Time Series Analysis of the lead-lag relationship of Freight Futures and Spot Market Prices

by

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Abstract

This thesis analyzes the relationship between the physical and paper shipping markets. The main objective is to find if one market leads the other by a specific time period so that market players can take advantage from that.

Three different methods were used to analyze this relationship. The first is a rolling average technique to smooth the strong fluctuations of the market and plot the relevant graphs. From there we can have a first look on whether there is a lead-lag relationship between the two markets. The second method was the cross-correlation function which allows us to time shift back and forth the two time series in order to compare the relevant correlation coefficients. In the third method, a Vector Error Correction model was created for each pair of time series in order to test the influence of the one series to the other. Finally, we present a brief comparison between the volatility of the freight rates and the trading value of freight futures so we can judge if the spot market became more volatile with the growth of trading of freight futures.

Thesis Supervisor: Henry S. Marcus
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1. Introduction

The position of an owner mainly depends on the cash-flow of his ships. In good market conditions the outcome of the operation of a fleet can be very profitable while on the other hand, under adverse market conditions, the operating income may be insufficient to cover even the expenses of a vessel. The general formula to understand the key elements of a cash-flow is the following:

Overall Cash-Flow = Operating Revenue - Operating Costs – Voyage Costs – Capital Costs

From these quantities, "Operating costs" are usually fixed, "Voyage costs" (for ships operating in the spot market) are float depending mainly on the fuel prices and "Capital costs" are either float or fixed depending on the terms of the loan. "Operating Revenue" is the most important and most volatile factor to the above equation because it is directly connected to the market conditions.

Various risk management techniques in order to hedge against market risk were developed during the years. The most common way for an owner to cover from this risk, is to commit his ship in long time charter contract with which he agrees to a fixed freight rate from 1 to 10 or even more years depending on the agreement. The main disadvantage of this strategy is the almost always reduced freight rate that is agreed compared to the rates of the spot market upon the signing of the contract. The more the years of the time charter, the less the freight rate of the agreement becomes.

Some more empirical risk management techniques include the identification of the seasonality of the spot market due to the seasonality of the demand in commodities. In the dry bulk market for example, spot rates increase significantly during the spring months because of the increase of the demand from Japanese importers for all commodities because of the end of their fiscal year by the end of March. Additionally, the harvest season in the Southern Hemisphere plays a role on the surge of demand for Handysize and Panamax vessels. On the other hand, a seasonal decline takes place during summer months mainly because of the summer holidays and the respective drop in the industrial output of the industrialized countries.

1.1.Spot rate mechanism

Before making an analysis of how spot rates could be affected or predicted by freight futures, it would be useful to have a brief look to the most important mechanism which plays significant role in spot rate pricing. That is supply and demand. Shipping markets, except liners, are considered to be a very good example of a perfect competition market. The supply for shipping capacity is controlled by a very large number of ship owners while the demand is represented by a vast number of companies which want to transport their goods. Entry and exit to the market are also very easy.

1.1.1. Demand

The demand for transportation of goods has to be examined separately for each type of cargo. Generally, the demand is affected by the world economy and the global need for transportation of goods. Since trade flows fluctuate, so does the activity in freight markets. Additionally, the distance between two ports is an important measure of the demand. The nearer this distance is, the lower the demand becomes. Therefore, if for example a new iron mine is constructed near a major iron importer, the demand for transportation will decline as a ship will be able to transport the same quantities as before in smaller time period.

Another example for the effect of demand is China. The last 8 years were characterized by its booming economy which increased the country's needs for goods tremendously. Additionally, this economic boom made many industries move there to take advantage of the cheap labor. Therefore, the exports from this country increased significantly too.

1.1.2. Supply

Contrary to the demand which is directly connected to global economy and trade and, therefore, cannot be controlled from the shipping community, the supply side of freight markets is expressed through the fleet capacity and fleet utilization. Fleet capacity alone is not a safe measure of supply. The speed of the ships, port congestion and port productivity are some of the factors playing an important role. When supply exceeds demand, a slow balancing process is initiated. Some ships may start laying up or finally go for scrapping. During this period, freight rates decrease significantly. If market conditions get stronger, newbuilding activity can be observed.

1.2. Derivatives

A derivative is a financial instrument whose value depends on the value of other, usually more basic, underlying variables. The underlying assets include physical commodities, financial assets, indices, spreads or even weather phenomena such as amount of snowfall.

Derivatives are used to manage the risk in the shipping industry which is characterized by cyclicalities in its rates and prices. The main market agents, shipowners and charterers, are the most vulnerable to these cyclicalities facing many times multi-million dollar losses.

The types of contracts that we will examine in this study are Forward and Futures contracts. Although forwards and futures have exactly the same use, there are some points in which they differ significantly.

1.2.1. Forwards

A forward contract is an over the counter private transaction under which the buyer and the seller agree upon the delivery of a specified quality and quantity of a commodity (or a service such as transportation of goods) at a specified future date at a specified price. The forward contract is, as a consequence, a "derivative" to the underlying commodity, as its value derives from it. The specified underlying asset of the contract is not literally bought or sold, but the market price of that contract at maturity, compared to the contract price, determines whether the holder of the derivatives contract has made profit or loss.

A forward contract involves a settlement at maturity, which results in a net cash outflow to one counterparty and a net cash inflow to the other counterparty. The possibility of the one side defaulting is called Credit Risk. If during the life of the forward contract, spot prices continually mirror the forward price on which the contract is based, then there is negligible credit risk associated with the contract. On the other hand, if the spot price deviates greatly from the forward price, it is probable that one counterparty will owe a large settlement amount to the other at the maturity date. The only payment made under a forward contract is at its maturity. We can conclude that the longer the maturity of a contract, the greater the credit risk becomes.

1.2.2. Futures

A futures contract is similar to a forward, but it is traded in an organized exchange. Its price is not a private agreement but it is determined by the current supply and demand conditions in the market. Contrary to forwards which are tailor made to the needs of their users, futures are standardized in terms of quantity, quality and delivery time of the underlying asset, so both counterparties know exactly what is being traded.

1.2.3. Differences of Forwards and Futures

In this part we will summarize the differences between forward and futures contracts which apply also in the relevant freight derivatives.

- Futures contracts are standardized contrary to forwards which are custom made.

- The same price is available is available for all traders regardless of the transaction size in futures contracts. Forwards prices often vary according to the size of the transaction and the credit risk involved.
- Futures are traded in organized exchange trading floors only during trading hours while forwards are traded over the counter 24 hours per day.
- Futures contracts markets have high liquidity allowing for easy closing of positions while forwards have limited liquidity and are more difficult to be sold due to the tailor made specifications.
- Futures contracts are cleared in clearing houses and it is the house which assumes the credit risk. On other hand, in forward contracts there is no clearing at all.
- Only 2% of the futures contracts are delivered because the investors close their position usually just before the maturity date. 90% of forward contracts are delivered.
- The information on the prices and trading is publicly available for futures contracts while this information is not disclosed to the public for forward contracts.

1.2.4. Pricing of futures

The pricing of futures is based on the Cost-of-Carry Model which relates the futures price (F) to the spot price (S) of the underlying asset. Before proceeding with the model it would be useful to present the notation that will be utilized: T is the time to maturity of the contract, in years; S is the spot price of the underlying asset; F is the futures price; r is the annual risk-free interest rate, with continuous compounding which expires on the delivery date and C is the cost-of-carry for the possession of the underlying asset over the maturity of the futures contract.

The assumptions made are:

1. There are no transaction costs.
2. The same tax rate applies to all participants in the market.
3. There is no bid-ask spread.
4. Borrowers and lenders use the same risk-free interest rate.
5. Markets are perfect, where all arbitrage opportunities are eliminated instantly.
6. There are no restrictions in short-selling.
7. There is infinite divisibility of the assets.

When someone needs to possess a commodity in a future time period T, three months from now whose spot price today is S, has two choices: borrow the required amount for three months at interest rate r and buy the commodity at the spot price S prevailing today, store it and have it available in three months. Alternatively one can buy a futures contract on the commodity which promises to deliver it in three months at a price F agreed today. These alternative ways of obtaining the required commodity in three months are equivalent for an investor and should cost the same.

Now consider the alternative of obtaining the commodity through the spot market, in order to have it available in the future. The investor borrows at interest rate r, buys the commodity at the prevailing price S in the spot market and stores for three months. During that period he has to pay interest, storage and insurance costs. For certain assets it is possible to receive income, such as dividends or interest payments during the period. Ignoring this and denoting these costs to carry the commodity forward in time as C, this alternative costs to an investor S+C. This cost must be equivalent the cost of obtaining it through the futures market. Therefore, we come up with the following formula:

$$F = S + C = S(1+r)^T = Se^{rT}$$

1.3. Freight derivatives

The most modern and effective short-term way of hedging the freight market risk is through freight derivatives. Their market was first established in 1985 with the launch of "Baltic Freight Index" from The Baltic Exchange. The index included a variety of cargoes and capacities and was used as the settlement index for BIFFEX (Baltic International Freight Futures Exchange). The latter ceased its trading in 2001 due to lack of liquidity. However, the development of reliable shipping indices which were widely recognised by market practitioners was very important for the industry. The indices not only reflect the market conditions, but they are used as settlement indices for freight futures contracts.

1.3.1. Hedging with Freight Futures

Traditional risk management techniques may prove to be inflexible, expensive or even non existent. More specifically, it is not easy to buy and sell vessels frequently and is hard to go in and out of freight contracts. Concerning the long term charters, it is not always feasible to find them, especially in declining markets. The opposite happens when the market is improving and a shipowner is unwilling to fix a freight rate in a low price. Another disadvantage of long time charters is the abandonment of the contracts when the market conditions change too much against one party. Moreover, the continuous acquisition and sale of ships in order to get profit from the seasonality of the markets is difficult because of the time consuming negotiations as well as the fast change of prices occurring until the deal is closed.

