburg and Asia. Therefore the throughput in Hamburg is able to recover over time. Besides, the short sea shipping is increasingly important to the port (EuroStat Statistics in focus, 2010). Comparing to other ports, Hamburg has its competitive advantage over Rotterdam on connecting the East Europe and Baltic Sea region. Six to eight of the most important short sea connections in Europe involve to port of Hamburg (Merk and Hesse, 2012). As the economic recovery in Europe and increase in volume of short sea shipping, the cargo throughputs of Hamburg are expected increasing over time. Therefore, the cargo throughput gap between Rotterdam and Hamburg is expected to reduce in the post crisis era.

Meanwhile, the differences between Rotterdam and Antwerp are not that much. Both ports are diversified in the commodities handed in the port and have large portion of liquid bulk handling. Although the demand of cruel oil in Europe is declining, yet the volume of liquid bulk handling did not volatiles that much as containers during and after the crisis. However, some shipping lines re-route their shipping routes from Antwerp to Rotterdam for lower costs. In the post crisis period, it is possible yet costly to re-route again to the ports before. Additional cost will be recognized if the shipping lines re-route back to the route before crisis. The cost related to re-route can be huge considering the indirection costs related to re-design the route, scheduling and human capital (Christiansen, 2004). Therefore, the ports can hardly recover this part of lose.

In terms of validity, the internal validity of this research is high since the data are collected from reliable sources and the models are well fitted to the data in most of the cases. It is able to provide constant and reliable outcome with same methods and data. The findings in this research are stable and able to be applied directly on the sample ports with high level of accuracy.

The external validity is somehow limited since only port of Antwerp, port of Hamburg and port of Rotterdam are studied in this study. All ports are located in Hamburg- Le Havre range and featured as the largest container load centers in the Europe. Therefore, the findings in this study may not apply for the other multi-ports ranges or other ports differ in size and other port characters.

5.5 Summary

In this chapter, the different models estimating and forecasting the cargo throughput of Antwerp, Hamburg and Rotterdam are performed and compared. From the linear regression model, the significant effects of GDP on cargo throughput in the ports are proven. The results from VEC model indicate the port cargo throughput may have influence on the other ports in both long run and short run. It also suggests a substitute competition position among port of Rotterdam and Hamburg. The forecast results show that all models illustrate the main trends of cargo throughput development in the ports. Comparing with other models, the VEC model is chosen as optimal for lowest prediction errors and the forecast outcomes most close to the original data in most cases. Then the impact of economic crisis is investigated through testing the sign and significance of dummy variables that presenting the period of economic crisis. The results show that the gap between Rotterdam and Antwerp is not significantly decreasing, indicating the benefits that Rotterdam gained from economic crisis continues in the post-crisis period. Meanwhile, the gap between Rotterdam and Hamburg is significantly decreasing; indicating the benefits that Rotterdam gained from crisis is diminishing.

Chapter 6: Conclusion

In this chapter, the results will be discussed and the conclusions will be given. The conclusions of this thesis will be given in Section 6.1. The limitations will be explained in Section 6.2. At the last part of this chapter, suggestions for further study are included.

6.1 Conclusion

This study examines the impact of economic crisis on the cargo throughput in Hamburg – Le Havre range. In order to investigate the long run impact, the future cargo throughputs have to be forecasted. The quarterly cargo throughputs from 1997Q1 to 2013Q4 of port of Antwerp, port of Hamburg and port of Rotterdam are collected. They are used for identifying the determinants of cargo throughput of a port and forecasting port throughputs in short term future.

The aim of this study is to extend empirical knowledge and add values to the existing researches with respect to the impact of economic on port development and cargo throughput forecasting. On one hand, by analyzing the impact of economic crisis in future cargo throughput, it is able to get better understand of port development and competition in the post- crisis period. On the other hand, the commonly used forecasting models are compared with the cargo throughputs at Antwerp, Hamburg, and Rotterdam. The findings in this study can be also contribute to the port throughput forecasting for using the most recent data and reached the optimal model. Additionally, as the multi-variate models are applied, the interactions among the ports can be reviewed and improved the traditional concept that the cargo throughputs are independent. The findings in this research may helpful for the business planning and port authority during the investments and making strategies.

