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ΝΑΥΤΙΛΙΑ

Correlation and Volatility Dynamics Across International Freight Indices

Τυπογιώργος Δημήτριος

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ABSTRACT

This paper aims to provide correlation, volatility and dynamics across international freight indices. The findings of this dissertation are of critical importance in development and construction of investment portfolios in the maritime sector especially on periods the experience high volatility or market shocks. We incorporate three existing indices the BDI (Baltic Dry Index) that tracks worldwide international shipping prices of various dry bulk cargoes, BEP (Baltic Exchange Panamax Index) which is one of the four indices that are forming BDI and BEC (Baltic Exchange Capesize Index). Using prediction models we aim to investigate two scenarios. The first is if there are statistically correlated positively or not the three above mentioned indices, and secondly the objective is to investigate if those indices are following a lead lag pattern after a market's shock. The data of this dissertation were collected from the Shipping Intelligent Network operated by Clarksons. Our results seem to suggest that there were time lags between these three indices. Moreover, the relationship between those indices was more positive rather negative. The message of the findings for a diversified investment portfolio is that worldwide shocks affect the volatility and the correlation of those markets so any possible risk diversification benefits in positively related assets. In addition it is important to realize the value of rebalancing of those portfolios due to the time-varying nature of those indices correlations. Although it is important to mention that due to the several internal and external factors that the maritime sector is affected from, and the global environment that this sector operates is difficult to evaluate and utilize the analysis.

1. INTRODUCTION

1.1 Characteristics of the shipping industry

Shipping is a very important industry since it serves the 90 % needs of international trade it has played a very important role in worldwide economic development over the centuries and has provided a means through which several countries in entirely different geographical areas have established commercial relationships. The main services provided in the shipping industry are the shipload services, which move goods in bulk according to the demand conditions and not on a regular basis and linear services which carry relatively small equipments of general cargo on a regular schedule for many shippers. The firms that operate in the shipping industry offer or charter out their vessels to importers or exporters while receiving a corresponding fee through an efficient network of shipping brokers (**Stopford, 2008).**

Depending on the nature of the cargo transported the industry consists of the dry bulk sector, the tanker sector and the containership sector. Dry bulk ships carry products such as iron steel, coal which are significant inputs for the industrial sector. Tankers carry petroleum chemical products and refined products. Containerships carry any kind of products that can be shipped in bundles something, which renders this means of transporting goods very flexible and has naturally led to an enormous growth of this sector.

Referring to the linkage of cash flows the shipping industry consists of the freight market, the new building market, the second hand market and the scrap market. The freight market is a service market in which cargo owner's charter vessels to cover their transport needs. The new build market is a rather different market since the product traded does not exist. As we know it takes a lot of time for a ship to be constructed and payments for a specific ship are made in parts.

The new building market is very significant since it is a market that major yards compete internationally to receive orders from agents that are or plan to be ship-owners. In the second hand market the parties that are involved are the ship builders and the ship brokers and their interaction in the market is based on the sale or purchase of a ship according to certain price. The price of the ship depends on the age of the ship its quality attributes, the general market conditions, the prevailing level of freights e.t.c. The scrap or demolition market refers to the conversion of the ship into steel and other components when it can no longer be used since its age has exceeded its estimated lifetime .**(Stopford, 2008)**.

The demand for shipping services apart from the level of freight which is supposed to be an endogenous factor is affected by factors such as the state of the global economy the way natural resources are allocated amongst several geographical areas or elsewhere their dispersion, the political conditions, natural disasters e.t.c .**(Stopford, 2008)**.

The supply for shipping services depends on factors such as the fleet size, the scrapping of vessels, the flow of new orders for ships, the capacity for shipbuilding, the labor and capital productivity etc. All the above factors affect the supply and demand for services and therefore the level of freights. If for instance the capacity for shipbuilding shrinks the supply curve will shift to the left and freights will rise or if a natural disaster occurs the demand for shipping services will drop and therefore freights will normally decline .**(Stopford, 2008)**.

In this dissertation we try to investigate from an investor's point of view, what would be the best way to construct a model portfolio with assets of the shipping sector? The point of working with the three indices of the dry bulk sector is so as to specify and isolate the factors as much as we can in a rather global sector with several internal and external factors that affect this industry. However, the models that have been used in this thesis are the Vector Autoregressive Model (VAR), the Vector Error Correction Model (VECM) which tries to approach and examine presence of relationship between these factors. The Dynamic Conditional Correlation (DCC) is a model that captures the time – varying correlations, and also computes correlations among freight returns. Preliminary Statistics such as means, standard deviations, skewness etc and empirical results helped us to compare with the above mentioned models and lead us to our conclusions and results.

1.2 Charter contracts

The parties that get involved in the freight market are the ship owners who own the vessels, the charterer who carry the cargo and the ship brokers who bring into contact the ship owner and the charterer. The most common contractual arrangements are the voyage charter contract , the time charter contract and the bareboat charter contract.

In the voyage charter contract case a cargo is transported from one place to another for a fixed price per ton, and the ship owner undertakes all the costs relating to the ship meaning that apart from being the owner of the ship he also has the responsibility of transporting the good. The charterer through his ship broker will ask which ships are available for the transportation of the specific cargo for a specific destination and he will close the deal at a specific freight rate which covers all the expenses relating to the trip and at the same time generates a profit margin for the ship owner. A Consecutive Voyage Charter is similar to a Voyage Charter, but the ship is contracted to undertake a series of cargo carrying voyages on a defined route (**Crarkson, 2004)**.

In a time charter contact the ship owner attains the management and ownership of the vessel while the charterer uses the ship. The ship owner pays the financing and operating costs of the ship while the charterer being in charge of the commercial operations of the ship bears the entire voyage costs. The ship owner being aware of the relating costs will charge a corresponding freight rate. Ship owners might also resort to time chartering if they do not have the adequate capital to finance the purchase of more ships or if they want to spread their risk by possessing a mix of owned and chartered ships (**Crarkson, 2004)**

Time chartering or subcontracting is attractive to the shipper for the following reasons. First time chartering does not require committing a considerable amount of capital; therefore it can be economically more convenient. Secondly, time chartering will be cheaper especially if the ship owners operating costs are low. Third the shipper might use time chartering for speculating reasons.

A bareboat chartering contract is created when the charterer wants to have full operating and technical control of the ship but at the same time does not want to be the owner of the ship due to the above mentioned reasons. The charterer manages the vessel and pays all operating and voyage costs while the ship owner is not active in the operation of a vessel and does not require any specific maritime skills. At the end of the charter the ship is returned to the owner, although some bareboat charters include an option to purchase the vessel on termination of the charter (**Crarkson, 2004)**

1.3 Positioning and diversification in the shipping market

As already mentioned the freight market is very volatile which means that the charterer should be aware of the shipping cycle so that he hires the vessel at the right time and at the right place. By the term positioning we refer to the charterer ability to place his vessel near regions where the demand for shipping services is high. A positioning strategy should have as an objective to select a chart in such a way so that the vessel will be led at the profitable locations at the appropriate time (**Mageirou, 1997)**.

An optimal chartering decision involves the selection of the appropriate charter that maximizes the daily revenue net of voyage costs. This is often referred as maximizing the time charter equivalent. The charter equivalent maximization is being performed not only for one voyage but for many future voyages as well as long as the future freight rates can be forecasted in a relatively effective way. When the profitability of future voyages is estimated, then the corresponding revenues should be discounted taking into consideration the time value of money. Moreover, if the vessel operates jointly with other vessels, than the positioning strategy should be employed for the fleet as a whole. Another aspect of a positioning decision is to consider the cost of switching amongst cargos if the vessel we refer to is a combined carrier (**Mageirou, 1997)** .

Diversification in shipping is very popular in view of the volatile shipping environment. Diversification is accomplished if a ship-owner does not invest only in one sector but operates several types of vessels in different sectors. The benefit of diversification is to be weighed against possible increases in operating costs that result from running several types of vessels, and the loss in expected earnings that is in line with reduced risk.

Diversification in the shipping industry is quite difficult due to the fact that most freight indices exhibit positive correlation with each other. If for instance the tanker market performs well than the bulk sector will perform well too. This will occur since both sectors are influenced by the same underlying factor which is the level of economic activity**.** The high correlation amongst indices can also be documented from a technical point as well. If the tanker freights are high, then many combined vessels will switch from the bulk to the tanker sector. This will result in a shortage of supply in the bulk sector and therefore in an increase in the corresponding freights (**Mageirou, 1997).**

1.4 The impact of the crisis of 2008 on the shipping industry

While shipping has benefited from globalization since more and more countries participated in international trade, the industry was largely exposed to the financial crisis of 2008. Freight and charter rates considerably dropped, jobs at shipping companies were lost and many ships were laid off.

Before the crisis year after year, new and ever more massive ships were built, ports were expanded and new scheduled service introduced. The cargo capacity of the world's combined container fleet increased from 4 million TEUs in 2000 to 12.5 million at 2008.

At the beginning of 2008, large commercial shipping companies like Maersk and Hapag-Lloyd were still charging about $2,000 to ship a container from Asia to Europe. After the crisis , some companies were collecting only $500 for the same service. Before the crisis , it cost $30,000 a day to charter a ship containing 2,500 standard containers (TEU). When the crisis broke up , that price has dropped to less than $12,000 .Bulk commodity freighters in the Panamax class commanded a daily charter fee of $64,000 in June 2008. At the end of 2008 they could be provided for less than $11,000 (www.businessweek.com/globalbiz/content/dec2008/gb2008128_376582.htm. Thomas Schulz December 2008)

The low freight and charter rates, combined with the decline in trade volumes, have led to historical financial losses for the operators. The world's largest container shipping company, Maersk Line, reported a loss of $2.1 billion in 2009. Hanjin Line lost $1.1 billion during the same year, Neptune Orient Line lost $741 million, and similar losses were recorded all across the industry.8 The shares of container carriers today are worth two-thirds less than at their peak in 2007**.(Clarkson report 2009)**

Although ship owners were familiar with recessions in the industry following huge booms, the recent crisis was unprecedented in the industry's history. The shipping of raw materials that are so important for international trade came to a halt since banks were reluctant to issue letters of credit to the exporters. The big problem was that the industry is capital intensive and at that time there was a considerable lack of capital. (www.businessweek.com/globalbiz/content/dec2008/gb2008128_376582.htm. Thomas Schulz December 2008)

Almost all shipping companies sent teams to the shipyards in Korea and Japan to negotiate cancellations or postponements in view of the deteriorating global economic conditions. According to industry estimates, at least one-fourth of all ships under construction worldwide, worth a total of about $500 billion), either lacked sound financing or could not be financed at all. The combination of excess of capacity with declining consumption contributed to the BDI freight index drop from 8.500 points to 733 points. (www.businessweek.com/globalbiz/content/dec2008/gb2008128_376582.htm. Thomas Schulz December 2008)

Many ship financiers decided to forfeit down payments already paid to the shipyards, which can amount to up to 40 percent of the total price, because they lack the additional funds needed to take delivery of the ships they had already. Many others were trying to negotiate with the shipyards a delay construction, in the hope that the situation would improve significantly in the following years. **(Alexander Jung, Thomas Schulz and Wieland Wagner, 08/11/2009)**

The crisis that hit the marine industry apart from everything was the result of two types of irrational behavior that ship owners' exhibit when trying to maximize their profits. The first mistake is associated with the flawed decision making process where the involved parties exhibit extreme optimism or pessimism leading to a herding behavior despite the existence of the shipping cycle that provides investors wi th a sort of forecasting tool. The financial consequences are reflected in freight rates which demonstrate adverse upward or down ward movements. A mistaken analysis of the shipping cycle could result to freight rate distortions which in turn would trigger wrong decisions such as for instance when to order a ship or when to sell it. **(grammenos 2002)**

The second type of mistake refers to the luck of information investors have regarding the market which leads to bad decisions. An investor should not only rely on investment sentiment but should possess broad knowledge of the entire market. **(eclac Issue 271, Number 3/ 2009 The economic crisis and the maritime and port sector).**

However the roots of the crisis in the shipping industry are not necessarily found in the decline of global demand. The deterioration in economic conditions was the final factor that resulted in the collapse of the shipping sector. Most of analysts had warned of a downturn for at least a couple of years prior to mid 2008 due to the growing size of the order book. Although many ship owners shared this view almost all were caught out by the extent and severity of the fall. **(CEFOR 24TH March 2010)**

The main roots of the downturn in the bulk sector apart from the financial crisis were the following

- The extra fleet supply from vessels being delivered
- A complete absence of scrapping of bulk carriers
- A fall in congestion during 2007 releasing many ships in 2008

Although global demand has been recovering due to the highly developing market of China, India and Brazil the shipping industry is still very far from reaching the pro crisis levels which in fact constituted a shipping bubble. The problem is that the surge of the legacy in new buildings will be evident for many years to come.

1.5 The shipping cycle

The shipping cycle is a concept that refers to the fact of how freights respond to the change of market conditions and to be more specific to supply and demand. The shipping cycle also tries to identify the factors that affect the selling price of the ship and what kind of ships are being sold when the market is at a recession. It consists of four stages such as trough, recovery, peak and collapse **(Stopford, 1997)**.

The maritime cycle can be described as what economists call a cobweb cycle in which price and output behave in a cyclical way : in a given period, prices are above the equilibrium level, which means that supply in the following period due to the lag effect that will be described below will be higher than the equilibrium level. Once supply is above the equilibrium level, prices will be below that equilibrium level, and so on. Therefore a sequence of balances and imbalances between supply and demand give rise to the Cobweb effect **(eclac Issue 271, Number 3/ 2009 The economic crisis and the maritime and port Sector).**

The stage of trough is characterized by excess in capacity in which ships begin to accumulating at trading ports while ships that are traveling delay their arrival to save up cost. At this stage freights will decline to such a point that they will be equal to operating costs rendering the entire business non profitable, so many shipping companies enter into financial trouble. The selling price of the ship might reach its salvage rate **(Stopford, 1997)**.

At the stage of recovery supply and demand tend to move towards equilibrium the market regains to some extent its optimism while more ships start traveling being stimulated by the improvement in demand conditions. Finally freights rates enter into an upward trend

At the stage of peak most of the fleet of ships in operation and only the most inefficient vessels are laid off. At his stage there is perfect equilibrium between supply and demand though this equilibrium is rather shaky. Freights range at very high levels leaving huge profit margins for the shipping companies. The latter generate very high cash flows **(Stopford, 1997)**,.

At the stage of collapse there is excess of supply, therefore freights start to decline. Although shipping companies are still at a satisfactory financial condition they shrink to a great their operations leaving the majority of their fleet at port **(Stopford, 1997)**.

Cuffley (1993)drew attention to three fundamental events that take place in a shipping cycle. First a shortage of ships exists which results in the sharp increase of freight rates. Then high freight rate result in over ordering of ships which are delivered with a time lag. Finally, excess of supply, leads to the collapse of the market and to a recession.