Freight derivatives have helped to overcome these problems by making risk management in freights cheaper, more flexible and more readily available to the owners. More analytically, the uses of freight derivatives include but they are not limited to:

- The hedging of the position of a market agent against a future rise/ fall of the market up to three years ahead. A fixed income during a certain period of time makes the cash-flow of a company stronger.
- The speculation from an investor who is convinced as to how the market will move in the future. An individual or an institution may take a position on freight markets without participating in the physical market and by taking advantage of the volatility of the market can have serious profits. Therefore, if an investor believes that the market will fall, he will sell some future contracts.
- Arbitrage opportunities by taking advantage of the price difference of the freight derivatives (according to historical data) between two routes. In this case a market agent can sell the expensive route and buy the cheap one anticipating gathering a profit when the prices return to their normal differentials.
- An alternative to time-chartering contracts. An owner, who sells freight derivatives, i.e. hedges his position against a market decline, has the same results as having his ship under time-charter but without brokering costs. Additionally, he

is more flexible on when he can gets in and out of his market position while the liquidity of freight futures is much better than this of time-charter contracts.

Freight futures are settled against a shipping index depending on the route or the capacity that they are traded. In order to have an efficient and reliable freight derivatives market, the underlying freight index has to reflect accurately the spot market. According to SSY Futures, this is possible only if the index is trusted, unbiased, rigorously computed, frequently and regularly published. It should be published by a representative and reliable panel in a transparent and simple way and be monitored by an international body that is able to deal with any problems or complaints.

1.3.2. Freight derivatives trading at IMAREX

The International Maritime Exchange (IMAREX) based in Oslo utilizes mainly Baltic Exchange indices as well as some indices from Platts to write freight derivatives upon. IMAREX is a professional freight derivatives exchange for the global maritime industry, founded in 2000.

Someone who wants to trade at IMAREX can either obtain a membership account or get access to the marketplace through a financial intermediary, which is called a General Clearing Manager. IMAREX provides a trading environment to the shipping market by offering trading systems and rules, guaranteed settlement through the NOS clearing house (Norwegian Options and Futures clearing-house), anonymous trading, flexible and tailored contracts, firm trading prices etc.

One of the objectives of IMAREX is to increase the liquidity of freight derivatives through: market-maker agreements with professional companies, attracting as members the largest existing freight derivatives players; increasing the trading volumes of committed IMAREX shareholders, trading on expectations on future freight market directions; and offering extensive customer training and support. Freight derivatives players include international shipping companies, energy companies and refiners, commodity trading houses, banks and hedge funds.

In the table below we can see the contract details of tanker routes traded in IMAREX

Delivery	Cash settled against Baltic Indices Cash settled against Platts (for routes TC1, TC4 and TC5)
Pricing	Worldscale points
Minimum Tick	0.25 Worldscale point
Trading Period	Month, Quarter, Calendar
Minimum Lot Size	1 Month lot = 1,000mt, 1 Quarter lot = 3,000mt, 1 year = 12,000mt
Contract Value	No of lots x lot size x WS Flat rate x WS points / 100
Expiry	Last business day of expiring month
Daily Margining	Marked-to-market at end of every day against prices supplied by the Baltic Exchange or Platts
Final Settlement	The average of all Baltic (for routes TD3, TD4, TD5, TD7, TD9 and TC2) or Platts (for TC1, TC4 and TC5) spot price assessment prices over the number of index days in the delivery period

Contract Series	Front 4 months, front 6 Quarters, front 2 Calendar Years
Clearing Fee Settlement Fee	0.4% of Contract Value 0.05% of Contract Value

Table 1: Contract details of IMAREX Tanker derivatives, 2005

[Kavussanos, Visvikis 2006]

1.3.3. Freight Options Contracts

Besides futures and forward contracts, options are another derivative tool available for risk management or speculation. This type of financial derivatives contracts has been used extensively in finance on a number of underlying instruments, including exchange and interest rates, stocks and commodities. A call option gives the holder the right to buy the underlying asset by a certain date for a certain price. A put option gives the holder the right to sell the underlying asset by a certain date for a certain price. Consequently, the holder does not have to exercise the right which distinguishes options from forwards and futures. However, whereas it costs nothing to enter into a forward contract, there is a premium to acquiring an option.

It is argued that options should be thought of as buying insurance, for a premium, rather than as derivatives trading. This is because the maximum loss is the premium of the option, while the gain is proportional to the adverse movement in the price of the underlying commodity.

The standard freight option contract is either a freight put or call option, where their settlement is similar to that of freight futures. Freight options settle the difference between the average spot rate over a defined period of time and an agreed strike price.

Settlement prices for the tanker routes and time charter dry routes are calculated as the arithmetic mean across all trading days in a calendar month and those for dry voyage routes are calculated as the mean price over the last seven working days of the month.

Shipowners wishing to hedge against freight rate decreases may buy put options while charterers wishing to hedge against freight rate increases may buy call options. If their expectations materialize they exercise the options. If not, they let the options expire only losing the premium paid.

1.3.4. Example of hedging with freight futures

A shipowner can hedge his position against adverse market conditions with these contracts by fixing a rate for a future time period starting from one month ahead to three years. A future price is agreed between two counterparties, e.g. a ship operator and a charterer. When the maturity date of the contract arrives, the exchange of cash flows takes place. Due to the clearing of the contracts, exchange of cash flows could be initiated even a few days after the agreement, representing the price difference between the settlement price of the future and the level of the settlement index. Let's see the procedure with an example.

Suppose we have a tanker owner of a 130,000 dwt Suezmax who wants to employ his ship on route TD5 (West Africa- USAC) of BDTI (Baltic Dirty Tanker Index) in April and May. In this derivative contract each lot is 1,000 mt and therefore the owner sells 130 lots for his Suezmax. The April contract was closed at WS181.5 and the May contract at WS168. The Flat rate for the route is $10.28/mt as obtained from Worldscale organization. Thus, the futures contract position opened for April is $2,425,566 (130 lots x 1,000mt/lot x $10.28/mt x WS181.5/100) and $2,245,142 for May.

The settlement prices used in the contract come from the Baltic Exchange and they were published to be WS165 and WS162 respectively for April and May. That means that the market was lower than the agreed price in the future contract. The total settlement amount (calculated as above) for April and May is $2,205,060 and $2,164,168 respectively. At the end of this transaction, the owner had gained $301,480 his position was higher than the market. Apparently, if the market went up, the owner would suffer losses.

The real value of using freight derivatives (same applies to every kind of derivatives) comes from the hedging opportunities that they provide. An owner can calculate his income with certainty without being affected by the market volatility.

1.4. Data description

The historic prices of futures contracts, used for the examination of the lead-lag relationship of the spot and paper market, were provided by IMAREX. They consist of the daily closing prices of the 1 month contracts. The routes analyzed for the dry market are CS4TC, PM4TC and SM5TC which are the combination of 4 routes for Capesize and Panamax vessels and of 5 routes for Supramax. The prices used for Capesize and Panamax markets were from 4/4/2005 to 12/17/2007 while Supramax futures contracts started trading on 01/03/2006. These routes are displayed in the table below:

CS4TC	C8	172,000 mt	Gibraltar/Hamburg trans Atlantic RV
	C9	172,000 mt	Continent/Mediter trip Far East
	C10	172,000 mt	Pacific RV
	C11	172,000 mt	China/Japan trip Mediterranean/Cont
PM4TC	P1A	74,000 mt	Transatlantic RV
	P2A	74,000 mt	SKAW-GIB/FAR EAST
	P3A	74,000 mt	Japan-SK/Pacific/RV
	P4A	74,000 mt	Far Easr/N.Pac/SK-PASS
SM5TC	S1A	54,000 mt	Antwerp-Skaw Trip Far East
	S1B	54,000 mt	Canakkale Trip Far East
	S2	54,000 mt	Japan-SK/N.Pac or Australia rv
	S3	54,000 mt	Japan - SK Trip Gib – Skaw range
	S4	54,000 mt	Transatlantic rv

Concerning the tanker routes, we analyzed TD3, TD5, TD7, TD9 which were priced in Worldscale units, as characteristic routes for VLCC, Suezmax and Aframax (both TD7 and TD9) respectively. The data used for the calculations of tanker market were dated from 01/03/2004 until 12/17/2007. The daily prices were compared and analyzed with respect to the daily prices of the spot market. The routes of the tanker market are presented in the following table:

TD3	260,000 mt	VLCC	AG-Japan
TD5	130,000 mt	Suezmax	West Africa–USAC
TD7	80,000 mt	Aframax	North Sea – Cont
TD9	70,000 mt	Aframax	Caribs – USG

Summarizing, two time series were compared for each route, the one being the monthly futures contract prices and the other the respective spot ones.

2. Rolling Average Calculations

2.1. Introduction

The simplest and fastest way to observe the lead lag relationship between the two markets is the physical examination of their graphs in a common grid. Instead of using the raw data which include a significant amount of volatility, we chose to apply the moving average technique. It is often applied to stock prices, returns or trading volumes. Its main use is to smooth out short-term fluctuations, thus highlighting longer-term trends or cycles. The threshold between short-term and long-term depends on the application, and the parameters of the moving average will be set accordingly.