The cargo throughput in sample period shows an overall increase trend, the cargo throughput increase largely in the 21 century before the attack of economic crisis in 2008Q3. During the crisis, the cargo throughput dropped in all selected ports and start recovering in 2010.

GDP is recognized as a factor that positively affects the cargo throughput of a port in most models. Yet when considering the interactions among the ports, GDP of neighboring countries are also found influencing port throughput significantly.

The cargo throughputs of ports are dependent to each other. There are both long run and short run causal relationships existing among the selected ports. In the long run, the cargo throughput in Antwerp is affected by the cargo throughput of Rotterdam and Hamburg positively, indicating a long run complement competition with port of Hamburg and Rotterdam. The long run relationship between Hamburg and Rotterdam are proven to be slightly negative, indicating a long run substitute competition may exist. The short run relation between Hamburg and Rotterdam is positive, indicating in the short Rotterdam and Hamburg plays complementally.

Comparing the different models used in this study, all models are able to illustrate the trends in cargo throughput development along the time yet with less volatility than actual. The error criteria such as MAE, RMSE, and MAPE are used as main selection criteria, and VEC is selected as optimal model since it performs well and has lowest prediction errors.

The result from testing cargo throughput gap between two ports suggests that the long run impact of economic crisis is partly diminishing. There are no significant changes in the cargo throughput gap between Rotterdam and Antwerp, indicating the benefits Rotterdam gained from economic crisis will keep for longer time. The gap between Rotterdam and Hamburg is significantly decreasing; indicating the benefits Rotterdam gained from economic crisis is diminishing as time passes.

6.2 Limitation

The limitations of this study are related to three aspects, the sample data and the model used for forecasting, and the forecast period.

In this study, the sample period is from 1997Q1 to 2014Q4, the time span is 17 years in total and only 68 observations are used for the model estimation for each port. The time span is relatively small comparing with previous studies with time series. The development of cargo throughput in each port may not possibly be fully reviewed during the sample period. As the sample size increase, more reliable and valid result may approach.

With respect to the model, as stated in the residuals tests in Chapter 5, the models are not perfectly fitted into the data. The serial correlations exist in linear regression models, the residual terms are not normally distributed and even hetroskadasticity is proven exist in some of the estimations and forecasting models. From the forecast graphs, it can be also seen in sometimes the forecast throughput deviate from the actual throughput for a relatively large prediction error. It additionally indicates the limitations of the forecasting models that are not perfectly fitted into the data. Additional variables or more sophisticated models may improve the estimations and provide better forecasts.

Meanwhile, the advantage of VEC models and VAR models is that both models allow forecasting basing on different scenarios of future development. It should improve the validity in the forecasting outcomes for increasing the flexibility. However, only baseline scenarios are used in this study since the scenario discussion is not included in this study. Moreover, the GDP in each country is assumed to be independent distributed, which is not the case in actual GDP series. It also limits the accurate of models and introduces prediction errors in forecasting.

Forecast period is another limitation. In this study, the out of sample forecast is set for two years (8 years) from 2013Q4 due to the limitation in data availability on GDP projections. The forecast for two years is able to reveal the cargo throughput development in a short run, yet maybe too short for investigating the impact of crisis. The economic crisis may have long term impact for more than seven years (IMF World Economic Outlook, 2009). Considering the economic crisis in 2008 and 2009, the forecasting to 2015Q4 may not sufficient to investigate the long term impact of economic crisis.