Haptons (1991) describes the shipping cycle as following : higher freight rates trigger increased orders but those orders will at some point of time undermine freight rates so the latter will decline and will encourage demolition. Reduced ordering and demolition shrink the supply and set the grounds for a new upward trend in freight rates. According to Hampton shipping cycles are unpredictable because investors are the ones who determine what happens and their course of action varies from case to case. Investors do not act always rationally when it comes to investment decisions and they over react to price signals being trapped in a mix of feeling of fear and greed. This means that investors take decisions on the basis of emotion overlooking very often the objective economic conditions **(Stopford, 2008)**

Seasonal cycles occur very often and represent the fluctuations that occur within a year in response to seasonal patterns of demand for sea transport. In the agricultural trades there is a noticeable cycle in freight rates for ships carrying grain which has to do with the timing of harvesting. Another strong seasonal cycle in the reefer trade exists and is associated with the movement of fruit during the harvest in the northern hemisphere **(Stopford, 2008)**.

The main causes of shipping cycles are the business cycle of the world economy. The latter injects a cyclical pattern into the demand for ships which works through into the sea trade. Historically there has been a close relationship between cycles in world production and cycles in sea born trade. During the major economic crisis of 1957 , 1973 ,1981 and 1997 the correlation was particularly clear **(Grammenos, 2002).**

Business cycles occur due to firms overestimating inventory requirements during cyclical upswings and then reducing inventory to a great extent when the economy dips into a recession. This means than investors overreact to price signals meaning that they emphasize the upswing of a cycle and they are too pessimistic when the economy is at a depression (**Grammenos, 2002).**

Moreover it has been said that the multiplier effect contributes as well to the formation of business cycles. When the economy recovers and investment increases the increase in income will be bigger so the economy will expand rapidly. When labor and capital will be fully employed as a result of the expanding economy, the expansion will come to a halt and the upward trend will instantly be reversed. **Grammenos, 2002**

1.6 Freight fluctuations

Based on the analysis of the shipping cycle it is reasonable to infer that freight indices fluctuate according to the stages of the cycle that characterize a certain period. When the market is at a peak, freights are at very high levels while when the market is at the stage of recession the level of freights barely covers operating costs.

Generally speaking the fluctuation of freight rates is very significant for decision making purposes. When the freights are high shipping companies are making big profits and ship-owners are motivated to build new ships to exploit the current opportunity. When freights are low this has a significant impact not only on ship-owners but on the entire economy and society and particularly for the economies that heavily rely on marine services. Banks for instance bear a high risk on their shipping loans since the probability of default from the part of ship-owners that resorted to borrowing is high. For the above reasons bankers should always be aware of the nature of the shipping cycle. Moreover when freights are low the quality of services considerably drops since ship companies seek for ways to reduce their cost. Low profits in the shipping industry result in ships layoffs which in turn can result in unemployment for the crew that works in the industry. Finally the construction of a ship requires several kinds of inputs therefore the level of shipping activity has an impact on other sectors as well. Moreover many countries that are deeply engaged in international trade will be significantly affected by the level of freights **(*Meifeng Luo, Lixian Fan and Liming Liu A dynamic-economic model for container freight market*)**.

As we mentioned before the industry is cyclical, something which means, that the companies' profitability and cash flow stream exhibits particularly high volatility. The more aware is a company of the shipping cycle the better it will synchronize its ship purchases with the predicted market conditions and therefore the lowest will be its operational and financial risk. When analyzing the credit risk of a company factors such as economies of scale, economies of scope, revenues characteristics, operating efficiency, cash flow volatility and capital mix should be considered. (www.careratings.com/Content/creditratings/ship.pdf). CREDIT ANALYSIS & RESEARCH LIMITED

The industry apart from being cyclical is capital intensive since the cost of purchasing a ship can range from 20 to 300 mn. The age of the ship can substantially affect profits since the higher the age, the higher the cost and the more vulnerable are vessels to accidents. (www.careratings.com/Content/creditratings/ship.pdf). CREDIT ANALYSIS & RESEARCH LIMITED

Due to the importance of freight fluctuations many economists have been concerned with this issue. A very special feature in analyzing this phenomenon is the time lag between the order of the new ship and its deployment in the fleet. Due to the time lag element, fluctuations can be very intense. When for instance demand sharply increases, the time lag in shipbuilding will prevent supply to match in time increasing demand therefore freight rates will be rising, until this lag is smoothed. If demand declines, the ships that have been ordered will be delivered later so at a point of time there will be an even bigger supply than the one that should be justified according to the market conditions. As a result of this freights will drop much more compared to the situation where supply would respond more imminently to the market conditions. This would happen if no lag existed **(Stopford, 2008)**.

1.7 The development of freight derivatives for hedging strategies

Since the shipping industry is characterized by high volatility in freight rates, seasonality, strong business cycles and capital intensiveness exposure to risk can be very significant. Therefore managing the existing risk effectively is a very crucial issue for the agents that are involved in the industry. A very important source of risk is the freight risk which has necessitated the development of freight derivatives to deal with this type of risk. The volatility in freight rates implies a significant risk element for both the charterer and the ship-owner. If the freight rate rises, then the charterer who hires the vessel will realize higher costs. If the freight rate drops then this will be at the expense of the ship-owners interest. Forward freight arrangements can be beneficial to both parties since they represent contracts which settle a freight rate for a specified quantity of cargo or type of vessel for usually one or a combination of trading routes of the dry bulk or the wet bulk sectors of the shipping industry. (www.uadphilecon.gr/UA/files/83154291..pdf).

The above mentioned contracts enable the involved parties to lock in a freight rate. But this does not mean that the hedging strategy will yield the best outcome. Lets assume that a ship-owner wants to rent his vessel in one year and he desires to prearrange the freight rate. In this case he will resort to the futures market. But if in one year the freight rate will be at a much higher level than the prearranged price the ship-owner will have lost the opportunity to have a rented his vessel at a more convenient price. On the other hand by using the futures market he has fixed his price therefore eliminating risk.

Although little research has been done with respect to how futures freight contracts behave compared to other type of derivatives due to unavailability of data , it has been found that certain types of freight contracts are unbiased estimators of the prevailing spot freight rates. The BIFFEX which was the first derivative freight contract that was introduced in the market was not accepted as a viable hedging mechanism since its composition not sufficiently representative of the conditions prevailing in the shipping industry. While the majority of the investment community recognized the importance of the FFAS they still were not extensively using them since they lacked knowledge regarding the function of those contracts. Most of the investors were concerned with the probability of payment default on settlement, The benefits of trading those contracts should be effective risk management and price discovery. It still quite premature to assess if the FFAS effectively perform these functions. (www.uadphilecon.gr/UA/files/83154291..pdf)

Kassouvanos has investigated the impact of the FFAS contract introduction on spot freight rates volatility. By using the Garch model, he found that the onset of the FFAS has had a stabilizing effect on freight rate volatility. However if the model was transformed by including in the conditional variance equation other explanatory variables results indicated that the reduction of volatility was just partly attributed to the existence of FFAS.

1.8 Liner shipping market

Liner shipping is a sophisticated network of regularly scheduled services that transports goods from one place to another at any place in the world at low cost and with greater energy efficiency . There are approximately 400 liner services in operation today, most providing weekly departures from all the ports that each service calls. With respect to its efficiency a liner boat can carry up to 200.000 container loads of cargo. Many container ships have such a size that they can carry up to 8.000 containers in a single voyage. Today, the liner shipping industry transports goods representing approximately one-third of the total value of global trade. The containerized trade has been increasing four times faster than that of the world seaborne trade from 1985 to 2007. This indicates the importance and the dynamics of the liner shipping sector **(Stopford, 2008)**.

Linear shipping was developed due to the need of transporting quantities of cargos that were too small to be carried in a single ship. The liner operator should primarily perform the following functions **(Stopford, 2008)**:

- Offer a regular service for many small cargo consignments

- Load the cargo into the ship in a way that ensures that it is accessible for discharge
- Run the service to a fixed schedule
- Charge individual consignments on a fixed tariff basis that generates an overall profit

Due to high overheads and the need for the vessels to travel even when the ship is not full of cargo liner companies are very vulnerable to price competition from other companies that function in the same trading route. For this reason many conferences take place which ensure that competition will not threaten the existence of liner companies (**Stopford, 2008)**.

1.9 Tanker Market

A tanker is defined as a vessel that is designed specifically to carry liquid cargos. Refined oil products and crude oil are the most common types of cargo carried in such vessels but tankers also transport chemicals wine vegetable and other food oils. The market for crude oil tankers is considered to be the largest in the shipping industry.

The demand for tanker services is viewed by economists as a derived demand since the transportation of oil is made to add value to the commodity by selling it in a market where the marginal utility to the consumer is much higher than it is at the point of production. The process of moving oil is not determined by the consumer but by the production process as long as oil is usually used as an input. The rules that deternimne demands responsiveness for oil movements are the following **(Grammenos, 2002):**

- The elasticity of demand for transportation of oil will be higher the higher the elasticity of demand for the final product

- The elasticity of demand for transportation of oil will be higher the higher the degree of substitutability between the factor and other factor inputs in the production process.

- The elasticity of demand for oil transportation will be higher the highest the share that the oil as an input in the overall costs of the final product.

- The elasticity of demand will be higher the higher the elasticity of supply of the factor input.

From the above rules we can easily draw the conclusion that the elasticity of demand for oil transportation with respect to changes in the freight rate will be particularly small converging to zero (**Grammenos, 2002)**.

The supply of oil tankers is determined by all those vessels that are devoted to the movement of crude oil. It constitutes about 40 % of the worlds merchant fleet. The worlds tanker fleet is segmented into various submarkets according to the size of the vessel and the product type those vessels transport. The primary routes for those vessels ate from the Middles East to Japan and the Far East. Trading to Europe iS the other primary route**.**

The world tanker fleet has been rapidly growing over the last decade due to the remarkable increase in global oil trade. The world tanker fleet consists of more than 10.000 vessels amounting to more than 440 mil DWT. Crude oil is the largest commodity to be carried in tankers**.** As far as vessel size is concerned the tanker fleet has grown to an average of around DTW while the average size of the vessels on order book is more than 60.000 DWT indicating that there is a shift towards larger vessels. Nearly 35 % of the world fleet by volume comprises of very large crude carriers.

(www.mantrana.in/Tanker.html). Mantrana Maritime Advisory Pvt. Ltd.

Referring to the outlook of the sector, in the long term it is expected to expand both in number and average size. While the number of ports that can handle larger ships increases it will be easier to exploit economies of scale**.**

(www.mantrana.in/Tanker.html). Mantrana Maritime Advisory Pvt. Ltd.

1.10 Characteristics of the dry bulk market

Dry bulk commodities represent 38 % of the international seaborne trade. These commodities are divided into two distinct categories such as major bulks and minor bulks. Major bulks include iron ore, coal and grain, and are shipped on the larger size Capesize and Panamax vessels. They comprise 67% of the dry bulk trade. Minor bulks are fertilizers, steels, sugars, cement etc., which are shipped in smaller vessels such as Handymax and Handysize, and comprise about 33% of the dry bulk commodities trade (**Bornozis, 2006**) .

Iron ore and coal are the two most important major bulk commodities with 27% and 26% of total dry bulk trade respectively, with grain accounting for the remaining 14%. The global dry bulk fleet includes about 6,271 vessels which are distinguished into four basic categories based on their carrying capacity in deadweight tons (dwt). These statistics refer to the period of 2006 (**Grammenos, 2002)**.

As far as the trading routes are concerned coal is mainly shipped from Australia and Canada to the Far East and Europe, while iron ore is mainly shipped from Australia and Brazil to China, Japan and Europe. Grain is shipped mainly from the US Gulf, Brazil or Argentina to Europe and to the Far East (**Grammenos, 2002).**

Technological developments have led to the construction of larger vessels that do not only benefit from economies of scale but also match specific cargo and route requirements . Dry bulk shipping can be divided into four different sectors according to the carrying capacity of the vessels. These are handysize (30.000 dwt), handymax (45.000 dwt), panamax (65.000 dwt), and capesize (120.000 dwt and over) markets (**Grammenos, 2002)**.

While the tanker market is highly concentrated the bulk market has a more competitive structure with more than 1000 companies operating in the particular sector. Dry bulk vessels are employed either in the spot or the period time charter markets. The spot market refers to contracts for one or more voyages than can last up to a few months. Period time charters can range from several months to several years. Generally speaking , spot rates are usually higher than time charter rates. Spot rates generate higher profits when the market is doing well but those contracts imply much higher risk compared to period time charters which generate for the companies a more steady cash flow in the long term, therefore resulting in lower risk. The sector has demonstrated enormous growth rates from the beginning of the new century and until 2008 when the financial crisis broke up, due to increasing demand for dry bulk commodities. The sharp rise in demand was attributed to the strong industrial development in the economies of China, India and Southeast Asia (**Bornozis, 2006).**

The main advantage of bulk shipping is that economies of scale can be achieved while moving to the employment of bigger vessels. For example moving from a Handy bulk carrier to Handy max saves about 22 % per tone while upsizing to a Panamax bulk carrier saves 20 %. The use of Capesize saves 36 % which means that when the biggest vessels are employed almost half of the cost can be saved. Many large companies that transport big quantities of bulk cargo sometimes run their own shipping fleet (**Stopford, 1997)**

However when a charterer uses a huge carrier in order to minimize the average cost, he faces the following restrictions. First an industry will be willing to accept a maximum size of delivery which means that a certain type of ship might be too large to carry a specific cargo. This will result in the ship being half empty which in turns will result in a non efficient utilization. Secondly there are constraints imposed by some port authorities regarding the lay off of certain types of ships. A port might not have the infrastructure to receive a large bulk carrier something which will limit the shippers options regarding the scheduling of the trading routes **(Stopford, 1997).**

1.11 The trend of the bulk shipping sector over the last 50 years

In this section we describe how the industry evolved over the last decades starting from the 50s

In 1951 the Korean war led to increasing demand for shipping services. By the end of the war, freights considerably dropped due to conditions of over supply. By 1953 laid up tonnage had considerably increased. Owing to the recovery of the global economy, freights process started going up from 1954 and reached a peak in 1956. When the Suez Canal reopened, prices started declining signaling the beginning of a new recession in the market **(Tsolakis, 2005).**.