A moving average series can be calculated for any time series. More specifically, for a sequence $\{a_i\}_{i=1}^{N}$ an n-day rolling average is formed by the new sequence $\{s_i\}_{i=1}^{N-n+1}$ defined from the a_i by taking the average of subsequences of n terms:

$$s_i = \frac{1}{n}\sum_{j=i}^{i+n-1} a_j$$

In our case, the 3 days moving average will be:

$$s_3 = \frac{1}{3}\left(a_1 + a_2 + a_3, a_2 + a_3 + a_4, \ldots., a_{n-2} + a_{n-1} + a_n\right)$$

Our expectation for the lead lag relationship would be that the futures market leads the spot by one to five days. Therefore, the average price was taken for a three days period in order to take into account the fluctuations that may take place for this relatively short period of time. By isolating the daily high fluctuations that may exist in our data, we can observe more easily the relationship between the two markets. Due to the large number of observations the times series were divided to three parts for each route so that the diagrams are clearer. Each diagram includes about 250 trading days which correspond to almost one year of trading.

We examined each market, size and route separately in order to perform a more in depth analysis of the different market conditions. For example, the players of both physical and paper markets are usually different between dry and wet sectors. This indicates that their behavior may also be different, affecting also the lead lag relationship of the spot and derivatives market.

The graphs below present the 3 day rolling average time series created for both spot and futures market. By cautiously observing the graphs we can see how these two time series could possibly affect each other and more specifically the lead-lag relationship that may exist. In order to make this observation easier, each graph has several points marked with an "X" to help the reader identify the above mentioned relationship.

Assuming that one market leads the other, we should not expect necessarily that one has the same prices with the other after a time period. What we would expect is when the direction (from rising to falling or vice versa) of the one changes, same happens to the other after a time period. Additionally, we could observe also a lead-lag relationship between the two markets by the relative change of slope that occurs to the one after a change to the other. That means that if for example the paper market starts rising more steeply than two days before and the same happens to the physical one after a time period, then the paper leads the physical by this period. This type of relation is usually very hard to be identified because of the high volatility of the freight markets which do not allow a constant slope for more than two or three days.

2.2. Capesize market

As mentioned in previous part of the thesis, the Capesize market was examined by a combination of four routes of 172,000 MT each.

Brief market review: Capesize vessels are the biggest dry bulk vessels being able to transport over 120,000t of commodities. They are used to carry almost 70% of the total shipments of iron ore and 45% of coal. Their main routes for iron ore are from Brazil and W. Australia to W. Europe and Japan, while for coal the main routes are from Australia and South Africa to W. Europe, Japan and Far East. From 2005 until the beginning of 2007 the market ranged from \$23,000/day to \$70,000/day, way above the daily operating expenses which were about \$9,000/day. In 2007, the market boomed to unseen prices which exceeded \$150,000/day reaching \$194,115/day on 11/15/2007.

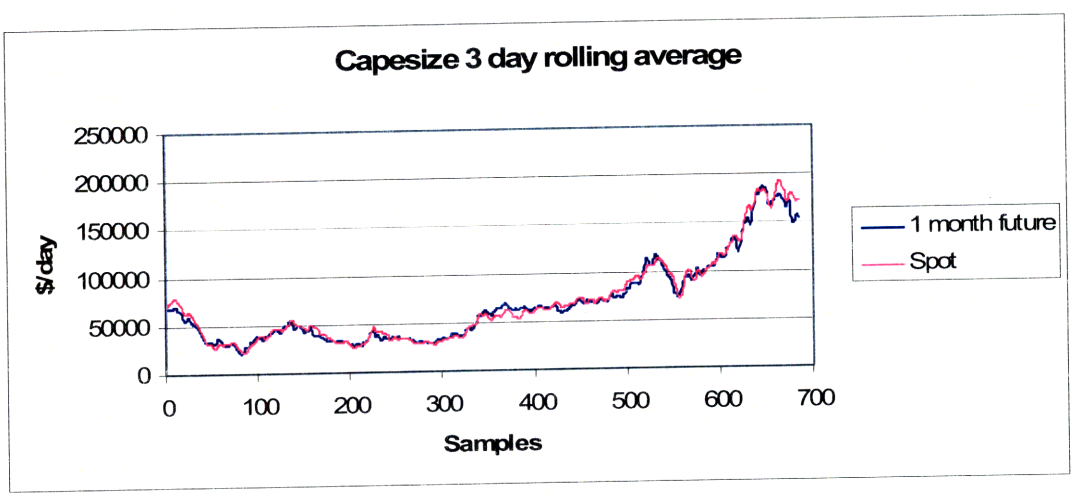

Fig 1 Rolling average for Capesize market for 1-685 days

In Fig 1 we can see the time series of the prices of the physical market vs. the paper one. It is clear that the two series are highly correlated. The same happens to any physical and paper market in stocks, commodities, foreign exchange or interest rates which need to be highly correlated in order to increase the hedging effectiveness.

In the following figures we can see the Capesize market in greater detail:

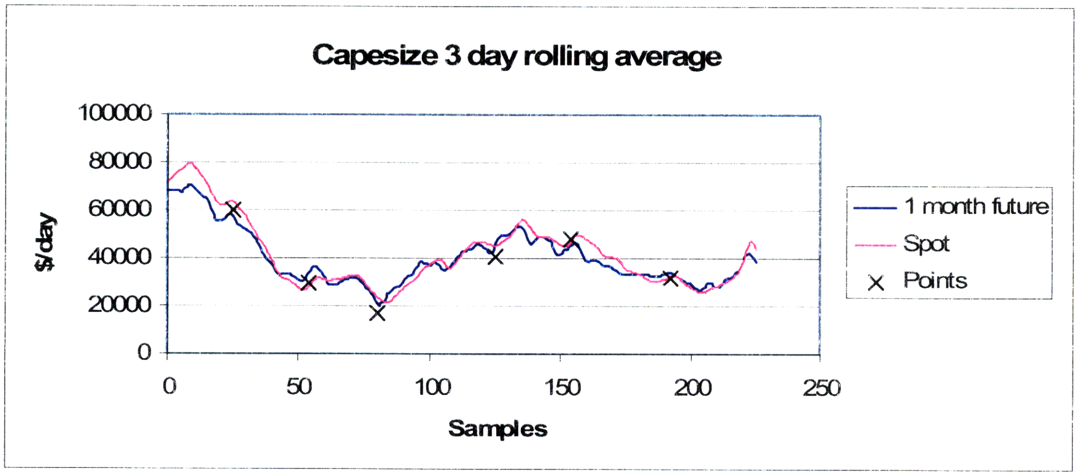

Fig 2 Rolling average for Capesize market for 1-230 days

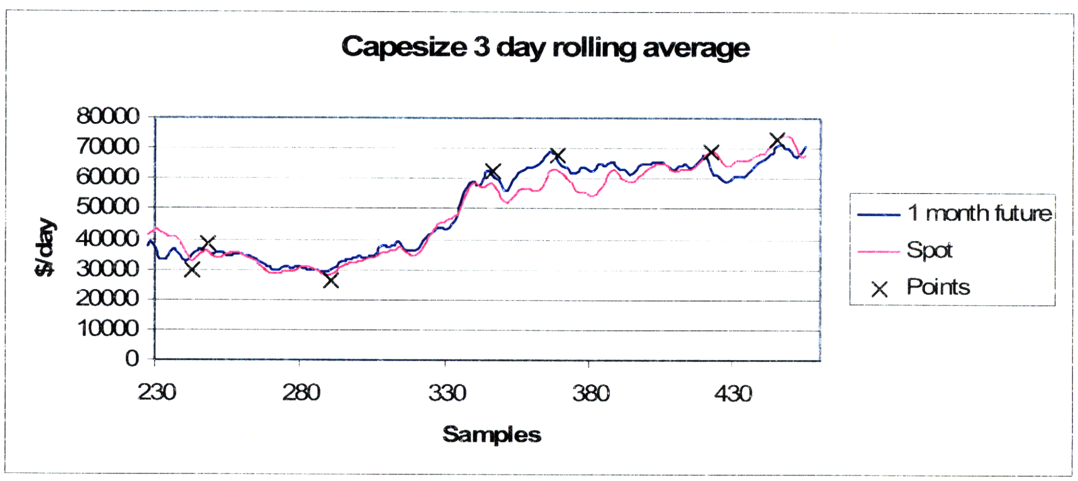

Fig 3 Rolling average for Capesize market for 231-460 days

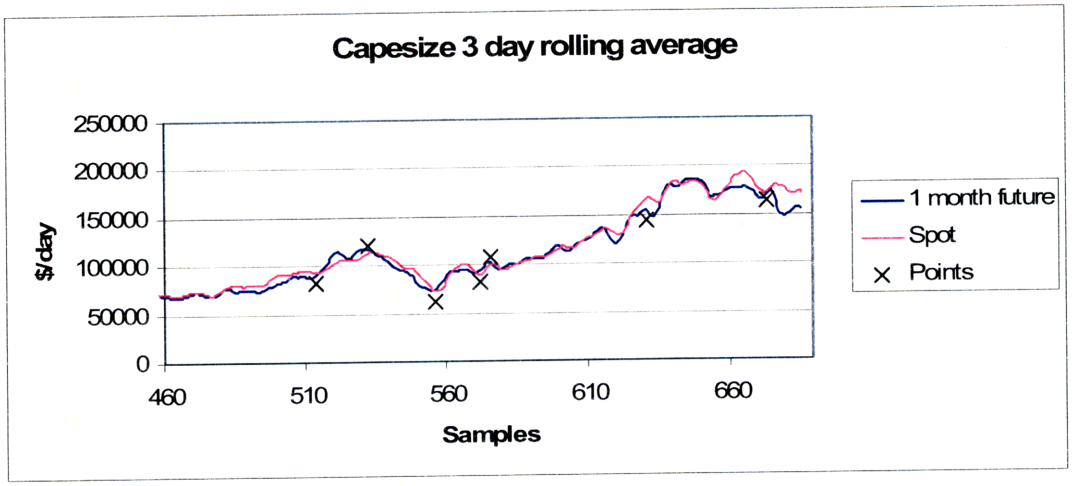

Fig 4 Rolling average for Capesize market for 46 1-685 days

From the Figures 2, 3, 4 above we can observe that during the period 4/2/2005-12/18/2007 the physical market followed the paper one at least 20 times. As mentioned above, we took into account only the cases in which the paper market changed direction and that means that on average the paper market leads 7 times per year.