6.3 Suggestion for future study

This study in addition shows some suggestions for further studies. Since the limitation of data availability of economic outlook, incorporate an outlook model for GDP as in Van Dorsser et al. (2012) should able to bring more information and forecast cargo throughouts for longer period. The flexibility is not considered in this study, yet it is very interesting to research in other studies.. The Genetic Programming method also allows for the flexibility in setting parameters and simulation. Therefore, for the future study, it would be interesting to investigate the cargo throughput with scenario discussions and using Genetic Programming to take the flexibility into consideration. Moreover, the results indicate that the economic crisis have made permanent impacts on parts of the components of port development. It will also be interesting to investigate which parts are permanently changed and which parts are recovering. Nevertheless, this study only investigate the impact of crisis among the largest ports in Hamburg – Le Havre range, it would be interesting to investigate the impact of crisis with an enlarged sample with not only the large ports but also medium and smaller ports.

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Appendix

A1: Linear regression outputs

Antwerp:

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(GDPB)	2.168537	0.082582	26.25928	0.0000
C	-14.15453	0.936684	-15.11132	0.0000

R-squared	0.912646	Mean dependent var	10.44149
Adjusted R-squared	0.911323	S.D. dependent var	0.183513
S.E. of regression	0.054648	Akaike info criterion	-2.946849
Sum squared resid	0.197101	Schwarz criterion	-2.881569
Log likelihood	102.1929	Hannan-Quinn criter.	-2.920983
F-statistic	689.5497	Durbin-Watson stat	0.605735
Prob(F-statistic)	0.000000		

Hamburg

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(GDPD)	2.802580	0.159291	17.59410	0.0000
C	-27.03400	2.109743	-12.81388	0.0000

R-squared	0.824259	Mean dependent var	10.08461
Adjusted R-squared	0.821596	S.D. dependent var	0.196126
S.E. of regression	0.082839	Akaike info criterion	-2.114854
Sum squared resid	0.452917	Schwarz criterion	-2.049574
Log likelihood	73.90504	Hannan-Quinn criter.	-2.088988
F-statistic	309.5522	Durbin-Watson stat	0.260873
Prob(F-statistic)	0.000000		

Rotterdam

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.909203	1.073293	-2.710539	0.0086
LOG(GDPN)	1.213571	0.091309	13.29083	0.0000

R-squared	0.727999	Mean dependent var	11.35541
Adjusted R-squared	0.723878	S.D. dependent var	0.117314
S.E. of regression	0.061645	Akaike info criterion	-2.705875
Sum squared resid	0.250808	Schwarz criterion	-2.640596
Log likelihood	93.99976	Hannan-Quinn criter.	-2.680009
F-statistic	176.6463	Durbin-Watson stat	0.372555
Prob(F-statistic)	0.000000		

A2: Time series outputs

A2.1 residual correlogram

Antwerp

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.683	0.683	33.118	0.000
		2	0.537	0.133	53.937	0.000
		3	0.323	-0.163	61.590	0.000
		4	0.187	-0.047	64.180	0.000
		5	-0.029	-0.227	64.244	0.000
		6	-0.064	0.097	64.554	0.000
		7	-0.076	0.098	65.002	0.000
		8	-0.016	0.085	65.021	0.000
		9	0.013	0.012	65.036	0.000
		10	0.090	0.021	65.696	0.000
		11	0.010	-0.226	65.704	0.000
		12	-0.006	-0.024	65.707	0.000
		13	-0.135	-0.147	67.288	0.000
		14	-0.219	-0.095	71.528	0.000
		15	-0.351	-0.100	82.607	0.000
		16	-0.390	-0.097	96.526	0.000
		17	-0.438	-0.098	114.42	0.000
		18	-0.284	0.216	122.12	0.000
		19	-0.245	-0.099	127.96	0.000
		20	-0.195	-0.194	131.72	0.000

Hamburg

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.867	0.867	53.404	0.000
		2	0.839	0.353	104.21	0.000
		3	0.777	0.000	148.41	0.000
		4	0.766	0.156	192.05	0.000
		5	0.655	-0.320	224.47	0.000
		6	0.603	-0.074	252.39	0.000
		7	0.502	-0.172	272.08	0.000
		8	0.475	0.101	289.95	0.000
		9	0.327	-0.341	298.56	0.000
		10	0.252	-0.091	303.77	0.000
		11	0.156	0.009	305.80	0.000
		12	0.091	-0.105	306.51	0.000
		13	-0.062	-0.246	306.84	0.000
		14	-0.152	-0.177	308.89	0.000
		15	-0.235	0.105	313.84	0.000
		16	-0.287	-0.034	321.38	0.000
		17	-0.390	0.026	335.59	0.000
		18	-0.435	0.055	353.59	0.000
		19	-0.486	0.000	376.56	0.000
		20	-0.496	0.093	400.92	0.000