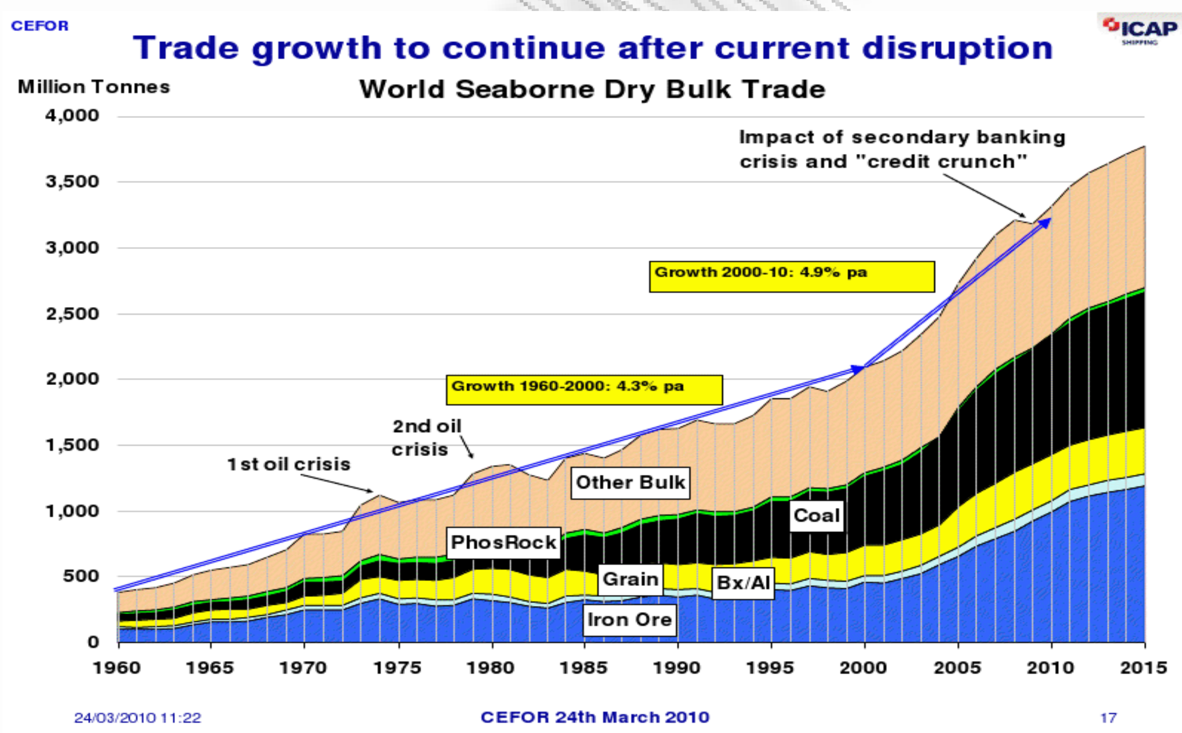
One of the most profitable periods for the industry after the Second World War, was the 1967 – 1973 period in which freight rates soared and the sector that benefited most from the high growth of the global economy was the tanker sector. Banks being carried away by the euphoria in the shipping industry and particularly in the tanker sector, were financing even more than 90 % the purchase of a ship. The oil crisis after 1973, brought about a deep crisis that severely affected the shipping sector. **(Tsolakis, 2005** The recession that followed was very deep due to the over supply of tankers many of which were built for speculative reasons, the excess in shipyard capacity, and the dramatic decline in imports of oil due

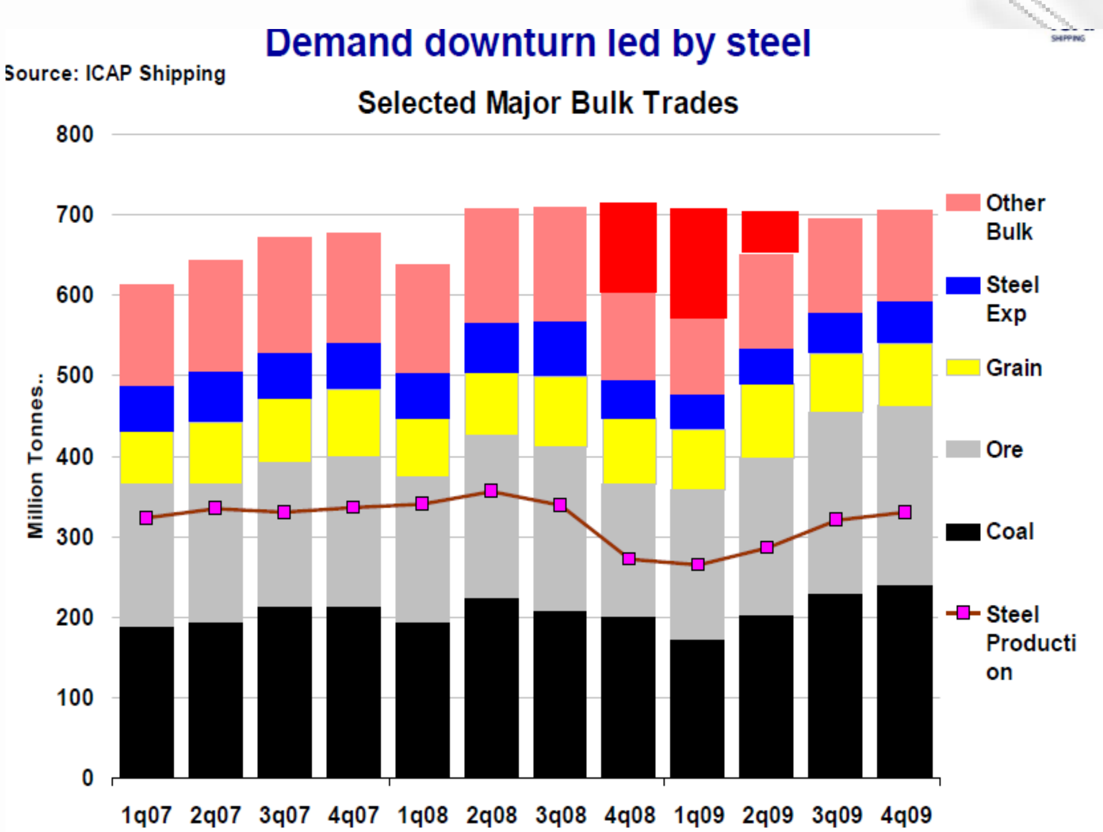
As far as bulk market was concerned in that period, the supply of ships carrying dry cargo increased due to the conversion of many tankers to bulk carriers. The dry bulk market unlike the tanker market reached a peak in 1974 and remained depressed until 1978 when it started recovering. One of the main reasons for the recovery was the high growth in demand for bulk commodities and the switch of power utilities from oil to coal that substantially increased thermal coal trade **(Tsolakis, 2005)**.

The increase in freight rates for the bulk industry continued until 1981. A sharp decline followed, that continued in 1982. The daily earnings of a Panamax fell from $14,000 per day in January 1981 to $8,500 per day in December 1981. A fall in commodity prices, a stagnant coal trade and elimination of congestion pushed rates down to levels that by 1983-84 some brokers were describing as particularly low. Equilibrium was restored by the end of the decade when five-year old Panamax, which sold for $6 million I 1986, was worth $12 million in 1987, $17 million in 1988 and $23 million in 1989. According to many analysts the bulk industry suffered a deeper crisis in the decade of the 80s compared to the previous decade **(Tsolakis, 2005**.

During the 90s the bulk industry experienced a strong growth until 1995 despite the global economic recession that started from 1993. The reason was the low orders that were placed the previous years which prevented the creation of over capacity. After 1997 the Asian and Russian crisis had a devastating effect in the bulk carrier market resulting in a large drop in freight rates. Ship building prices were severely affected by the increase in competitiveness of Korean building ships. The increase of competitiveness in the ship building sector was mainly attributed to devaluation of the local currency against the dollar. Bulk carriers started recovering first, along with improvements in world economy in late 1999 early 2000 and the recovery lasted until 2008 when a new financial crisis originating from the US affected the global economic environment and therefore the shipping industry as well **(Tsolakis, 2005**.

In the table below we can see the trend of the bulk trade from 1960 and the projected estimates until 2015.




Demand downturn led by steel
Source: ICAP Shipping
Selected Major Bulk Trades
Million Tonnes..
800
700
600
500
400
300
200
100
0
1q07
2q07
3q07
4q07
1q08
2q08
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4q08
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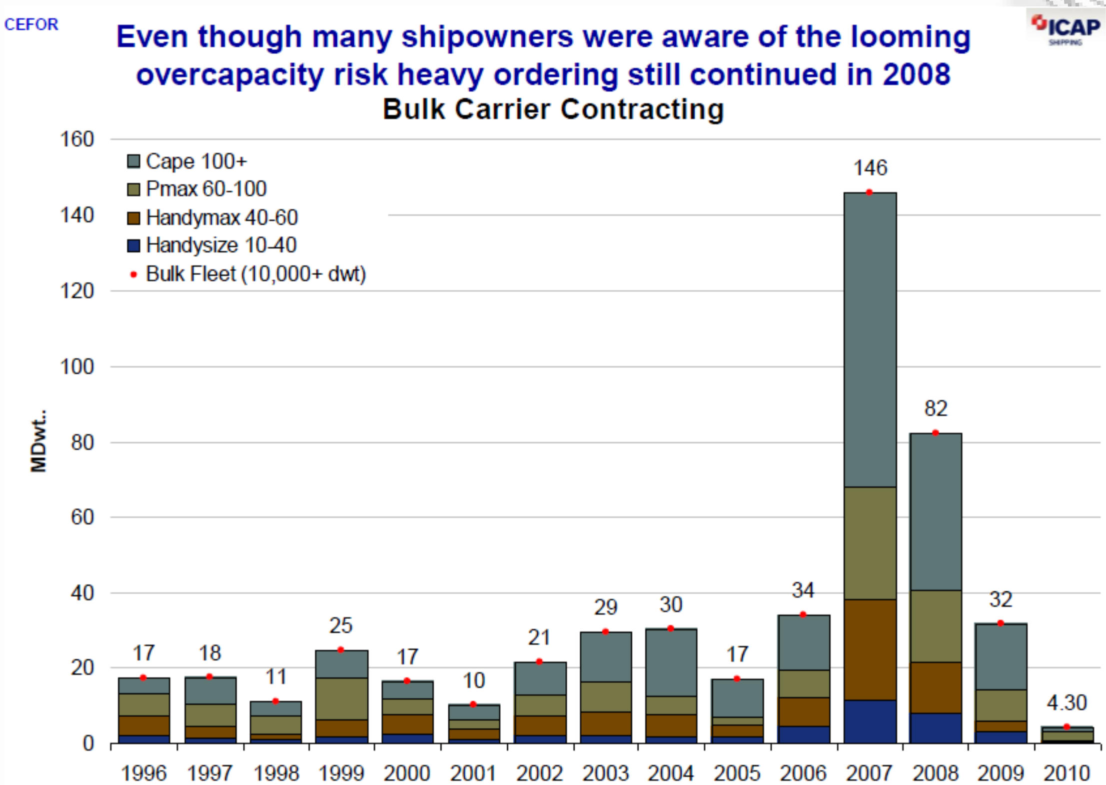
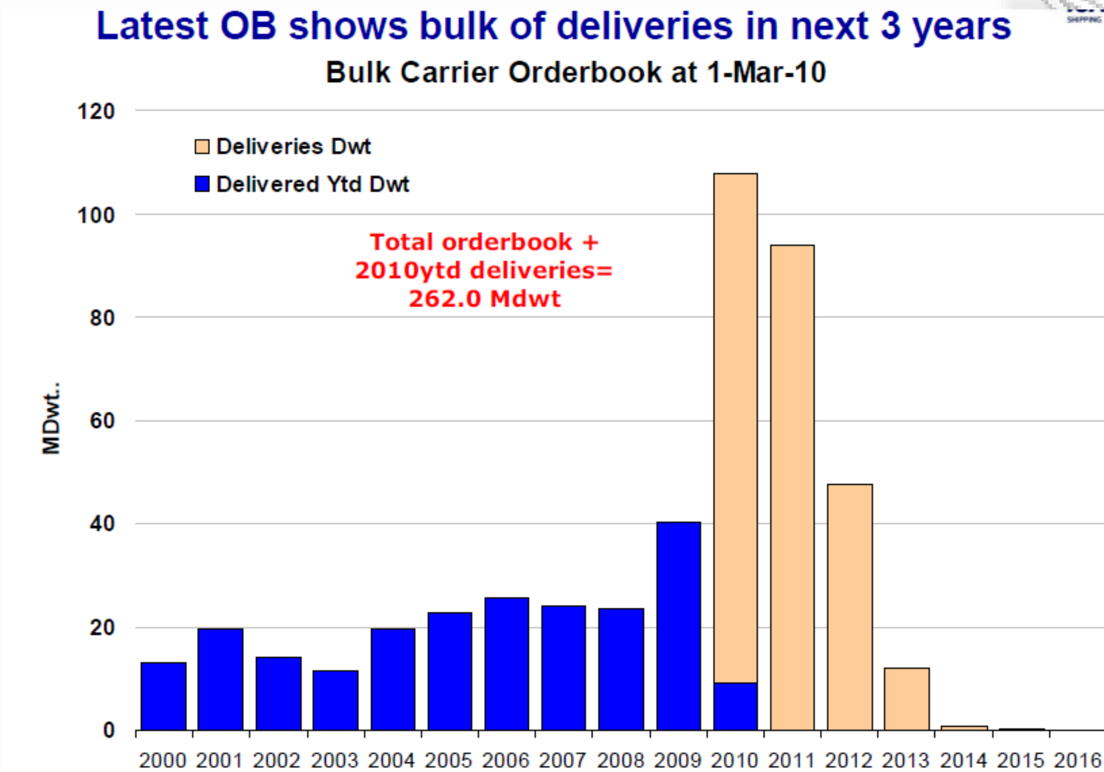
3q09
4q09
Other Bulk
Steel Exp
Grain
Ore
Coal
Steel Production



Source ICAP SHIPPING



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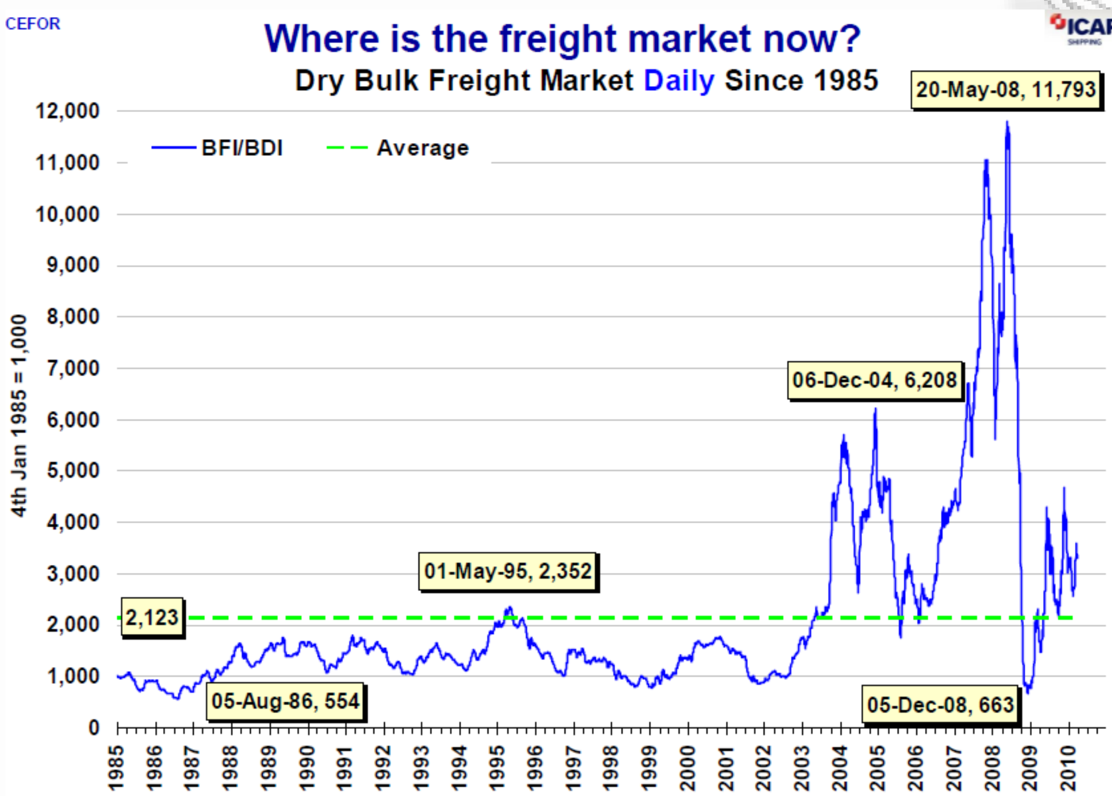


Source ICAP SHIPPING

1.12 Indices composition.

In our present study we are going to examine the interrelation amongst certain indices such as the BDI, the BEC and the BEP The Baltic Dry Index is a composite of the Baltic Capesize, Panamax, Handysize and Supramax indices. The index was designed as the successor to the Baltic Freight Index and was first published on January 4 1985 at 1000 points.