2.3. Panamax market

Brief market review: Panamax vessels are dry bulk vessels being able to transport about 70,000t of commodities. They are used to carry a wider range of commodities compared to capesize vessels like iron ore, coal, grain, bauxite and phosphate rock. Their main routes for iron ore are from Brazil and W. Australia to W. Europe and Japan, while for coal the main routes are from Australia and North America to W. Europe, Japan and Far East. As happened with the boom of Capesize market, the market was strong for April and May 2005 and went down to approximately $20,000/day until July 2006. From that time until the end of 2007 the market was continuously rising reaching $94,977/day on 10/30/2007. The daily operating expenses were about $6,000/day.

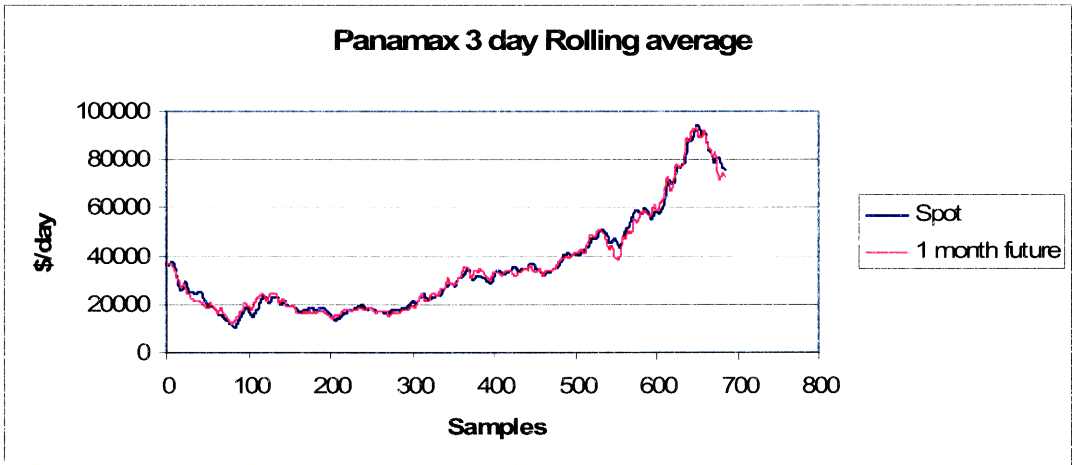

Fig 5 Rolling average for Panamax market for 1-685 days

Again, the relationship between the two markets will be examined more clearly by separating the time series in 3 parts in order to have a better view of graphs.

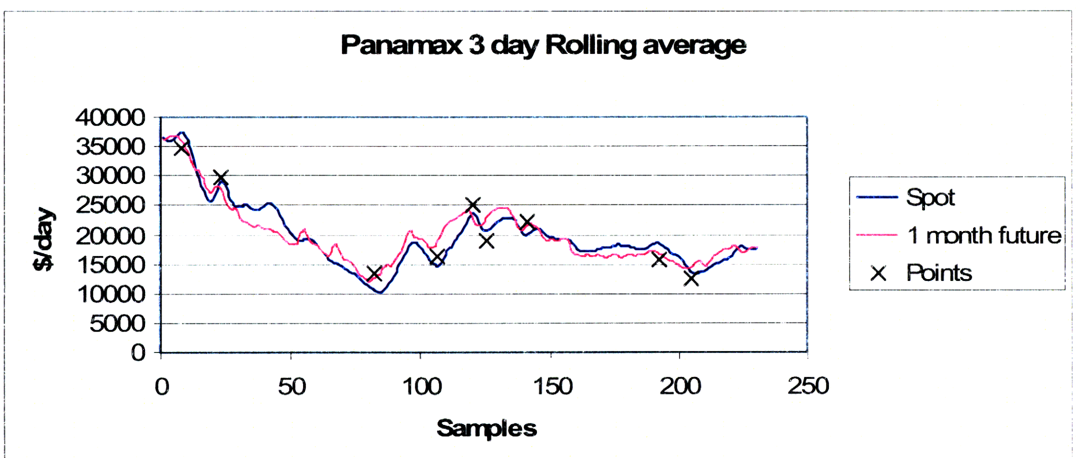

Fig 6 Rolling average for Panamax market for 1-230 days

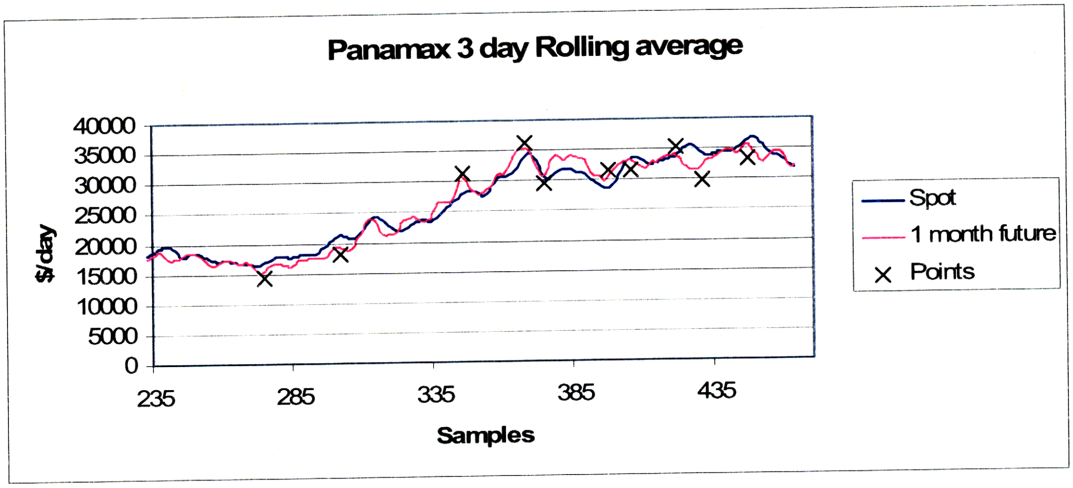

Fig 7 Rolling average for Panamax market for 231-460 days

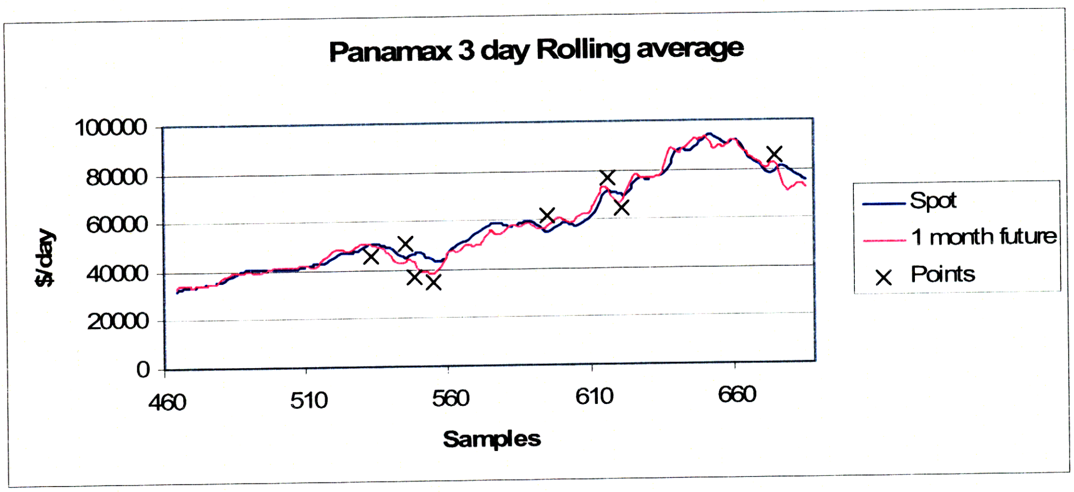

Fig 8 Rolling average for Panamax market for 461-685 days

In the above figures we can see 27 points in which the spot market follows the 1 month future in terms of direction. That means that, on average, 9 times per year the physical market changes direction after the paper one does. This period ranges from one to four days. The effect of the one market to the other in terms of slope could not be identified by simple observation and will be included in later chapter of the thesis.

2.4.Supramax market

Brief market review: Supramax is a relatively new capacity for the bulk carriers which replaced the Handymax in Jan 2006. Their deadweight is about 54,000t. These vessels carry the standard bulk commodities, as well as many parcels, some containers, and prove the vessel of choice for semi-finished steel products. The most frequently carried commodities are grain, bauxite and phosphate rock. Their main routes are from Australia and W. Africa to Japan and W. Europe. As they have their own cranes on board, they can also go to less sophisticated ports. Due to the late launch of this capacity, the analysis performed was for the years 2006, 2007.