Rotterdam

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.793	0.793	44.667	0.000
		2	0.721	0.247	82.109	0.000
		3	0.576	-0.142	106.44	0.000
		4	0.489	-0.005	124.25	0.000
		5	0.434	0.107	138.45	0.000
		6	0.342	-0.103	147.41	0.000
		7	0.312	0.052	155.00	0.000
		8	0.229	-0.068	159.16	0.000
		9	0.193	-0.008	162.16	0.000
		10	0.077	-0.203	162.64	0.000
		11	0.027	0.013	162.70	0.000
		12	-0.000	0.104	162.70	0.000
		13	-0.076	-0.172	163.20	0.000
		14	-0.094	-0.025	163.98	0.000
		15	-0.211	-0.183	167.99	0.000
		16	-0.236	-0.010	173.09	0.000
		17	-0.266	0.080	179.69	0.000
		18	-0.260	0.035	186.15	0.000
		19	-0.192	0.189	189.73	0.000
		20	-0.172	-0.018	192.66	0.000

A2.2 model outputs

Antwerp

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(GDPB)	2.372978	0.238967	9.930168	0.0000
C	-16.47399	2.715800	-6.065980	0.0000
AR(1)	-0.252108	0.087830	-2.870403	0.0056
AR(2)	0.741510	0.085826	8.639692	0.0000
MA(1)	0.999657	0.039702	25.17894	0.0000

R-squared	0.959658	Mean dependent var	10.45055
Adjusted R-squared	0.957012	S.D. dependent var	0.178554
S.E. of regression	0.037020	Akaike info criterion	-3.681962
Sum squared resid	0.083601	Schwarz criterion	-3.516079
Log likelihood	126.5047	Hannan-Quinn criter.	-3.616414
F-statistic	362.7663	Durbin-Watson stat	1.996526
Prob(F-statistic)	0.000000		

Inverted AR Roots	.74	-1.00
Inverted MA Roots	-1.00	

Hamburg

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(GDPD)	2.483416	0.404506	6.139380	0.0000
C	-22.78850	5.369705	-4.243901	0.0001
AR(1)	0.788108	0.082001	9.611000	0.0000
SAR(4)	0.435797	0.118907	3.665025	0.0005

R-squared	0.960085	Mean dependent var	10.11063
Adjusted R-squared	0.958056	S.D. dependent var	0.179189
S.E. of regression	0.036698	Akaike info criterion	-3.710783
Sum squared resid	0.079459	Schwarz criterion	-3.574711
Log likelihood	120.8897	Hannan-Quinn criter.	-3.657265
F-statistic	473.0507	Durbin-Watson stat	2.352552
Prob(F-statistic)	0.000000		

Inverted AR Roots	.81	.79	.00-.81i	-.00+.81i
	-.81			

Rotterdam

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-9.870194	4.666564	-2.115088	0.0384
LOG(GDPN)	1.803372	0.395395	4.560936	0.0000
AR(1)	0.888654	0.044815	19.82953	0.0000
MA(1)	-0.374274	0.135739	-2.757311	0.0076

R-squared	0.918921	Mean dependent var	11.35763
Adjusted R-squared	0.915060	S.D. dependent var	0.116761
S.E. of regression	0.034029	Akaike info criterion	-3.865346
Sum squared resid	0.072953	Schwarz criterion	-3.733723
Log likelihood	133.4891	Hannan-Quinn criter.	-3.813263
F-statistic	238.0066	Durbin-Watson stat	2.039804
Prob(F-statistic)	0.000000		