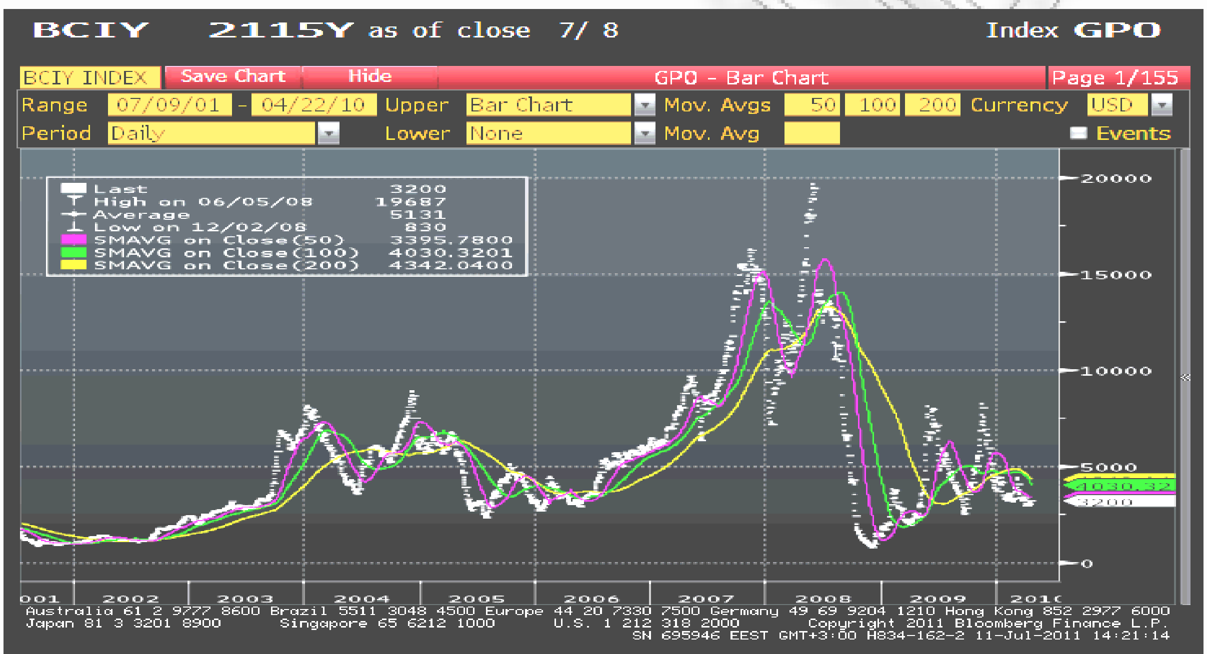
Chart describing the trend of the Baltic dry index

Source Bloomberg

The Baltic Capesize Index. was first introduced on 1 March 1999.

The Baltic Capesize Index comprises of sevenvoyage routes:. It is calculated as is calculated from the weighted, average rates on major routes, both voyage and timecharter, as assessed by a panel of brokers. The Baltic Capesize Index, BCI, which tracks the shipping costs on the largest of the dry bulk ships, the Capesize. Capesize vessels are those in excess of 80,000 dwt and primarily carry coal and iron ore. The BCI then tends to fluctuate with the amount of steel being produced.

Chart 2 chart describing the trend of the capesize index



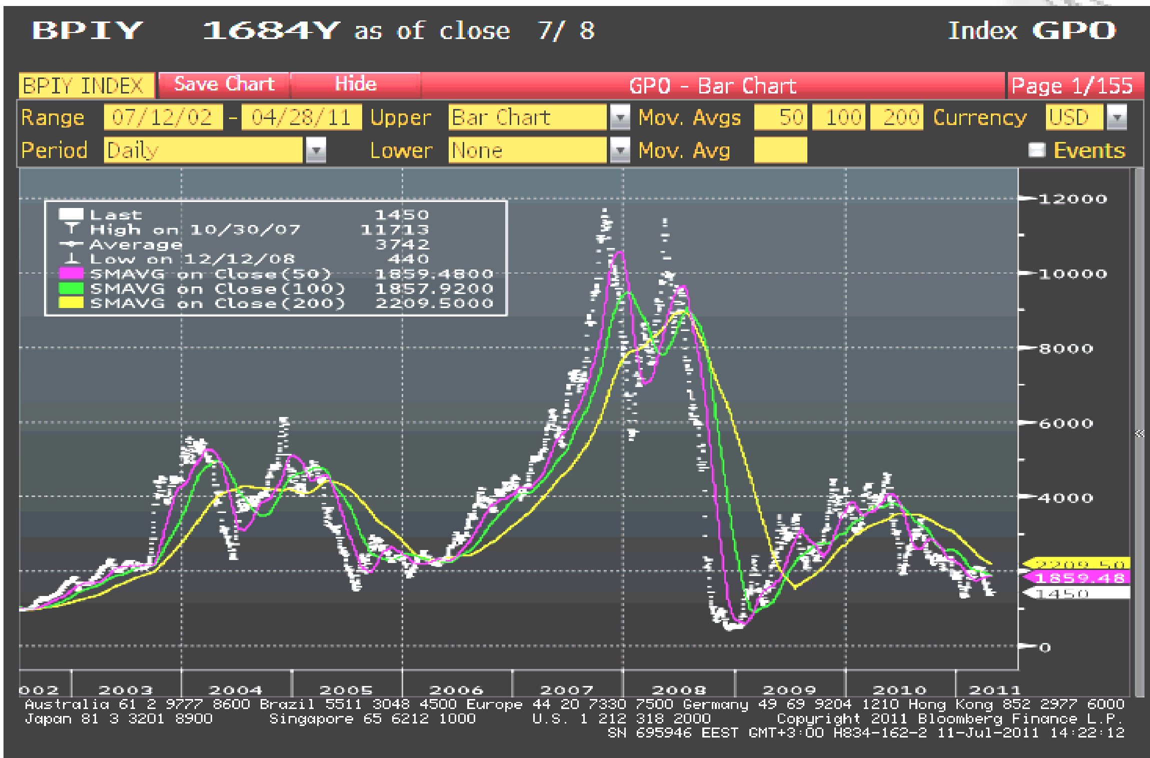
Source Bloomberg

The Baltic Panamax index consists of four charter routes, each having 25 weighting. This dry bulk shipping index was first published on 21 December 1998.

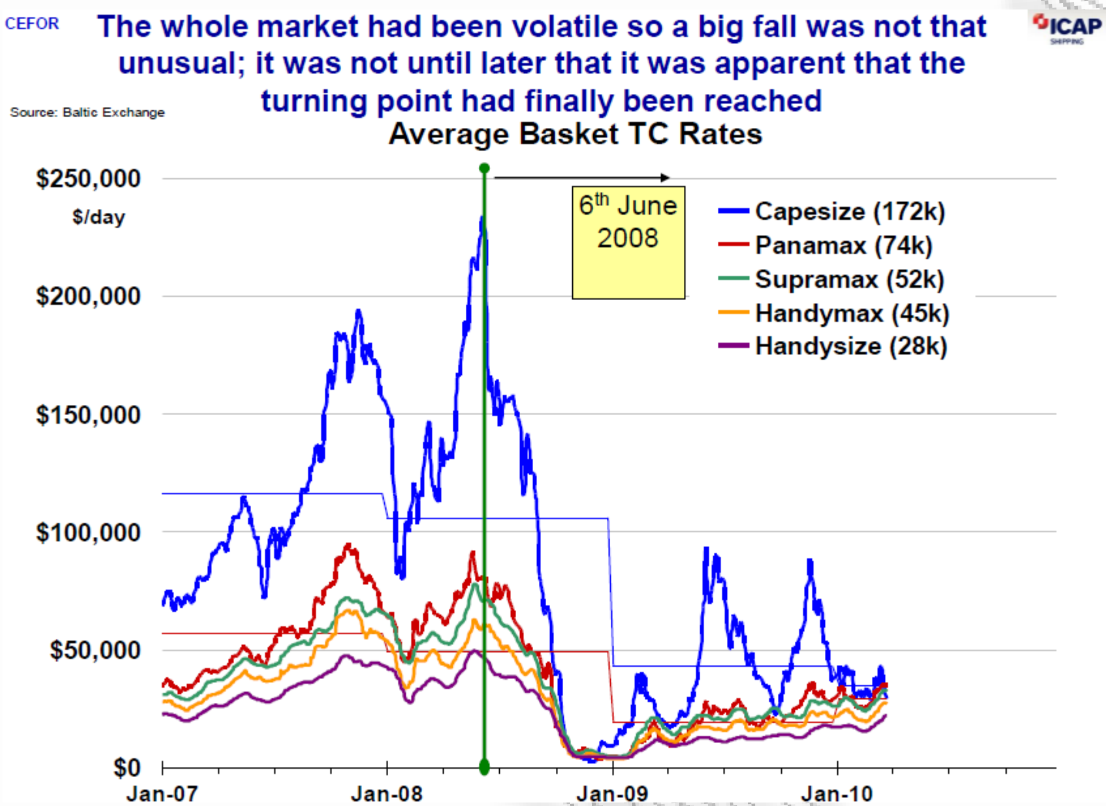
Panamax represents the largest acceptable size to transit the Panama channel which can be applied to both tankers and bulk carriers. Lengths are restricted to a maximum of 275 meters and widths to slightly more than 32 meters. The average size of such a ship is about 65.000 dwt and these vessels carry usually coal, grain and sometimes minor bulk products.

The Capesize refers to these ships that serve deepwater terminals carrying raw materials such as iron or coal. Capesize vessels transit through Cape Horn or the Cape of Good Hope. Their size ranges between 80.000 and 175.000 dwt. Due to their size there are only a small number ports with the infrastructure to accommodate such vessels.

Chart 3 describing the trend of the Panamax index



Source Bloomberg



1.13 Connection between freight rate indices and volatilities

Capes which are the largest ships than the other four types of vessels seem much more volatile. This can be explained because in expansion periods are the first to be hired from a charterer so as to capture and respond to that specific period's demand and reduce the expenses by hiring larger ships. On the contrary in shrinkage periods are the first to be released due to the lack of freights and the high operating expenses. In those periods smaller kind of vessels are preferred.

One of the main characteristics of the bulk market is that it is disaggregated in size and each vessel is involved in the transportation of certain commodities with a low degree of substitution between vessels of different sizes. However sometimes vessels of adjacent size can be used as substitutes such as for instance Panamax instead of handysize , Capesize instead of Panamax. The need for substitution can occur when the demand in one market is higher than in the other therefore larger vessels are attracted to accept part cargos and make a profit (**Grammenos, 2002)**.

One would expect that a shock to a sub sector can be transmitted to other sub sectors. If there is for instance an increase in demand for handysize vessels, then other ship categories such as panamax vessels will enter the handyzize market and accept part cargoes. Therefore there will be an over supply in the handysize market and a shortage of supply in the panamax market resulting in the drop of handysize rates and in an increase in the panamax rates (**Grammenos, 2002).**

Investigating the interrelationships amongst these sub markets in shipping can provide with substantial clues to issues regarding the degree of substitutability between different dry bulk sectors. Beenstock and Vergiotis investigated the spillover effects between the tanker and dry bulk markets by using dynamic econometric models**.**

Analysis of spillover effects between volatilities of freight rates for different size levels reveal that volatilities of freight rates for capsize vessels affect volatilities of freight rates for smaller vessels while the other round does not occur. This is due to the fact that the market for larger vessels is more sensitive to news than the market for smaller size vessels. Smaller vessels are more flexible in terms of operational flexibility.

2 Econometrics in Shipping

2.1 GENERAL MODELS

Although the shipping market is a rapid developing sector there have been few attempts to model the specific market through econometric techniques. Before the World War II efforts were concentrated on modeling the supply side in the freight market. Little efforts were made to model the demand side because things in this field appeared to be much more complicated. Little progress was also made in the market for ships despite the availability of sufficient data). After World War II research in the area of shipping was intensified and several econometric studies investigated the demand and supply conditions in the shipping market (**Vergotis, 1993)** .

Tinbergen investigated the sensitivity of freight rates to changes of factors that affect demand and supply for the period between 1870 and 1913. Such factors are the level of tonnage the price of bunkers the size of the fleet the costs of fuel etc. He considers demand to be perfectly inelastic. He found that supply was fairly inelastic with respect to rates and bunker prices

Koopman (1939) investigated the behavior of tanker rates. He found that the demand for shipping services was very inelastic with respect to freight rates while the supply of freight services was also quite inelastic with respect to freight rates and fuel prices.

Hawdon 1978 developed a model that determines tanker freight rates in short run and in the long run. Hawdons model consists of a freight market a shipbuilding market and a scrap market. His model is estimated by regressing tanker rates against variables such as demand per unit of capacity, the level of dry cargo rates the price of new tankers wages of seamen the average size of ships e.t.c. The period under investigation is from 1950 to 1973.