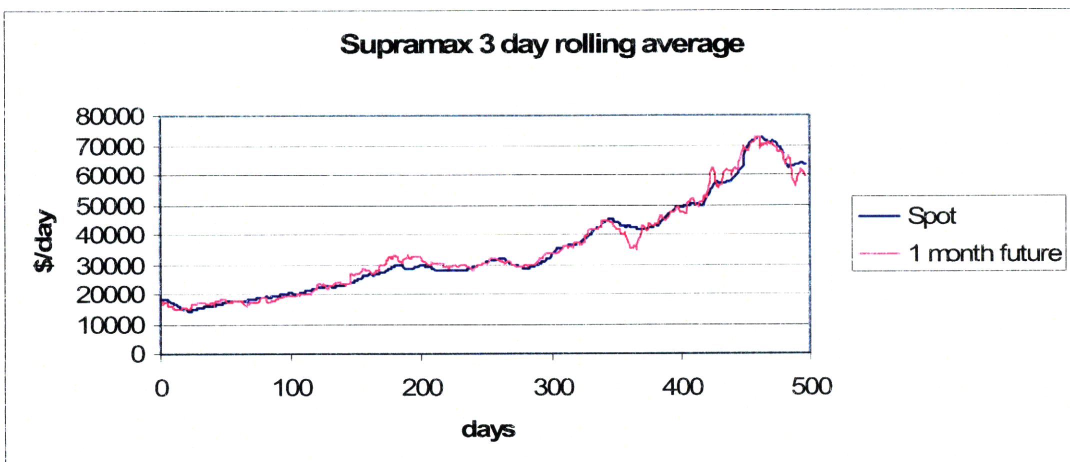

Fig 9 Rolling average for Supramax market for 1-497 days

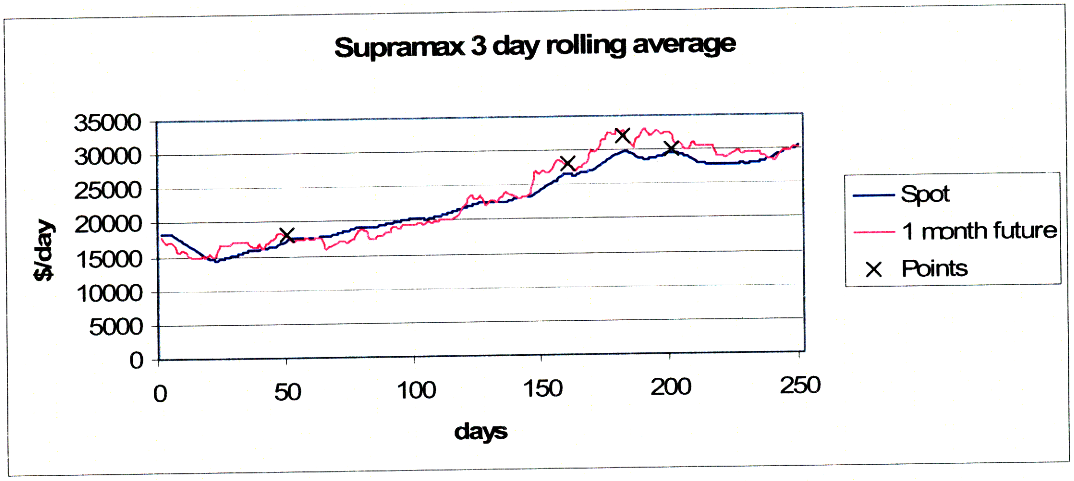

Fig 10 Rolling average for Supramax market for 1-250 days

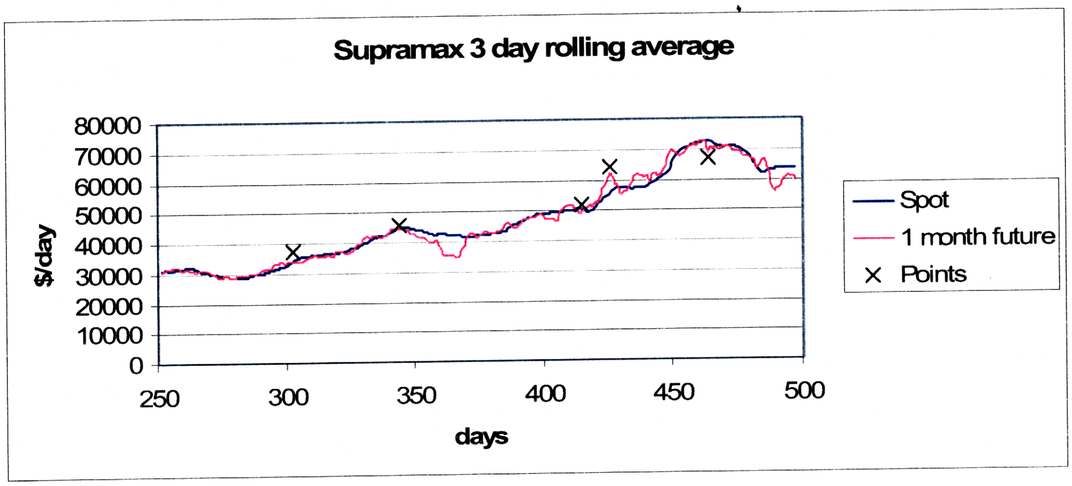

Fig 11 Rolling average for Supramax market for 251-497 days

In the Fig 10 and Fig 11 we can see clearly the time series of the two markets and observe their relationship. As it can be seen in Fig 9, the market for this type of ships was rising constantly over the two years that it was launched. There were a few time periods in which the market fell but they were very brief. Therefore, the lead lag relationship of the two markets was more difficult to be identified. However, even in these slight corrections of the market, we did observe the paper market leading and the spot following one to three days later. Overall, these points were nine resulting in about 5 points/year.

Concerning the slope of the two graphs, we can observe that they are very close, not allowing for concluding that there is any lead-lag effect.

2.5. Tankers TD3

Brief market review: TD3 is the crude oil tanker route from Ras Tanura (Saudi Arabia) to Chiba (Japan) and the vessels used are VLCCs of 260,000 deadweight tons. The futures trading for this route is the highest within the tanker freight derivatives according to IMAREX.

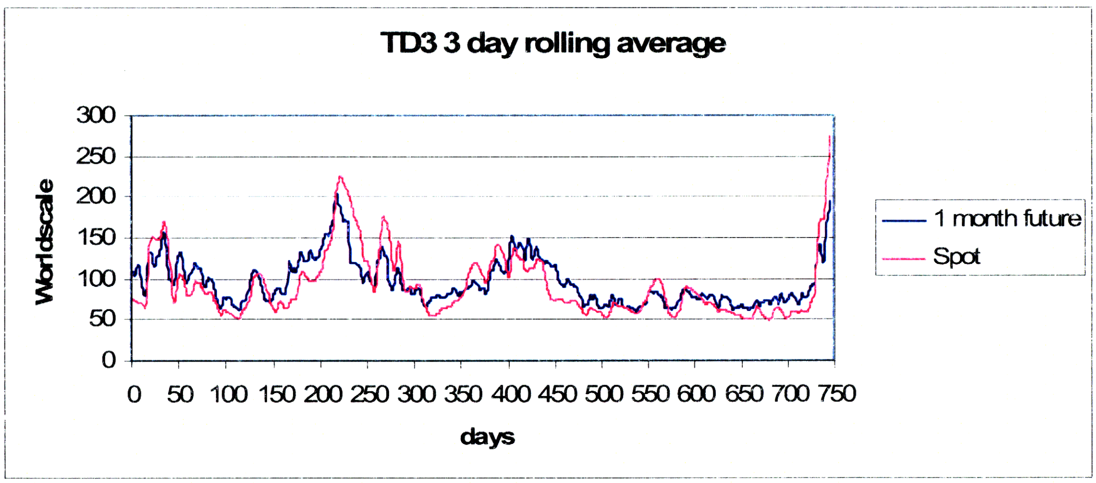

Fig 12 Rolling average for TD3 market for 1-747 days

In Fig 12, we can see the time series of the two markets from 01/03/2005 to 12/18/2007. The market was significantly strong in the last quarter of 2005 and the first quarter of 2006 while in 2007 the market was weak except a boom in the last two months of the year. Although dry spot and futures markets are highly correlated (over 0.99), the two markets in TD3 have lower correlation factor of 0.84 (detailed analysis on the correlations will be presented in the next chapter).