Inverted AR Roots	.89
Inverted MA Roots	.37

A3: Multi-variate models

VAR

```
VAR Model:
===============================
LOG(YA) = C(1,1)*LOG(YA(-1)) + C(1,2)*LOG(YA(-2)) + C(1,3)*LOG(YA(-3)) + C
(1,4)*LOG(YA(-4)) + C(1,5)*LOG(YA(-5)) + C(1,6)*LOG(YH(-1)) + C(1,7)*LOG(YH
(-2)) + C(1,8)*LOG(YH(-3)) + C(1,9)*LOG(YH(-4)) + C(1,10)*LOG(YH(-5)) + C
(1,11)*LOG(YR(-1)) + C(1,12)*LOG(YR(-2)) + C(1,13)*LOG(YR(-3)) + C(1,14)
*LOG(YR(-4)) + C(1,15)*LOG(YR(-5)) + C(1,16) + C(1,17)*LOG(GDPB) + C
(1,18)*LOG(GDPD) + C(1,19)*LOG(GDPN)

LOG(YH) = C(2,1)*LOG(YA(-1)) + C(2,2)*LOG(YA(-2)) + C(2,3)*LOG(YA(-3)) + C
(2,4)*LOG(YA(-4)) + C(2,5)*LOG(YA(-5)) + C(2,6)*LOG(YH(-1)) + C(2,7)*LOG(YH
(-2)) + C(2,8)*LOG(YH(-3)) + C(2,9)*LOG(YH(-4)) + C(2,10)*LOG(YH(-5)) + C
(2,11)*LOG(YR(-1)) + C(2,12)*LOG(YR(-2)) + C(2,13)*LOG(YR(-3)) + C(2,14)
*LOG(YR(-4)) + C(2,15)*LOG(YR(-5)) + C(2,16) + C(2,17)*LOG(GDPB) + C
(2,18)*LOG(GDPD) + C(2,19)*LOG(GDPN)

LOG(YR) = C(3,1)*LOG(YA(-1)) + C(3,2)*LOG(YA(-2)) + C(3,3)*LOG(YA(-3)) + C
(3,4)*LOG(YA(-4)) + C(3,5)*LOG(YA(-5)) + C(3,6)*LOG(YH(-1)) + C(3,7)*LOG(YH
(-2)) + C(3,8)*LOG(YH(-3)) + C(3,9)*LOG(YH(-4)) + C(3,10)*LOG(YH(-5)) + C
(3,11)*LOG(YR(-1)) + C(3,12)*LOG(YR(-2)) + C(3,13)*LOG(YR(-3)) + C(3,14)
*LOG(YR(-4)) + C(3,15)*LOG(YR(-5)) + C(3,16) + C(3,17)*LOG(GDPB) + C
(3,18)*LOG(GDPD) + C(3,19)*LOG(GDPN)
```