His results indicate that the wages of seamen and the average size of tankers is not statistically significant for explaining tanker rates. More over neither dry cargo freight rates are statistically significant in the regressed equation. However he finds that the demand per unit and the fuel prices were found to be statistically significant **(Beenstoch, Vergotis, 1993).**

Norman and Wageland (1981) developed a theoretical model for large tankers that was not based on econometric concepts but on micro data on the technology of the four kind of ships in order to derive a theoretical supply generated by each type of ship. The optimum speed is determined by several real world features that are usually not used in the typical econometric models. The technological relation between speed and fuel consumption are derived from the micro data and then profits are maximized with respect to speed which means that the optimum speed is a relation freight rates fuel costs and other sort of operating costs.

Strandemes (1984) investigates the determinants of time charter rates and second hand prices. In a time charter hire contract the control of the ship passes from the ship owner to the charterer. The latter must pay a rent which is a negotiated fixed amount of money known as the time charter rate. The fixed operating costs are paid by owners while the variable costs are paid by the charterer. Strandemes introduces the time charter equivalent concept and tries to determine the importance of the short term and long term time charter equivalent on the level of various charter rates.

Charmza and Gronick 1984 consider an integrated model of the shipping markets which consists of a freight market a shipbuilding market and a scrap market . **(Beenstoch, Vergotis, 1993).** The model is applied to both the dry cargo and the tanker market. The districts feature of the model is that it considers the possibility of disequilibrium in the freights market. The disequilibrium models state that the change in price is directly proportional to change in demand and that quantity changed in the market is not equal to supply or demand but to the minimum of the two.

The freight market model is estimated using data for the period from 1961 to 1980. The estimated t statistics indicate that the freight market supply y in the tanker and dry cargo market is influenced by changes in the size of the fleet and freight rates. The long term time charter is according to the results positively affected by freight rates and the level of demand in relation to the fleet.

In the shipbuilding market the demand for tonnage was found to be inversely related to the level of prices and positively related to the level of demand for freight. A separate demand for new orders is also estimated to be positively related to the level of demand for freight and negatively related to the size of the fleet.

Finally the scrapping of tonnage was estimated to be positively related to the size of the fleet and negatively related to the level of the long term time charter.

Beenstock and Vergotis (1989) distinguish between the market for new-built

vessels and second-hand vessels and follow an asset pricing model approach. At the time of their contracting, new-built ships will typically be sold for prices that can differ from the prices of identical existing new ships by a larger or smaller amount. The main reason for the difference in price, is attributed to the fact that a new vessel is immediately available to trade, while a contracted new-building ship only becomes available after the construction period has elapsed and this might take a long time. Since contracted ships are to be delivered in the future they resemble a future market. Prices will reflect market expectations, at the time of contracting, regarding the value of new ships at the time of delivery **(Beenstoch, Vergotis, 1993)**.

Rander forms a model that consists of a tanker freight market a shipbuilding and shipping market. One of the main features of the model s that the tanket market is disaggregated into tankers that operate in the spot market and tankers that operate under time charter contract. The period examined is from 1950 to 1975.

In the freights market economic agents are assumed to be influenced by the projected freight rate rather than the spot rate. The short term expected rate is modeled as a projection of long term trends through the latest 12 months average rate. The freight market is assumed to clear instantaneously so freight rates are determined by the conditions of demand and supply. Supply in the freight market is equal to the size of the tanker minus the laid up ships times the vessel utilization rate. That is

$Q= K(1-\lambda)*U$

where λ is the fraction of the ships laid up and u= the utilization rate.

The utilization rate is equal to a weighted average of the spot and time chartered fleet utilization rates. This rate can be changed either by increasing the speed of the ship or by reducing the number in port or the number of days under repair.

The parameters of λ and U were found to be positively related to freight rates.

Kavussanos (1996) investigates the temporal links between the freight and ship market relating to two sectors such as the dry bulk and tanker sector. The evidence from Granger equality suggests that the linkages amongst the two markets differ inside the two shipping sectors.

All the models described despite their differences come to the conclusion that freight rates depend positively on the level of demand relatively to the fleet. If an increase in fuel prices takes place, than the supply curve will shift to the left and freight rates will be rising . In periods of recession wide fluctuations of demand will have a small impact on freight rates since demand and supply intersect at the elastic region of the supply curve. Unlike the level of freight rates in depressed periods the impact on the lay up will be more significant. However in periods were the shipping industry exhibits high performance, small changes in demand will have a considerable impact on the level of freight rates since demand intersects to the inelastic region of the supply curve while the impact on the lay up that is the number of ships that are inactive will be trivial (**Beenstoch, Vergotis, 1993)**

While there is a consensus view regarding the freight market thinks appear to be different with respect to the interaction of the new building the second hand **market** and scrap market amongst themselves and the freight market? The reason for this is attributed to the fact that there are considerable differences in the second hand market shipbuilding and scrapping market structures amongst the models that have been mentioned. The fact that there are many model structures is the result of a different treatment regarding expectations of future market developments. Moreover not all the models are consistent with the optimizing behavior concept.

Generally speaking most of the models do not explain sufficiently the factors that determine the demand in the shipbuilding and second hand markets. However the above demand is very crucial regarding the fluctuations in the shipping industry. Moreover most of the models, use extrapolating mechanisms of current and recent trends lets say for the freight rates to predict future rates. But if the models described above embody any kind of predicting value then each shipping cycle would be predictable something which of course does not happen in the real world. Evidence has shown that market movements in the shipping industry usually take investors by surprise and as we have mentioned in an earlier section each shipping cycle is different from the previous one rendering any forecasts very risky.

2.2 INTRODUCTION TO THE GARCH MODEL

In the classic linear model we usually assume that the variance of the errors remains steady meaning that no heteroscadasticity exists. But in time series data the variance of the error changes over time. This means that if we use the OLS method to estimate the coefficients, the estimators will be inefficient. To allow for heteroscadasticity we transform the original model in such a way so that the variance of the errors in the new model will be steady **(Xristou, 2007**).

An issue of great importance would be to model heteroscedasticity. By achieving this, financial analysts will not only be able to predict the mean return but the variance as well. The Garch model is a special version of the Arch model andit has been introduced to model heteroscedasticity based on historical data. A very common application of the Garch model is the fact that the variance of the error for the next period consist a function of the average long term variance and a function of the errors referring to the most recent data. These factors that affect variance are weighted in the proper way. The Garch model assumes that the volatility in any kind of returns will affect the volatility of returns in the next period and this why it is being called a generalized autoregressive conditional model. The formula is the following

$$h_{t+1} = \omega + a(r_t - m_t)^2 + bh_t = \omega + ah_t\varepsilon_t^2 + bh_t$$

The GARCH model has been used to estimate the volatility of the shipping freight rates **(Nomikos, 2009).** The FIGARCH model is .the version of the Garch model which is used**.** Data consists of returns on weekly spot freight rates for VLCC, Suezmax and Aframax tankers and Capesize and Panamax bulk carriers.

Dynamic conditional correlation models attempt to estimate volatilities and correlations for a large class of assets. The Dynamic Conditional Correlation (DCC) model introduced by Engle (2002) uses a sequential estimation scheme and a very parsimonious parameterization to enable it to estimate models with fifty or more assets rather easily

The FIGARCH model was found to provide the best specification for volatility dynamics in the freight markets.

Regarding the value at risk calculations it was found that the GARCH model was the most appropriate for the VLCC and Capesize data series , the FIGARCH model was found to be the most appropriate for the Suez MAX and AfraMax while the IGARCH model was the most appropriate for the Panamax data series.

The conclusion regarding volatility in freight rates is that smaller vessels exhibit more persistence in volatility in freight rates, while there was strong evidence of fractional integration in freight rate volatility.

2.3 VECTOR AUTOREGRESSIVE MODEL and VAR MODEL

A vector autoregression model is an econometric model that tries to assess the evolution and interdependencies between multiple time series. The general form of this model is

$$y_t = c + A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + e_t,$$

A Vector Error Correction Model (VECM) can lead to a better understanding of the nature of any nonstationarity among the different component series and can also improve longer term forecasting over an unconstrained model.

The VECM(p) form is written as

$$\Delta \mathbf{y}_t = \delta + \Pi \mathbf{y}_{t-1} + \sum_{i=1}^{p-1} \Phi_i^* \Delta \mathbf{y}_{t-i} + \epsilon_t$$

The most popular measure of risk is volatility. **Var** answers the question which is related to which the maximum amount of money an investor can lose**.** A VAR statistic has three components such as a time period, a confidence level and a loss amount. The methods that are used in calculating Var are the historical method, the simulation method and the variance co variance method.

Veenstra (1999) reexamines the relationship between spot rates and time charter rates in the context of a Var model. The model lies on the concept that if market efficiency prevails, the ship-owner should be indifferent between the choice of a series of spot rates that generate the same profit as a time charter hire of an equivalent duration**.**

Veenstra and Charalambidis (2000) try to forecast seaborne trade flows by presenting multivariate time series models that can be used to produce long term forecasts. Their analysis is based in four dry bulk commodities such as crude oil , iron ore, grain and coal. The trade flow matrices provide total yearly trade volumes by major exporting and importing countries. With the exception of Australia and Japan related to coal and South America Japan related to iron ore all route series are non stationary to the first order.

Results indicate that commodity trades on different routes are related. For coal iron ore and grain the maximum number of co integration relations is achieved. Most of the forecasts are reasonable in predicting a steady increase in shipments. This is compatible with the general expectations regarding world wide economic growth. What is remarkable is that the model predicts a decrease in the shipment of coal between Australia and Europe for the next ten years, after the research was conducted and also predicts stabilization after that period **(Transportation Research part E 37 2001**).

Alizadech investigated the spillover effects between the different segments within the bulk sector of the shipping industry by using the Var, cointegration and impulse response analysis. In total three different systems of VECM and VECM –GARCH models for freight rates for three size vessels have been estimated over the period January 1980 to August 1997

His analysis reveals that the interaction between freight rates for different size vessels is higher in the spot market compared to the one year and the three year time charter markets. This might be due to the difference between the charterers decision making process on hiring vessels in the spot market and time charter markets.

Another interesting finding of this study is that the levels of the time varying volatilities of the freight rates in each of the spot and forward rates are directly related to vessel size. The level of the time varying volatility is higher for larger vessels compared to the smaller ones.

3.METHODOLOGY AND DATA

3.1 Methodological Design

In order to investigate the dynamic linkages among freight index returns, we employ two approaches, a bivariate and a multivariate. The bivariate approach seeks to examine presence of (short- and long-run) relationships between any pair of returns. In other words, which return serves as a 'price discovery' vehicle for another market return. For this reason, we use the bivariate Vector Autoregressive (VAR) model for each return pair. The model is given below:

$$\Delta r^i_t = \alpha_i + \sum_{i=1}^{N} \beta_i \, \Delta r^i_t + \sum_{j=1}^{N} \gamma_j \, \Delta r^j_t + u^i_t \qquad (1)$$

$$\Delta r^j_t = \alpha_j + \sum_{j=1}^{N} \beta_j \, \Delta r^j_t + \sum_{i=1}^{N} \gamma_i \, \Delta r^i_t + u^j_t \qquad (1a)$$

where Δr^i_t and Δr^j_t are the changes in index *i* and *j* at time t, respectively, and u^i_t and u^j_t are the error terms for each of the indices. The optimal lag length, *N*, will be determined by the Akaike Information Criterion. For example, if we find that β_j (in equation (1a)) is not (statistically) zero, then we would conclude that the return of market *j* is 'Granger-caused' by the return in market *i*. This means that market *j*'s current return is significantly correlated with past returns of market *j* and, thus, we would infer that price discovery exists in market *j*'s return. Hence, changes in market *j*'s returns leads changes in market *i*'s returns. This is also known as information efficiency, whereby new information first takes place in one market (and is embedded in the return) and then spills over to another market's freight index (and thus its return). Similar interpretations apply to the other two parameters of the system.

Although returns may exhibit short-run linkages between themselves, it is possible that they also exhibit long-run linkages. That is, they may share a long-run relationship or that they are cointegrated. Thus, it is important to test for bivariate and multivariate cointegration between and among the series. In case of evidence of cointegration, equations (1) and (1a) must be augmented to reflect that common, stochastic trend. Thus, the system will look as follows:

$$\Delta r^i_t = \alpha_i + \sum_{i=1}^{N} \beta_i \, \Delta r^i_t + \sum_{j=1}^{N} \gamma_j \, \Delta r^j_t + \zeta \, \varepsilon^i_{t-1} + v^i_t \qquad (2)$$

$$\Delta r^j_t = \alpha_j + \sum_{j=1}^{N} \beta_j \, \Delta r^j_t + \sum_{i=1}^{N} \gamma_i \, \Delta r^i_t + \zeta \, \varepsilon^j_{t-1} + v^j_t \qquad (2a)$$

where ε_{t-1} is the error-correction term (for *i* and *j*). The error-correction term should be negative and statistically significant, which would be interpreted as one return adjusting to the other in the long-run. The system of equations (2 and 2a) is known as a vector error-correction model (VECM). To see if any two are all three series are cointegrated, we will employ the standard Johansen (1995) cointegration method.

Finally, even though returns may exhibit short-run linkages between themselves, it is possible that they also display time-varying volatilities or, that they may be heteroskedastic. A model that captures the time-varying (dynamic) correlation structure in the conditional variances of the bond yields and, at the same time, corrects for heteroscedasticity in these returns, is Engle’s (2002) Dynamic Conditional Correlation (DCC) multivariate GARCH specification. This model is also useful because it computes current correlations among freight returns, which allow us to infer the nature of the impact of an event, incorporated in one market’s return, on the other markets’ returns. The basic DCC GARCH model is as follows.

Let r_{it} be the return of market *i* at time *t*, given the available information Ω_{t-1} at time *t-1*, and $\upsilon_{i,t}$ the error term at time *t*. The mean return equation (or the autoregressive return model) for each of the three markets’ returns is specified as

$$r_{i,t} = \delta_{i,0} + \delta_{i,1}\, r_{i,t-1} + \upsilon_{i,t} \qquad (3)$$

where $r_t = (r_{1t-1}, r_{2t-1}, r_{3t-1})$, $\upsilon_t = (\upsilon_{1t}, \upsilon_{2t}, \upsilon_{3t},)$ and $\upsilon_t,|\Omega_{t-1} \sim N(0,H_{ijt})$. The multivariate conditional variance is given by

$$h_{ij,t} = \alpha_{i,0} + \alpha_{i,1}\, \varepsilon^2_{i,t-1} + \gamma_i\, h_{ij,t-1} \qquad (4)$$

where $h_{ij,t}$ is the conditional variance between market i and j, at time t, $\varepsilon^2_{i,t-1}$ is the innovation at time $t-1$ ($\varepsilon^2_{i,t} = r_{i,t} - \mu_{it}$), and $\alpha_{i,0}$, $\alpha_{i,1}$, and γ_i are the important parameters to be estimated. Specifically, the $\alpha_{i,1}$ term measures the ARCH effect, or the short-run persistence impact of a shock to return i, and γ_i measures the degree of volatility persistence (i.e., the GARCH effect), or the contribution of a shock to return i to the long-run persistence. The above specification assumes a GARCH(1,1) process. Obviously, for shocks to die out and to ensure stationarity in the model, the sum of a_i and γ_i must be < 1. Finally, the model's unconditional variance will be finite if $\gamma_i < 1$.

The model's conditional covariance terms are assumed to follow a DCC(1,1) specification, as follows:

$$h_{ij,t} = \rho_{ij,t} \sqrt{h_{ii,t}} \sqrt{h_{jj,t}} \qquad (5)$$

$$\rho_{ij,t} = q_{ij,t} / \sqrt{q_{ii,t}} \sqrt{q_{jj,t}} \qquad (5a)$$

$$q_{ij,t} = (1 - \alpha - \beta)\, \bar{\rho}_{ij} + \alpha\, \eta_{i,t-1}\, \eta_{j,t-1} + \beta\, q_{ij,t-1} \qquad (5b)$$

where $\rho_{ij,t}$ is the unconditional correlation between the residuals ε_{it}, and $q_{ij,t}$ is the conditional covariance between the standardized residuals ($\eta_{i,t} = \varepsilon^2_{i,t} / \sqrt{h_{ii,t}}$). Equation (5b) captures the essence of the DCC model since the parameters α and β reflect the effects of previous standardized shocks and the dynamic conditional correlations, respectively, on the current value of the conditional correlation. Note that if $a + \beta < 1$ then the model is stationary, but if $a + \beta = 0$ then the DCC model reverts to the constant correlation model (CC-GARCH). The model's log-likelihood function to be maximized is given by

$$L = [-(0.5)\sum^{T}(kl\,og(2\pi) + log(|D_t|^2) + r'_t D^{-2}_t r_t)] - [(0.5)\sum^{T}(log(|R_t|) + e'_t R^{-1}_t e_t - e'_t e_t)] \qquad (6)$$

$i=1$ $i=1$

where the first bracketed term represents the volatility component and the second term the correlation component. k refers to the number of equations, T to the numbers of observations, D_t to the diagonal matrix (3×3) of the time-varying standard deviations from equation (5a), and R_t is the time-varying correlation matrix.

3.2 Data Sources and Construction

The data comprise three freight indices; these indices are BDI (Baltic Dry Index), BEP (Baltic Exchange Panamax) and BEC (Baltic Exchange Capesize) which are analyzed above in previous chapter.

4. EMPIRICAL RESULTS AND DISCUSSION

In this section, we present both some preliminary statistics and the main empirical results. We begin with the descriptive statistics, correlations and some graphs on each of the three series.

4.1 Preliminary Statistical Investigation

Table 1 shows the descriptive statistics (means, standard deviations, skewness, kurtosis, and a non-normality check test), autocorrelations and the correlation matrix for the series for the entire period, 2000:1:24 to 2010:5:25. Panel A shows the summary statistics on each series. It appears that the BEC and BEP freight returns experienced higher volatility compared to the BDI freight return and that they exhibit negative skewness. Thus, extreme negative returns (values) dominate these returns and thus, the actual level of risk (as measured by the standard deviation) is underestimated. This essentially means that occurrence of extreme negative values (from their mean) in the distribution of these indices' returns should be of concern to investors. Both skewness values are statistically significant (although this is not shown in the table). Negative skewness occurs because bad (adverse) information flows (relative to good news) generates occasional but strong negative jumps (spikes) in the prices of the freights. Thus, the probability of higher losses is higher than for a positive skewness value (drawn from a normal distribution). Finally, the high values of excess kurtosis (above 3 for the normal distribution) for all three returns imply that these fright rates distributions are 'fat-tailed' or leptokurtic and do not follow a normal distribution. This, actually is corroborated by the highly statistically significant values of the Jarque-Bera statistic which suggests departures from normality.

Panel B of the table records the sample autocorrelations of the returns for up to ten lags. All returns display positive serial correlation which means that returns are followed by predictable trends upwards or downwards. In addition, they are high and appear to decay very slowly over time. Perhaps, this implies evidence of economic significance for the realization of short-run profits by investors. In other words, in an efficient (freight) market the serial correlation (autocorrelation) should be zero for any successive periods. Finally, panel C displays the simple correlation matrix for the three freight returns. We see that the BDI and BEC rates are highly positively correlated but the BEc and BEP rates are moderately correlated over the entire period. However, these are simple measures and do not reveal the true extent of the relationships among the three variables. A more robust approach is needed and we present it in the next subsection.

Figure 1 shows all three indices (in logarithms) for the entire period. We observe that all freight returns took a hit during the 2008 global crisis but started recovering, rather quickly, thereafter. Figure 2 reinforces this observation by plotting the rates of return for each freight index. We see that all three returns exhibited heightened volatility since the mid-2000s and surfaces as more pronounced for the BEC return.

Table 2 displays the results from the bivariate and multivariate cointegration results. The results suggest one cointegrating relationship between BDI and BEP and between BEC and BEP but not a single cointegrating relationship between BDI and BEC indices. Finally, when all three indices are simultaneously examined, there is evidence of more than one cointegrating relationships. We interpret this evidence as existence of strong cointegration between BDI and BEP and between BEC and BEC but of weak cointegration between BDI and BEC and among all three freight indices. The above results are robust to the use of alternative cointegration assumptions (results are available upon request). As a result, we will employ the vector-error correction equation system (equations 2 and 2a) in the first two cases but not in the last two cases where a VAR specification is appropriate (equations 1 and 1a).

4.2 VAR/VECM Impulse Response Analysis

Estimation of the various VAR/VECM generates three outputs: the estimated models, variance decompositions and impulse responses. For the sake of space preservation, we only report and discuss the impulse response graphs (the other results are available upon request). Figure 3 exhibits these combined impulse responses for each freight return emanating from own shocks and from the other returns. Note that given that we show only combined graphs, error (confidence) bands are not available as for VECM impulses.

Looking at the first panel's graph, we see that the response of BDI's return to own innovations (the blue line) decays smoothly and dies off completely after 13 days, whereas that of BEP's return even faster, within a week following the shock from BDI's return. The second graph in the same panel, illustrates a longer reaction of BEP's return to own shocks and to shocks from BDI's return, namely two weeks. Notable is also the magnitude of the impact of the shock to BEP's return from its own past return behavior which appears to be larger than the magnitude of the shock from BDI's return. The second panel's graphs show the reactions of BDI's and BEC's returns to own shocks and from each other. In this case, we observe a longer response to either type of shocks which takes almost three weeks (21 days) to completely die out.

In addition, BDI's return response to innovations from BEC's returns turned negative after the shock initiation and remained so for several days before it is absorbed.

The graphs in the third panel show the reactions of BEC's and BEP's returns to own and shocks and shocks from each other. As in the case of the BDI and BEP, such shocks are short-lived, in the sense that they are cushioned fully within a week or so. Noteworthy are also the observations that BEC's returns reacts mildly to own shocks but BEC's returns react much stronger to such shocks. Finally, the last set of graphs depicts all three index returns reactions both to own and to each other's shocks. We can make the following observations. First, all shocks appear to die out within two (in the case of BEC's returns) to three weeks (in the cases of BDI's and BEP's returns). Second, shocks from BEC and BEP returns cause a positive and a negative reaction by BDI returns, respectively. By contrast, shocks from BDI and BEP returns cause BEC and BEP returns react positively. Third, shocks from BEP returns produce a positive reaction to itself but a negative reaction to BEC returns. The own positive reaction is much stronger than the negative reaction to BEC. Overall, we conclude that the returns are capable to absorb shocks within three weeks at the maximum despite their strong, positive initial reactions to these shocks.

4.3 DCC-GARCH Model Results

Table 3 contains the results from the estimation of the DCC-GARCH(1,1) model. One important result is that the coefficients of the lagged variance (b_i's*)* and the shock (a_i's) terms are all highly statistically significant. This finding is consistent with the time-varying path of volatility (or that the assumption of constant conditional correlation is rejected) and corroborates evidence of volatility clustering. In addition, note that the sum of the two coefficients is always less than 1 and all hover around the same value. The latter implies that volatility displays a near persistent behavior. For example, volatility persistence for BEC's return is 0.8737 while that for BEP is 0.8786. Another important finding involves the estimated dynamic conditional correlation coefficients (*dcc*), which are statistically significant for all three returns. In general, a high value of the correlation coefficient between yields signifies a higher comovement in the long-term returns of these markets.

Figure 4 displays the conditional volatilities for each return series as estimated from univariate GARCH(1,1) models (not shown). Notice the frequent spikes in the conditional volatilities of all returns since 2007 but that of BEC's returns is much less notable. Another noteworthy observation from these graphs is the lack of volatility in all three returns for the 2000, 2001 and 2002 years. However, some volatility is observed during the years 2003-2005 and then again since 2007, where volatility has reached historical highs for all returns series. Obviously, several events have contributed to such volatility clustering in the international freight market. For example in 2000 the Asian economies experienced an industrial boom which was crippled in the beginning of year 2001 when the business world experienced the so called Dot.com crisis. The latter event affected the majority of the industries that comprise the US economy. The effects of the crisis although were spread to other economies of the world such as those in the South East region did not last more than few months. Nevertheless, it did affect the freight rates in all sector of shipping, since freight rates dropped approximately by 70%. The situation change dramatically for the better, when China undertook an open market model policy, which attracted foreign investment. In the following years China's industrial miracle as a world exporter, lead to requirement of enormous quantities of raw materials affecting the freight rates upwards for the following four years. The dependency of many economies upon China's production lead to an increase in the volatility levels of the freight rates. Despite that, the stable economic conditions worldwide created the fundamental base for the increased industrial production and consumption that caused an immense increase of the freight rates in the era 2007 to mid 2008. The upswing of the market was followed by a sudden downswing due to the Lemman Brothers event which triggered the financial crisis that world's economies are still experiencing. This global event caught the capital intensive shipping sector unguarded, in a period of high investments in new-buildings that financially became unsecured. It is important to highlight here that the Shipping sector as it is depended on derived demand, it had no means to defend itself from the latter crisis.

Another important use of the model is that it permits us to trace the dynamic (or time-varying) path of the correlations and infer possible policy changes. Such plots are shown in Figure 5 for all returns series. Observe the 'unusual' spikes in the degree of association between return pairs during the entire period. Note that we had to convert the daily data into weekly in order to generate these graphs (as daily data obscured the ups and downs in correlations over time). Notice that correlation between BDI and BEC returns is positive most of the time except for a few years (2000, 2004 and 2007) when it turned negative. Negative correlations were more frequent for the other returns pairs, especially for the BEC and BEP pair. Using the original, daily data, we see that conditional correlations varied substantially from a maximum low of -0.86 to a positive high 0.99. Table 4 contains the summary statistics for each return series conditional correlations. Specifically, the maximum value for BDI return's conditional correlation was 0.9962, achieved in February 2008, and its minimum values was -0.5662, reached in March 2008. Similarly, the maximum value in the conditional correlation of BEP's return was 0.9940, reached in November 2007, while its lowest value was -0.8005, achieved in December 2009. Finally, the maximum value of BEC return's conditional correlation was 0.9859, realized in November 2007, and its lowest value was -0.8683, realized in March 2003. Finally, the statistics for skewness and excess kurtosis suggest that many of the conditional correlation series are significantly negatively skewed and leptokurtic relative to the normal distribution. An overall observation for all three conditional correlations is that the frequency of positive associations between any two series appears to be higher than that for negative conditional associations.

Can we infer from these graphs whether conditional correlations have increased or decreased during economic expansions and/or recessions? Forbes and Rigobon (2002) advanced the argument that higher volatility can cause higher correlations during periods of crises. We can roughly identify two expansion periods, one of the mid 2000s and one during the late 2000s, and two recession periods, one in the early 2000s and another in the second part of the 2000s. For the BDI-BEC pair, we see that the correlation during the two expansionary periods was mostly positive and high but, at times, it became negative and never exceeding -0.5 (as observed from the daily data). During the two recessions, the correlations were again mostly positive, albeit not always high, and occasionally turned negative. The negative correlation values were more notable in the recession of 2007/8 relative to the one in the early 2000s. Inspecting the graphs for the other two returns pairs, by contrast, does not allow us to detect a clear picture as what happened to correlations during expansionary and contractionary periods. What we can, perhaps, say is that the magnitude and frequency of negative correlations between the BDI and BEP pair is smaller than that of the BEC-BEP pair during both expansions and contractions.

Which factors might have caused these correlation coefficients to change over time? An observation of these six graphs reveals several interesting facts. Perhaps, some common factors are responsible for the changing conditional correlations are the following. First, the global financial crisis which erupted in 2007 and lasted for two years is a major source of such time-varying correlations among freight rates. Second, the de-synchronization of Europe's and the US's business cycles during most of the 2000s

Finally, from the perspective of a bond portfolio manager who holds portfolios that include freight assets (stocks or bonds), what could the above results suggest? The high(er) correlation coefficients during periods of economic prosperity imply that the diversification gains from holding diverse freight assets may decline as these assets are all subject to systematic risk. In addition, very high correlation coefficients may not be good indicators of constructing a well-diversified asset portfolio since such coefficients may stem from unstable (co)variances among asset returns. In addition, a general conclusion may be that assuming a constant correlation structure among asset classes in portfolio construction is not a correct approach and such portfolios need to be re-evaluated during different economic or financial episodes.

4.4 Relationships between Conditional Volatilities and Dynamic Correlations

An alternative way to interpret the time-varying correlations among these index returns is to think of them as risk factors given that, by default, the correlation coefficients were constructed from return volatilities (or standard deviations). So, a natural extension of our above analysis is to assess the impact of return conditional volatilities on the dynamic conditional correlations of the returns. We ask the following question: do the pair's volatilities (vol_1 and vol_2) have an impact on the pair's conditional correlation? Therefore, our proposed model is specified as follows:

$$\rho_{ijt} = \alpha_i + z_i\, vol_{it} + c_j\, rvol_{jt} + \omega_{it} \qquad (7)$$

where ρ_{ijy} is the dynamic conditional correlation of a pair's (ij) return, vol_{it} is own return volatility, vol_{jt} is volatility of j's at time t. The above specification can be expanded to include dummy variables, dum_k, to capture the impact of volatilities on conditional correlation during the two expansionary periods (k =1 and 2). The variable will take the value of 1 during an expansion period and 0 otherwise. The relative volatility variable can also take lags in the above specification. Stepwise regression is the best method in identifying the optimal lag length for the independent variables. In all cases, three lags (months) at the max were identified as optimal. All regressions are corrected for serial correlation and heteroscedasticity (using White's method). The summary results from the stepwise regressions are shown in Table 5.