VECM

```
VAR Model:
===============================
D(LOG(YA)) = A(1,1)*(B(1,1)*LOG(YA(-1)) + B(1,2)*LOG(YH(-1)) + B(1,3)*LOG(YR(-1)) + B(1,4)) + A(1,2)*
(B(2,1)*LOG(YA(-1)) + B(2,2)*LOG(YH(-1)) + B(2,3)*LOG(YR(-1)) + B(2,4)) + C(1,1)*D(LOG(YA(-1))) + C
(1,2)*D(LOG(YA(-2))) + C(1,3)*D(LOG(YA(-3))) + C(1,4)*D(LOG(YA(-4))) + C(1,5)*D(LOG(YA(-5))) + C(1,6)
*D(LOG(YH(-1))) + C(1,7)*D(LOG(YH(-2))) + C(1,8)*D(LOG(YH(-3))) + C(1,9)*D(LOG(YH(-4))) + C(1,10)*D
(LOG(YH(-5))) + C(1,11)*D(LOG(YR(-1))) + C(1,12)*D(LOG(YR(-2))) + C(1,13)*D(LOG(YR(-3))) + C(1,14)
*D(LOG(YR(-4))) + C(1,15)*D(LOG(YR(-5))) + C(1,16) + C(1,17)*LOG(GDPB) + C(1,18)*LOG(GDPD) + C
(1,19)*LOG(GDPN)

D(LOG(YH)) = A(2,1)*(B(1,1)*LOG(YA(-1)) + B(1,2)*LOG(YH(-1)) + B(1,3)*LOG(YR(-1)) + B(1,4)) + A(2,2)*
(B(2,1)*LOG(YA(-1)) + B(2,2)*LOG(YH(-1)) + B(2,3)*LOG(YR(-1)) + B(2,4)) + C(2,1)*D(LOG(YA(-1))) + C
(2,2)*D(LOG(YA(-2))) + C(2,3)*D(LOG(YA(-3))) + C(2,4)*D(LOG(YA(-4))) + C(2,5)*D(LOG(YA(-5))) + C(2,6)
*D(LOG(YH(-1))) + C(2,7)*D(LOG(YH(-2))) + C(2,8)*D(LOG(YH(-3))) + C(2,9)*D(LOG(YH(-4))) + C(2,10)*D
(LOG(YH(-5))) + C(2,11)*D(LOG(YR(-1))) + C(2,12)*D(LOG(YR(-2))) + C(2,13)*D(LOG(YR(-3))) + C(2,14)
*D(LOG(YR(-4))) + C(2,15)*D(LOG(YR(-5))) + C(2,16) + C(2,17)*LOG(GDPB) + C(2,18)*LOG(GDPD) + C
(2,19)*LOG(GDPN)

D(LOG(YR)) = A(3,1)*(B(1,1)*LOG(YA(-1)) + B(1,2)*LOG(YH(-1)) + B(1,3)*LOG(YR(-1)) + B(1,4)) + A(3,2)*
(B(2,1)*LOG(YA(-1)) + B(2,2)*LOG(YH(-1)) + B(2,3)*LOG(YR(-1)) + B(2,4)) + C(3,1)*D(LOG(YA(-1))) + C
(3,2)*D(LOG(YA(-2))) + C(3,3)*D(LOG(YA(-3))) + C(3,4)*D(LOG(YA(-4))) + C(3,5)*D(LOG(YA(-5))) + C(3,6)
*D(LOG(YH(-1))) + C(3,7)*D(LOG(YH(-2))) + C(3,8)*D(LOG(YH(-3))) + C(3,9)*D(LOG(YH(-4))) + C(3,10)*D
(LOG(YH(-5))) + C(3,11)*D(LOG(YR(-1))) + C(3,12)*D(LOG(YR(-2))) + C(3,13)*D(LOG(YR(-3))) + C(3,14)
*D(LOG(YR(-4))) + C(3,15)*D(LOG(YR(-5))) + C(3,16) + C(3,17)*LOG(GDPB) + C(3,18)*LOG(GDPD) + C
(3,19)*LOG(GDPN)
```

A4: Test cargo throughput gap

Gap between Rotterdam and Antwerp

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	58624.60	909.4869	64.45898	0.0000
D2	-1428.352	1016.837	-1.404701	0.1735

R-squared	0.079012	Mean dependent var	57481.92
Adjusted R-squared	0.038969	S.D. dependent var	2074.497
S.E. of regression	2033.675	Akaike info criterion	18.14969
Sum squared resid	95124141	Schwarz criterion	18.24720
Log likelihood	-224.8712	Hannan-Quinn criter.	18.17674
F-statistic	1.973185	Durbin-Watson stat	2.679392
Prob(F-statistic)	0.173472		

Gap between Rotterdam and Hamburg

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	72345.80	975.8304	74.13768	0.0000
D2	-2823.849	1091.012	-2.588285	0.0164

R-squared	0.225569	Mean dependent var	70086.72
Adjusted R-squared	0.191898	S.D. dependent var	2427.316
S.E. of regression	2182.023	Akaike info criterion	18.29051
Sum squared resid	1.10E+08	Schwarz criterion	18.38802
Log likelihood	-226.6314	Hannan-Quinn criter.	18.31756
F-statistic	6.699220	Durbin-Watson stat	2.492946
Prob(F-statistic)	0.016435		