The results indicate that own conditional volatility (*volatility1*, constructed as the conditional standard deviation or the square root of volatility) surfaces as significant in all cases, sometimes positively impacting the paired correlation and other times negatively. Thus, conditional correlation can be increased when the market becomes less volatile or decreased when the market becomes more volatile. A similar observation can be made for the other market's volatility (*volatility2*) on the paired conditional correlation. This interesting result of the alternating impacts of conditional volatilities on the conditional correlation is borne out of our previous analysis and graphs. Finally, the two expansion periods dummies (*dummy1* and *dummy2*) did not surface as statistically significant in the first paired correlation but did emerge as important in the other two paired correlations. Specifically, the first expansion period negatively affected the correlations between BDI & BEC and BEC & BEP whereas the second expansion period positively impacted upon their correlations.

What is the message of the above findings on diversified-portfolio investment strategies containing these freight assets? In view of the fact that worldwide shocks affect these markets' volatilities and (conditional) correlations, any possible risk diversification benefits from holding positively-related assets may be substantially reduced. The opposite is true for negatively-related assets. In addition, the finding that conditional correlations are time-varying, that is, changing over time and with higher frequency, it is important to realize the value of portfolio rebalancing to capture these changing correlation structures. Finally, the finding that different expansions differently affect the correlation structures of markets over time is useful in understanding the way markets comove during such periods so as to design an optimal portfolio. So, the overall conclusion is that assuming a constant correlation structure in the construction of diversified portfolios is no longer valid as market dynamics change and do so frequently as the pace of globalization sweeps markets across the globe. All the above findings are depicted in the Appendixes: Table 3.

5. SUMMARY AND CONCLUSIONS

Shipping is the forefront of global development since the first cargo was moved by sea more than 5000 years ago. From the pioneering voyages of Columbus till the era of ULCCs and Capesises, shipping was full of risks and opportunities, making it so interesting for economists and shipping investors. The aim of this thesis is twofold. Firstly, it investigates if three maritime indices, namely BDI, BEC and BEP are statistically correlated, positively or not. The second objective is to examine if the three indices following a market sudden upswing or downswing experience lead-lag pattern. Dynamic models such as, Dynamic Conditional Correlation, Multivarite GARCH Specification, Vector Error Correction and Vector Autoregressive models are utilized for the analysis for the period 2000 to 2010. All relevant data were collected from the Shipping Intelligent Network operated by Clarksons. The findings of the analysis indicate that there were time lags between the indices. In the majority of the periods under investigation the relationship was positive rather than negative. The changes in the correlation coefficients can be explained considering factors such as, the de-sychronization of the U.S and E.U business cycles, along with the financial crisis that erupted in 2007.

The findings of this thesis are of critical importance in constructing investment portfolios in the maritime sector and development of contingency plans on periods experiencing high volatility or market shocks.

It is important to mention at this stage that there are several external and internal factors affecting the maritime sectors that are difficult to evaluate and utilize in the analysis. However, the area needs further investigation since there are many grey or unexplored areas that are potentially fruitful. The implications of further understanding the lead-lag pattern of indices can result to an enhancement of risk management strategies that can result to higher returns or less capital losses.

Table 1. Descriptive statistics, aurocorrelations, and correlations on the returns series

Panel A: Descriptives

Series	mean	variance	stand. dev.	skewness	kurtosis (excess)	J-B
BDI	0.0160	3.2609	1.8058	0.0173	8.2678	744.23*
BEC	0.0144	6.5366	2.5566	-0.0005	7.3813	594.90*
BEP	0.0171	5.3819	2.3198	-0.5957	10.4371	891.77*

Panel B: Autocorrelations

BDI

1	2	3	4	5	6	7	8	9	10
0.8219	0.5979	0.3990	0.2675	0.1861	0.1552	0.1669	0.1951	0.2187	0.2192

BEC

0.7581 0.4518 0.2223 0.1140 0.0690 0.0679 0.0935 0.1185 0.1306 0.1257

BEP

0.8399 0.5950 0.3713 0.1826 0.0371 -0.0306 -0.0300 0.0142 0.0529 0.0905

Panel C: Correlations

	BDI	BEC	BEP
BDI	1.0000	0.8902	0.7831
BEC	0.8902	1.0000	
BEP	0.7831	0.4975	1.0000

Notes: BDI, BEC and BEP are the returns of each index; J-B is the Jarque-Bera statistic for checking for non-normality: the results show strong departures from normality (at the 1% level); autocorrelations are up to 10 lags.

Table 2. Bivariate and Multivariate Cointegration Test Results

Hypothesized No. of CE(s)	Trace Statistic	5% CV	1% CV	Max Eigenvalue Statistic	5% CV	1% CV
BDI & BEC						

None **	50.2704	15.41	20.04	46.1423	14.07	18.63
At most 1 *	4.1278	3.76	6.65	4.1274	3.76	6.65
BDI & BEP						
None **	47.6857	15.41	20.04	44.2335	14.07	18.63
At most 1	3.4521	3.76	6.65	3.4521	3.76	6.65
BEC & BEP						
None **	50.6142	15.41	20.04	46.9356	14.07	18.63
At most 1	3.6786	3.76	6.65	3.6786	3.76	6.65
BDI, BEC & BEP						
None **	95.0016	29.68	35.65	49.1460	20.97	25.52
At most 1 **	45.8556	15.41	20.04	41.3476	14.07	18.63
At most 2 *	4.5079	3.76	6.65	4.5079	3.76	6.65

Notes: *, ** denotes statistical significance at the 5% and 1^ levels, respectively; null hypothesis: one or more cointegrating relationships (equations, CEs) exist; trend assumption: linear deterministic trend; CV is critical value

Table 3. Multivariate DCC-GARCH Model Estimates

Variable	Coefficient	Std Error	T-Stat	Signif
Mean(1)	0.1459	0.0263	5.5429	0.00000
Mean(2)	0.1486	0.0371	3.9977	0.00006
Mean(3)	0.1427	0.0310	4.5917	0.00000
C(1)	0.0634	0.0051	12.259	0.00000
C(2)	0.1162	0.0109	10.602	0.00000
C(3)	0.0804	0.0106	7.5621	0.00000
A(1)	0.2731	0.0269	13.245	0.00000
A(2)	0.2832	0.0272	14.411	0.00000
A(3)	0.2768	0.0303	13.508	0.00000
B(1)	0.6018	0.0115	51.980	0.00000
B(2)	0.5905	0.0115	50.917	0.00000

B(3)	0.6010	0.0148	40.510	0.00000
DCC(1)	0.4188	0.0117	35.615	0.00000
DCC(2)	0.5372	0.0130	41.010	0.00000

Notes: means are (1) bdi, (2), bec, and (3) bep. DCC(1) and (2) are the DCC-GARCH parameters α and β.

Table 4. Descriptive Statistics of Conditional Correlations

Series	mean	variance	stand. dev.	max	min	skewness	kurtosis (excess)	J-B
BDI	0.8044	0.0695	0.2635	0.9961	-0.5662	-2.5673	6.8478	854.13*
BEC	0.6574	0.1350	0.3676	0.9940	-0.8095	-1.7705	2.4913	664.20*
BEP	0.3501	0.2506	0.5008	0.9839	-0.8637	-0.7207	-0.7201	981.37*

Table 5. Regressions of conditional volatilities on conditional correlations

Dependent	Independent variables	R-bar square

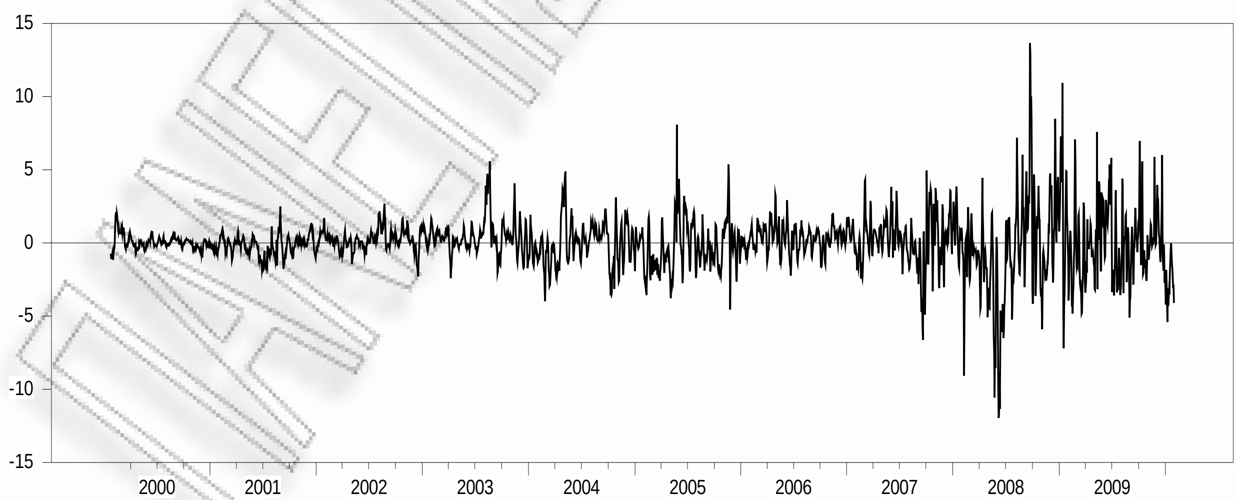
	Constant	Volatility1	Volatility2	Dummy1	Dummy2	
$Corr_{BDI,BEC}$	significant	negative (2)	positive (3)	not signif.		0.3579
					not signif.	0.3573
$Corr_{BDI,BEP}$	significant	negative (2)	negative (2)	negative		0.4034
		positive (2)				
					positive	0.4231
$Corr_{BEC,BEP}$	not signif.	negative (3)	positive (2)	negative		0.4008
		positive (2)	negative (2)			
					positive	0.4122

Notes: *volatility1* is own volatility and *volatility2* is other returns' volatility; *dummy1* refers to the first expansion period (mid-2000s) and *dummy2* to the recent expansion period (late 2000s); numbers in parentheses denote the number of significant lags for each variable; regressions were run using daily data using the stepwise regression technique; all results are corrected for serial correlation and heteroscedasticity.

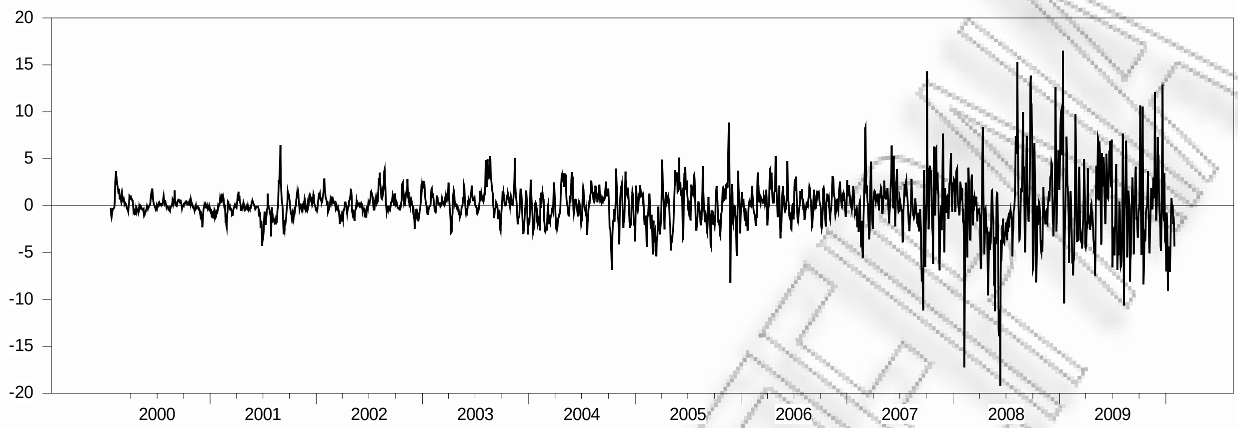
Figure 1. BDI, BEC and BEP indices (in logs)

Figure 2. Rates of Return of BDI, BEC and BEP

(a) BDI



(b) BEC



(c) BEP

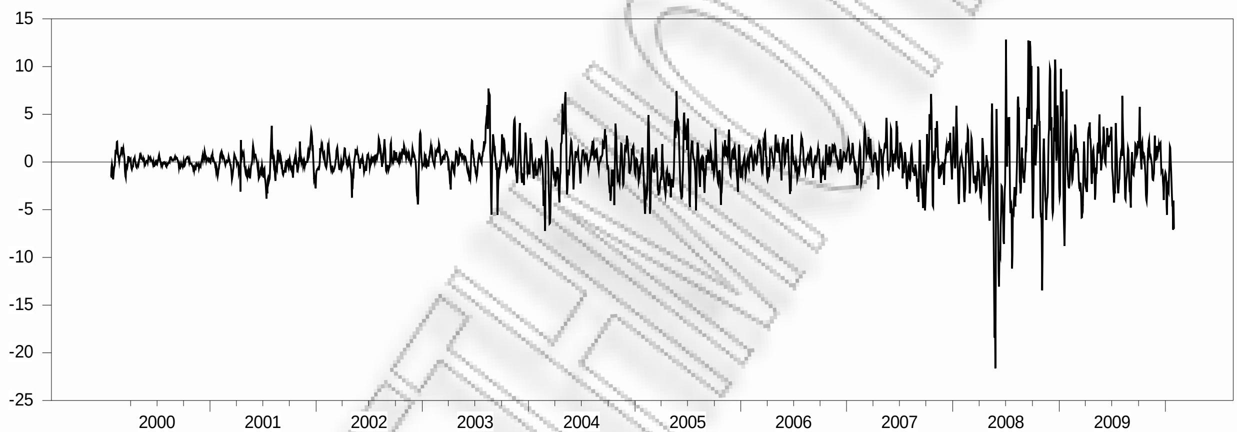
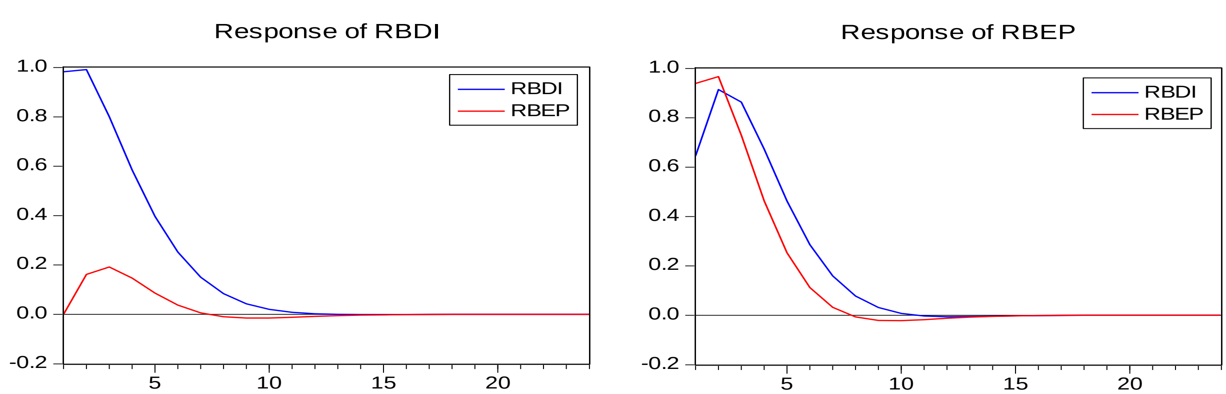


Figure 3. Impulse Response Graphs, RBDI, RBEC and RBEP



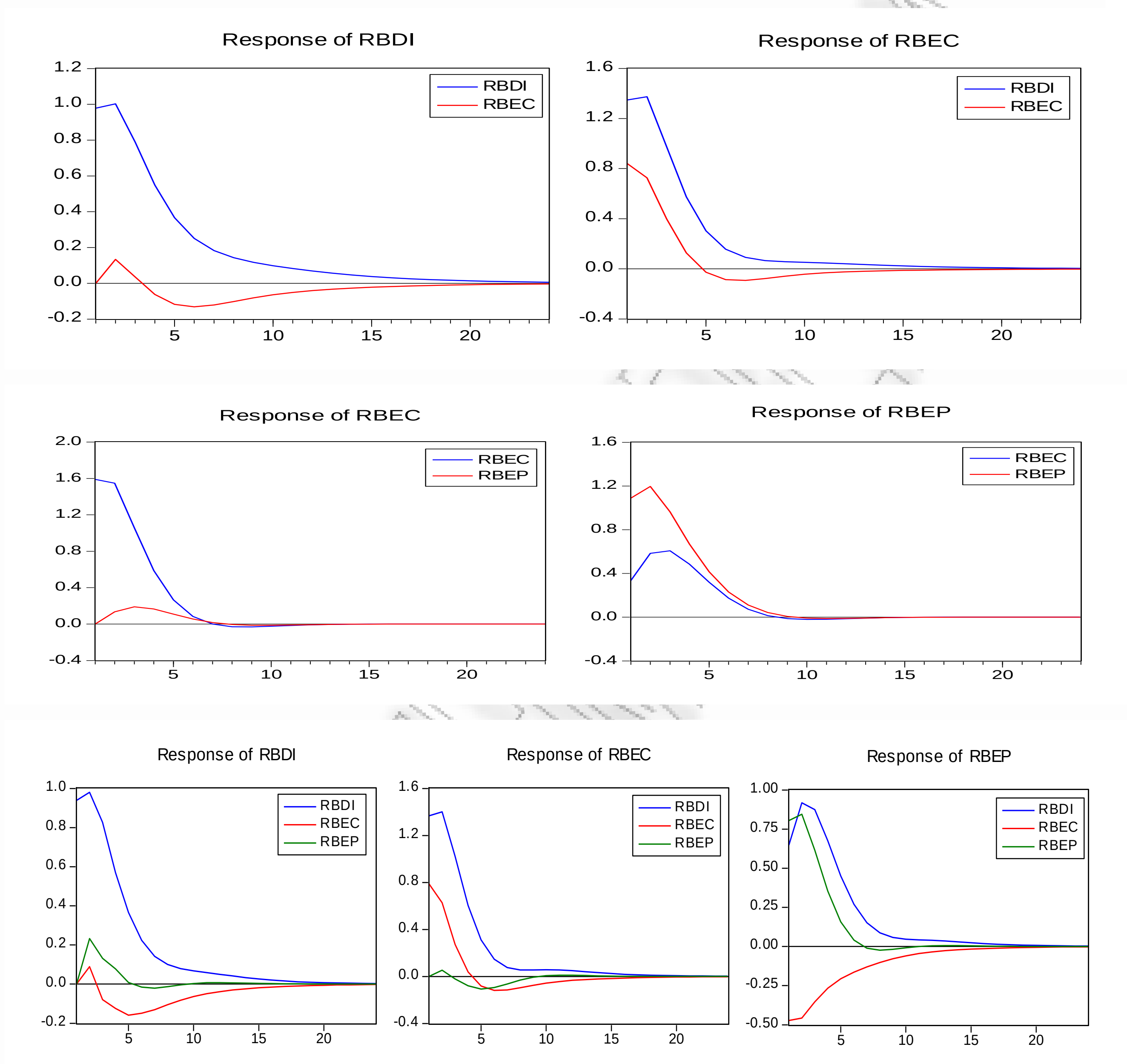
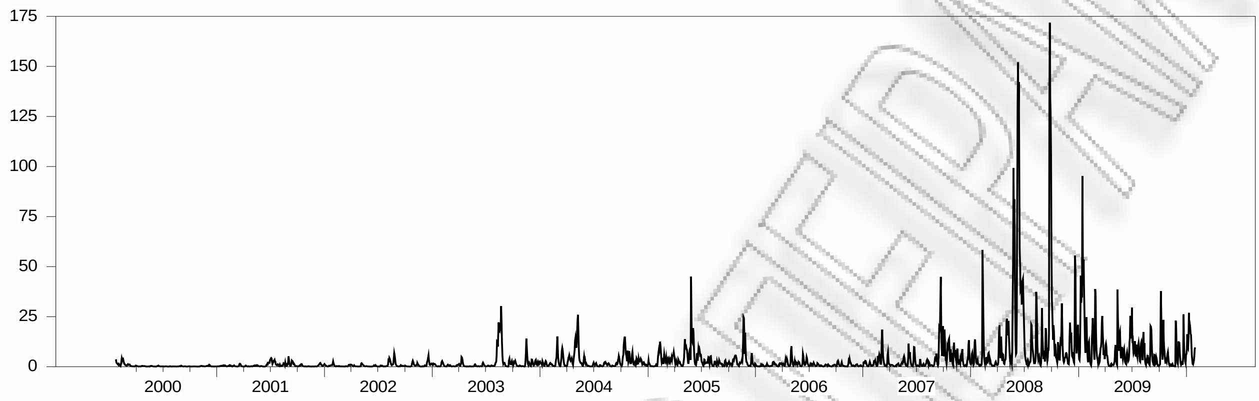
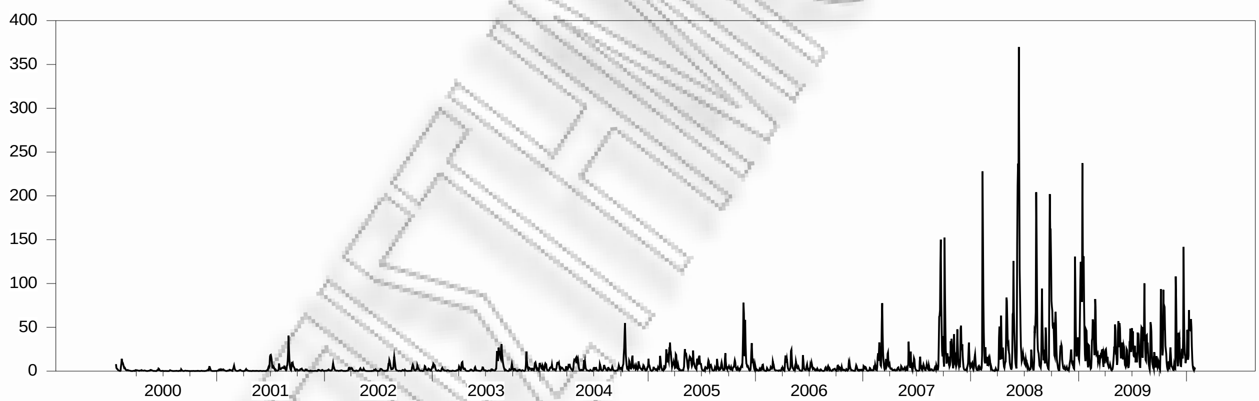


Figure 4. Conditional volatilities of return indices

(a) BDI



(b) BEC



(c) BEP

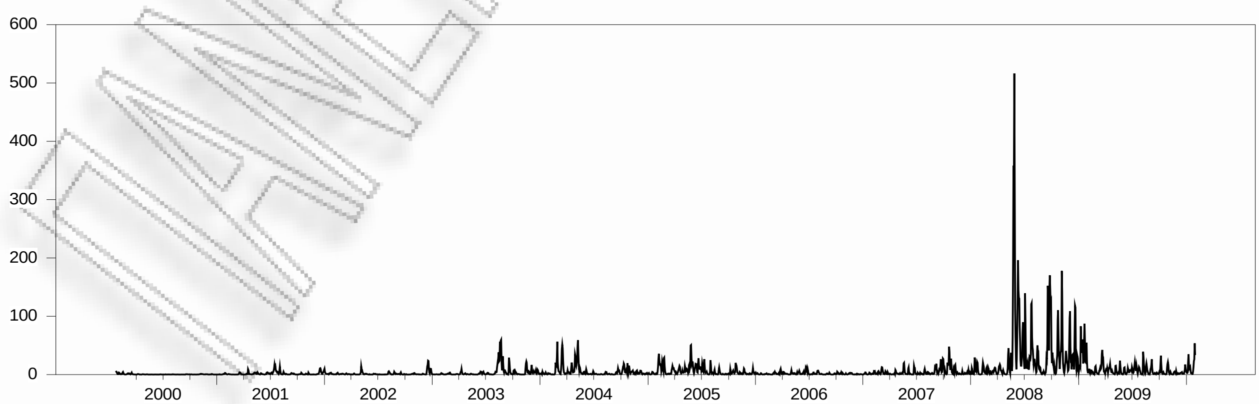
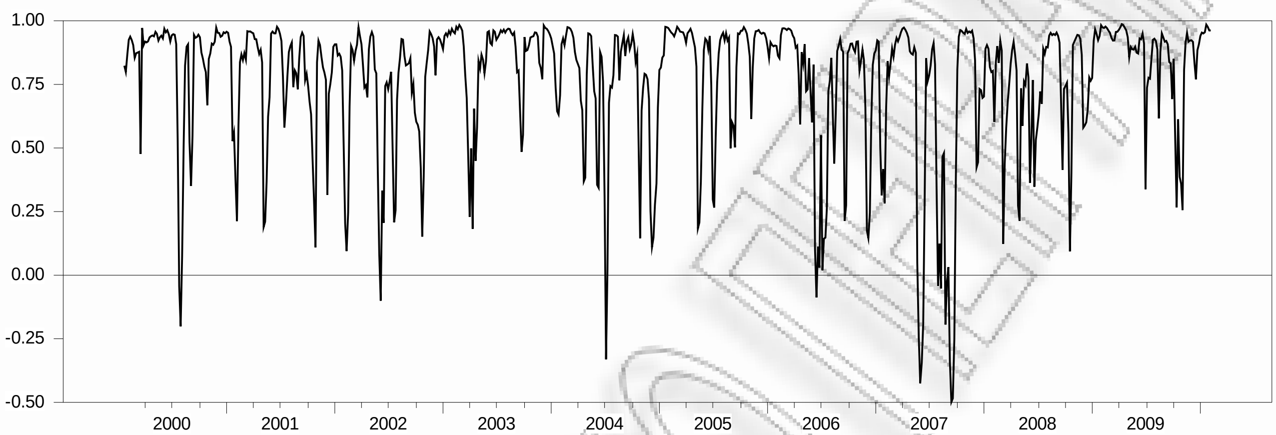
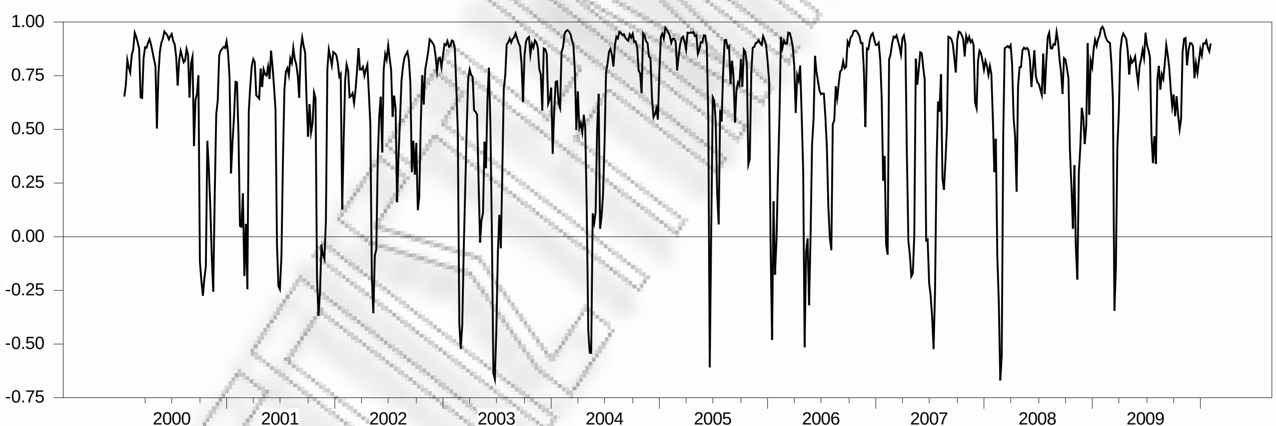


Figure 5. Dynamic Conditional Correlations among Returns

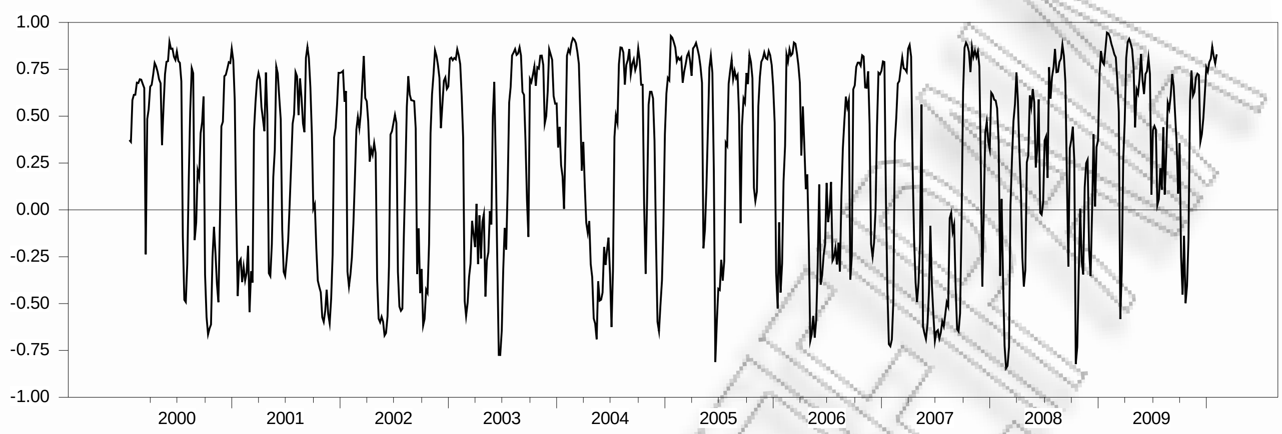
(a) BDI and BEC



(b) BDI and BEP



(c) BEC and BEP



Note: graphs were generated by converting daily data into weekly.

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