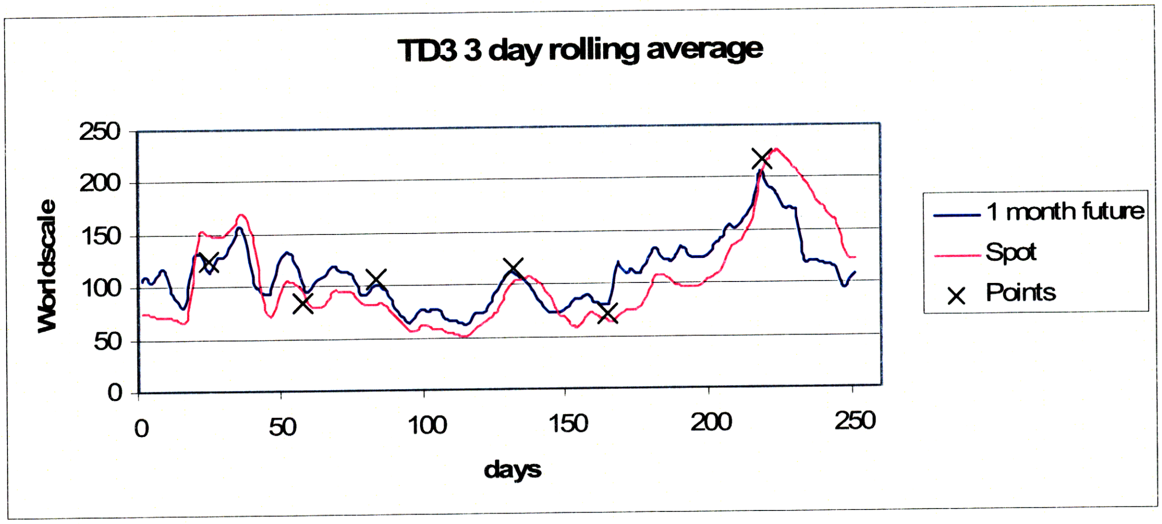

Fig 13 Rolling average for TD3 market for 1-250 days

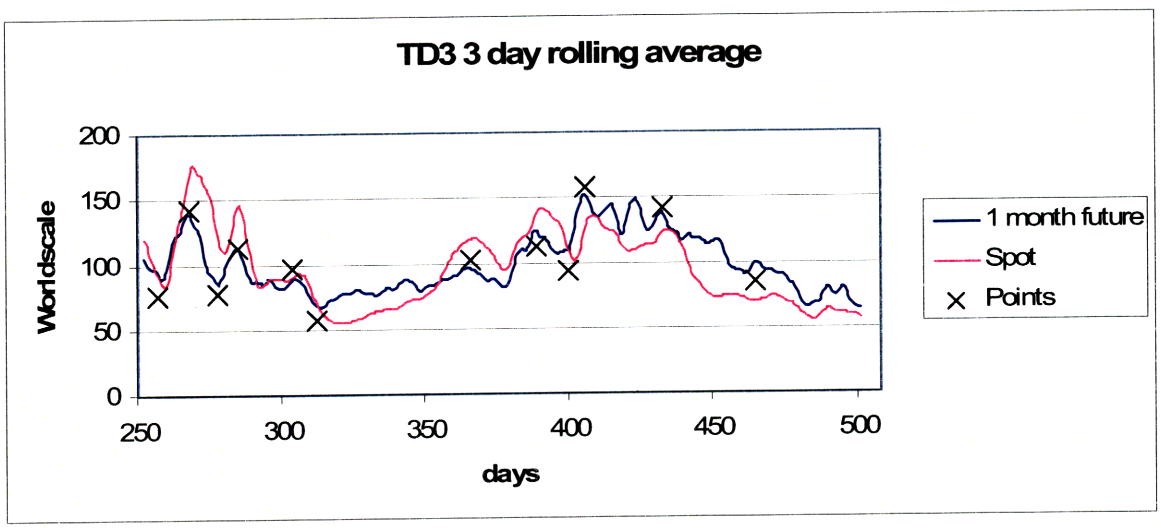

Fig 14 Rolling average for TD3 market for 251-500 days

In Fig 13, 14 we can observe many significant changes of direction. In almost every change which took place in this time period, the futures market led the spot one. Contrary to other cases, in these 250 days the market changed from falling to rising and vice versa many times. In each case the market kept its trend for a significant amount of time (over 7 days) which means that they were not instantaneous market corrections but rather supply-demand imbalances. Therefore, we could conclude that in a smoothly changing market without spikes or very long-term trends (like Supramax), the futures contracts do work as a predictor of the spot market.

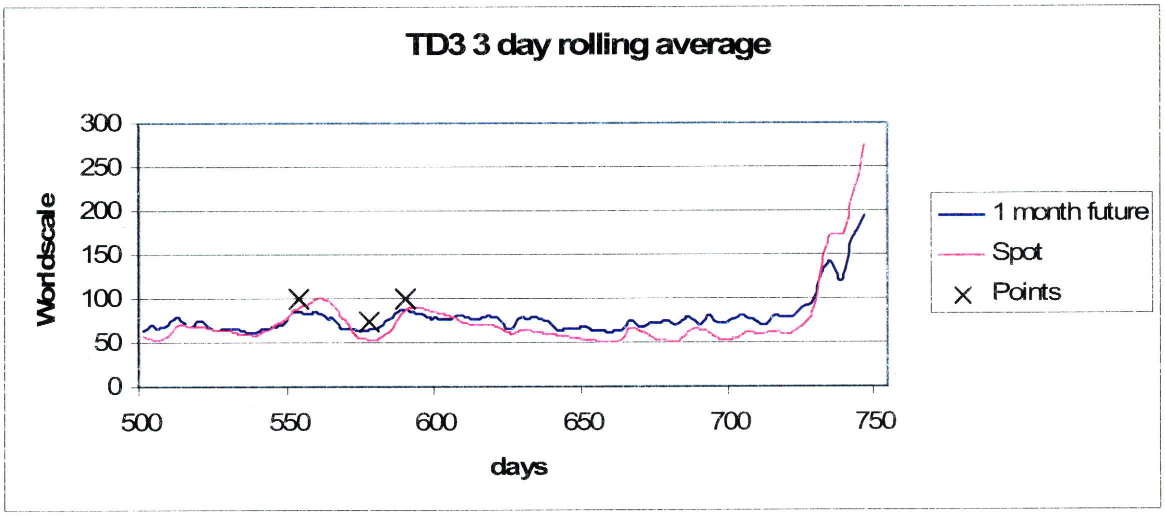

Fig 15 Rolling average for TD3 market for 501-747 days

Unlike the relationship of futures and spot prices shown in Fig 14, in Fig 15 we can see that when the market is relatively stable being disturbed only from small spikes, the futures do not contain any information for the spot. Only 3 points of interest were identified which, like above, appeared in smooth changes of the market which lasted over 5 days.

2.6. TD5

Brief market review: TD5 refers to the route from W. Africa (Nigeria) to US East coast (Philadelphia) carrying 130,000 tons of crude oil in a Suezmax tanker. The futures contract trading in this route is also very high among the other tanker routes.

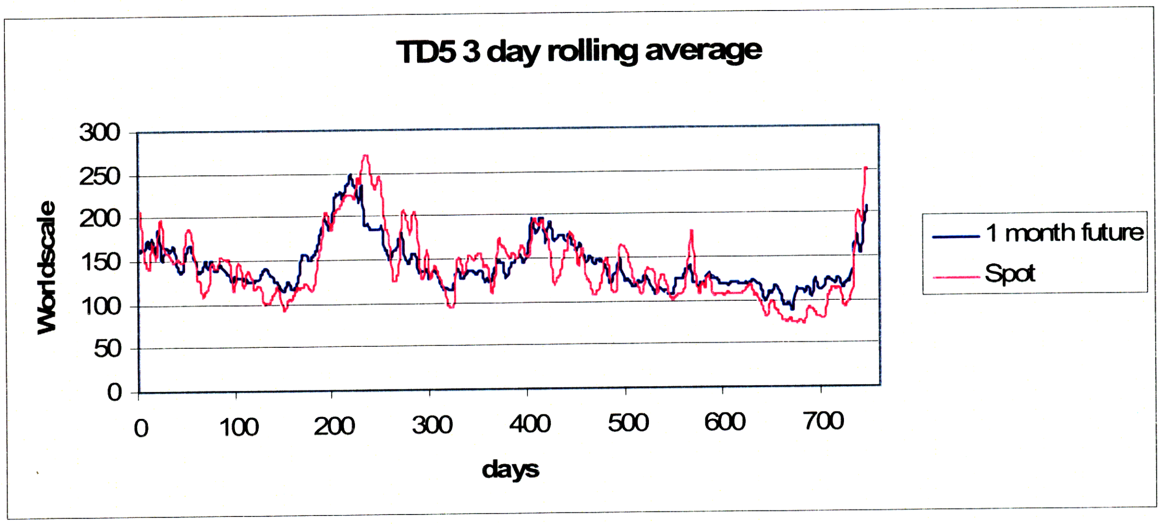

Fig 16 Rolling average for TD5 market for 1-747 days

In Fig 16, we can see the time series of the two markets from 01/03/2005 to 12/18/2007. The market was generally strong especially in the last quarter of 2005 and the first quarter of 2006 while it deteriorated in the first and second quarters of 2007. In the last quarter of 2007 the market was characterized from the booming prices. As expected the two markets are highly correlated. Unlike TD3 there were several cases in which the market fluctuated significantly in narrow time periods making the leading of the futures market more difficult to occur. Additionally, the correlation between the two markets is 0.83, much lower than the correlation of dry markets. The detailed figures of the two markets are presented below:

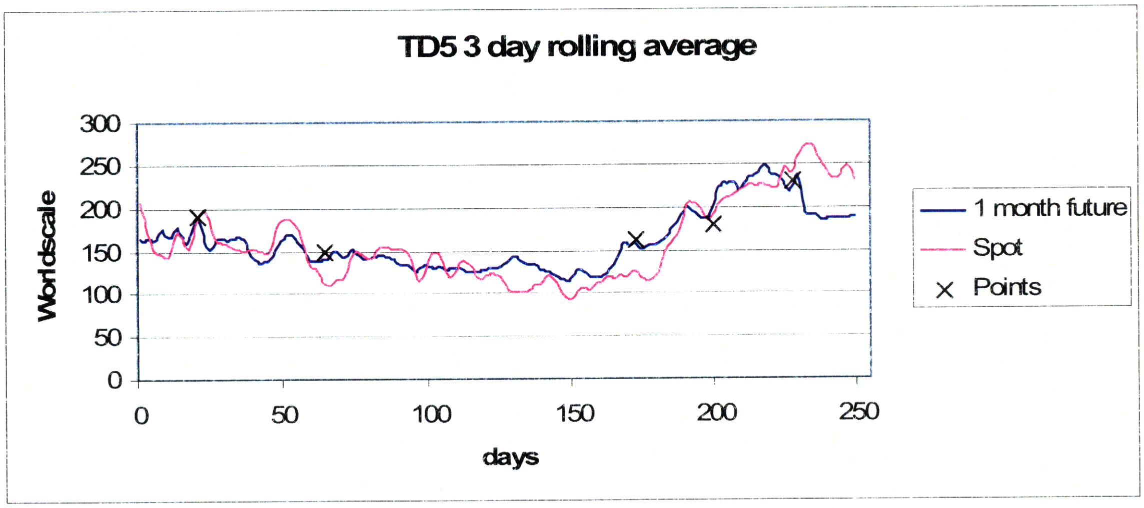

Fig 17 Rolling average for TD5 market for 1-250 days

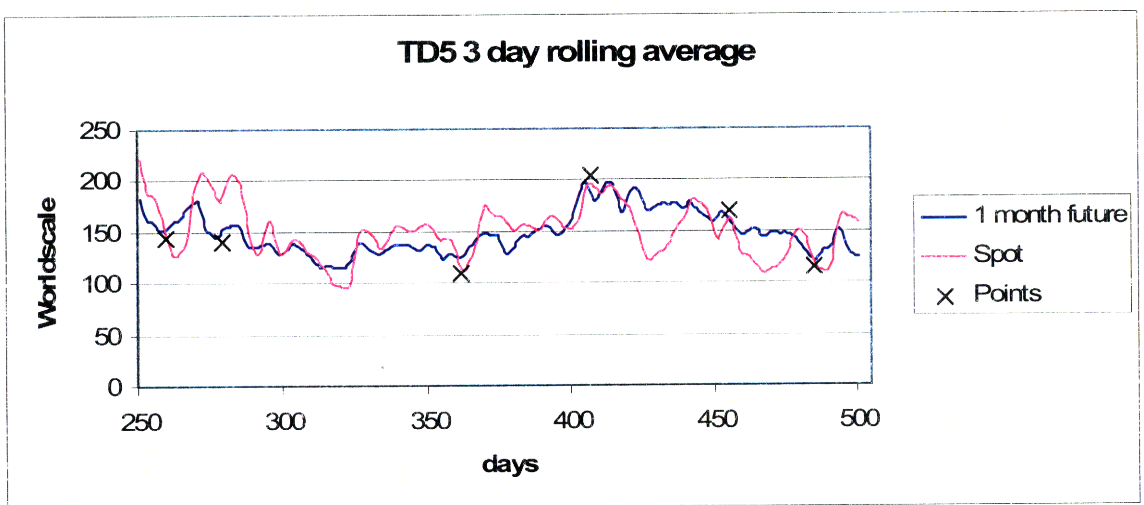

Fig 18 Rolling average for TD5 market for 251-500 days

In Fig 17 and 18 we can identify 10 points in which the spot market follows the 1 month future contracts. The lack of smoothness of the changes in prices in TD5 is probably responsible for this low number of points contrary to the respective number of

TD3. Additionally we can observe many time periods in which the two markets had completely different behavior.

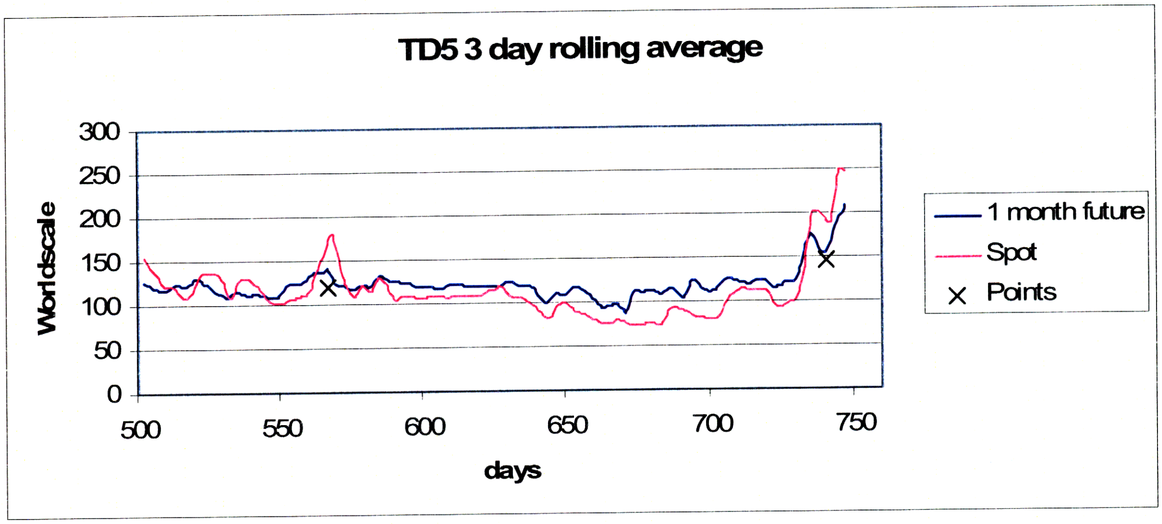

Fig 19 Rolling average for TD5 market for 501-747 days

As seen also in TD3, the last section of samples (days), which accounted for 2007, had very few points in which the paper market led the spot. The fluctuations of the spot market were small, compared to the other periods, and they were made simultaneously in the two markets. Therefore, only two points were identified.

2.7. TD7

Brief market review: TD7 is the route from UK (Sullom Voe) to Germany (Wilhelmshaven) for 80,000 tons of crude oil carried in an Aframax tanker reflecting the transportation of oil from the North Sea to Continental Europe. That type of tankers is mainly employed in the intra-regional trade of the North Sea, the Caribbean, the Far East and the Mediterranean. Future contracts of TD7 are the most frequently traded Aframax tanker contracts.

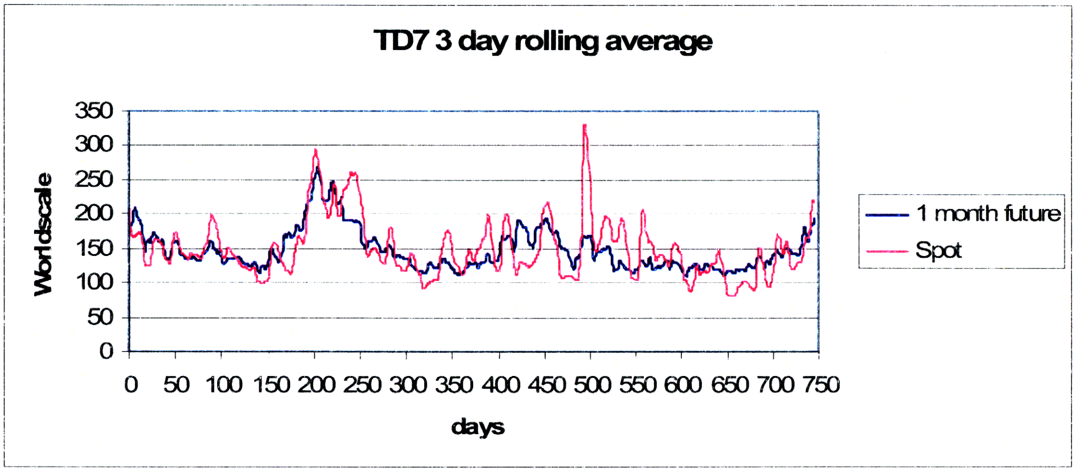

Fig 20 Rolling average for TD7 market for 1-747 days

As we can see from the above Fig 20 which has the complete time series from 01/03/2005 to 12/18/2007, the market was strong until the first quarter of 2007. There were some significantly high periods when rates exceeded WS 200 like in the last quarter of 2005 and a spike in the last days of 2006. In the second and third quarter of 2007 the market was weak until the last two months of the year when it started booming. More details concerning the relationship between physical and paper market can be seen in the next three graphs:

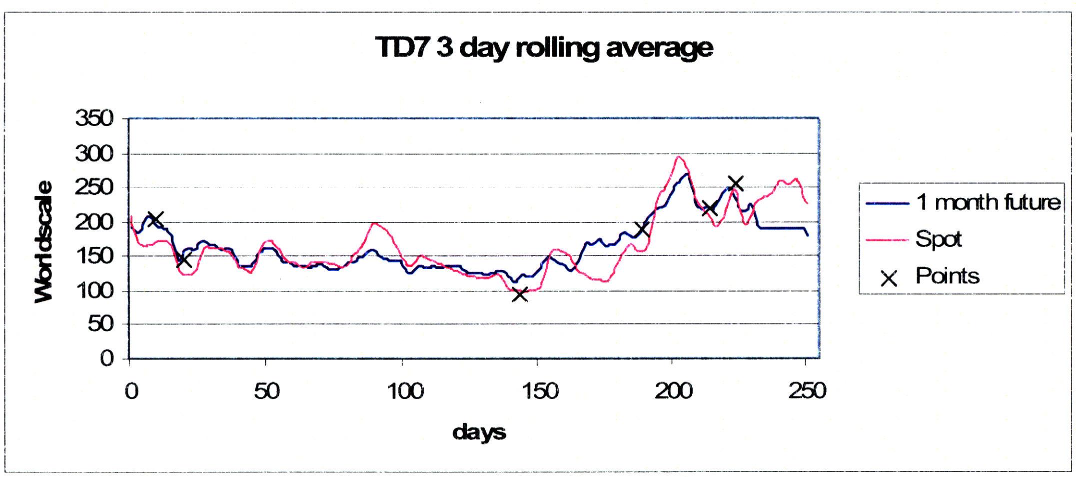

Fig 21 Rolling average for TD7 market for 1-250 days

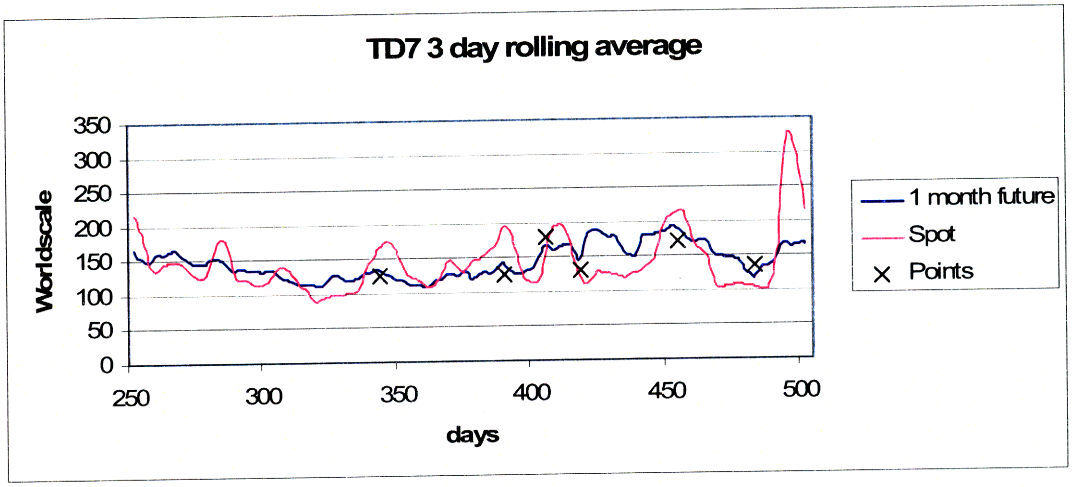

Fig 22 Rolling average for TD7 market for 251-500 days

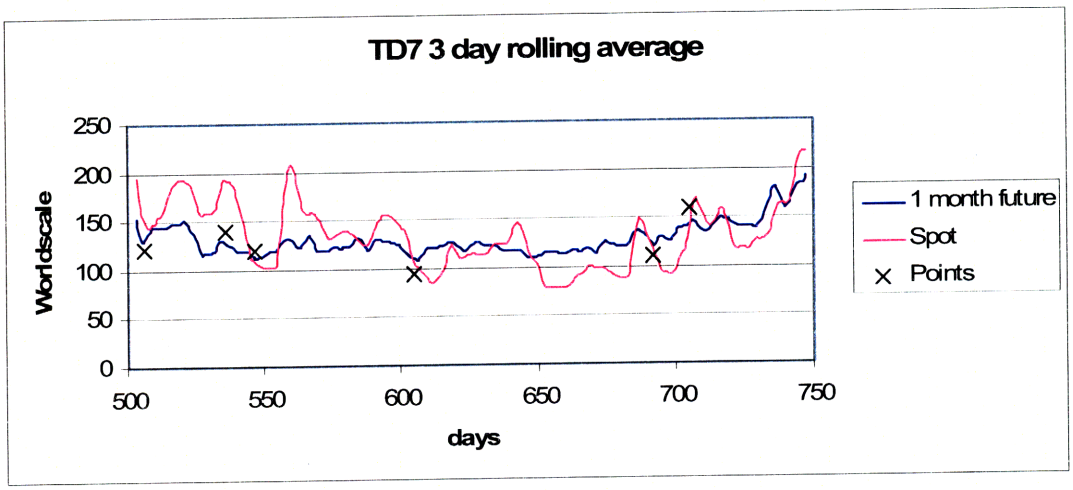

Fig 23 Rolling average for TD7 market for 501-747 days

Although the two markets were not highly correlated (0.69), there were several points identified where the spot market followed the derivative contracts. By carefully observing the graphs, we identified 18 points of interest. Again the effect of the one market to the other could not be identified in terms of slope because of the daily fluctuation of the rates which never keep a constant rate of growth. There were 9 points per year on average, on which the paper market led, and then lead period ranged from 2 to 4 days.

2.8. TD9

Brief market review: TD9 is an Aframax route from Carribean to US Gulf for 70,000 tons of crude oil. The market in this route was generally significantly stronger than in the other dirty tanker routes examined being almost always above WS150. The third and fourth quarter of 2005 had very high rates reaching even WS350 while the first and last quarter of 2006 were also very strong. A significant characteristic of this route is that spot and futures market are not highly correlated (0.76) and therefore the points in which spot rates followed the future prices were very few. We can see the details of the time series of the two markets in Figures 25, 26, 27.

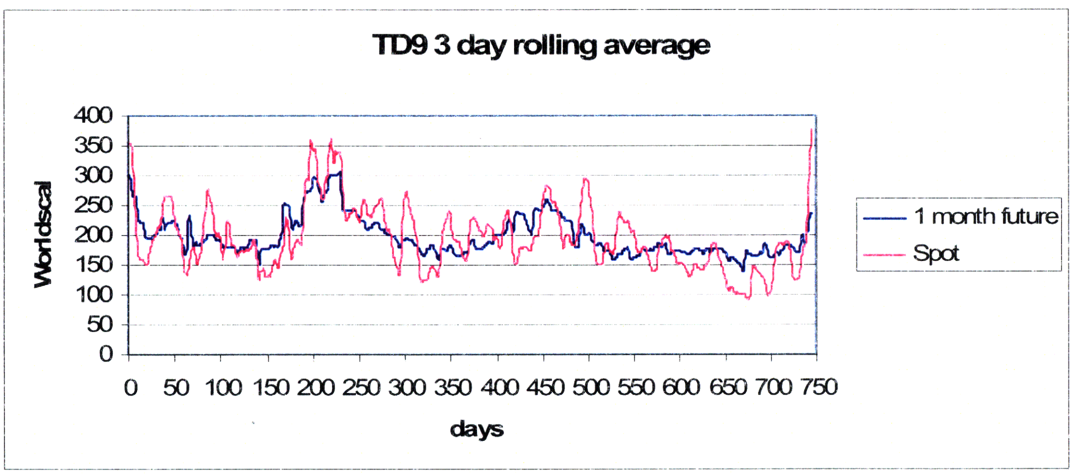

Fig 24 Rolling average for TD9 market for 1-747 days

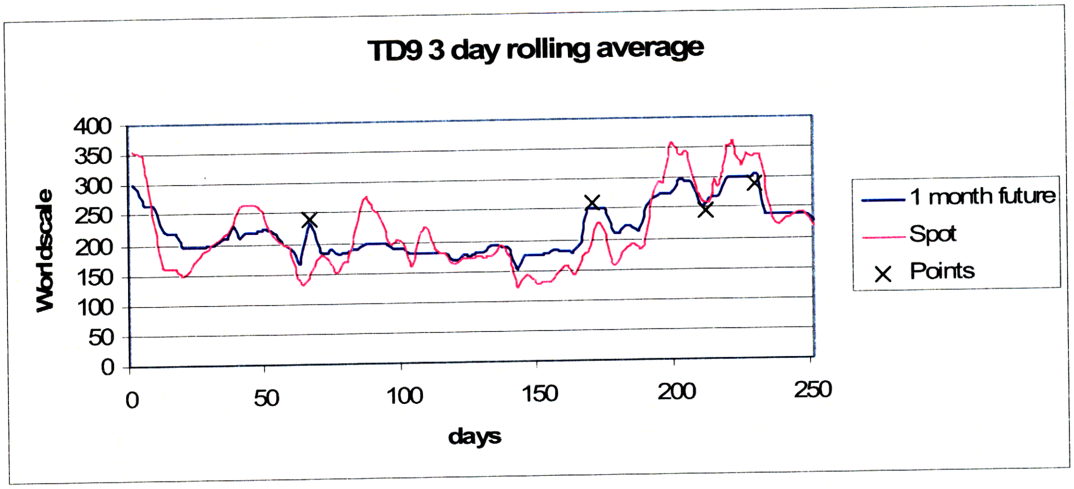

Fig 25 Rolling average for TD9 market for 1-250 days

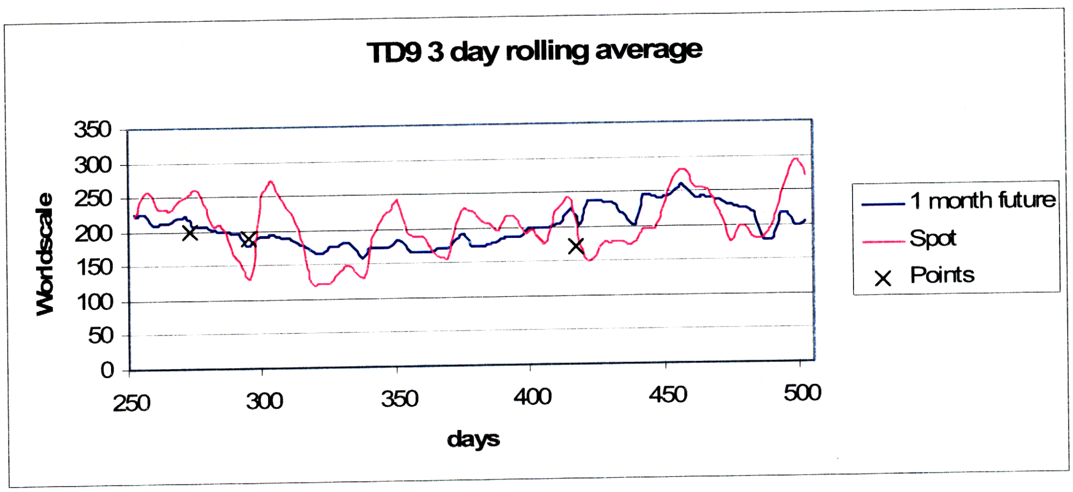

Fig 26 Rolling average for TD9 market for 251-500 days

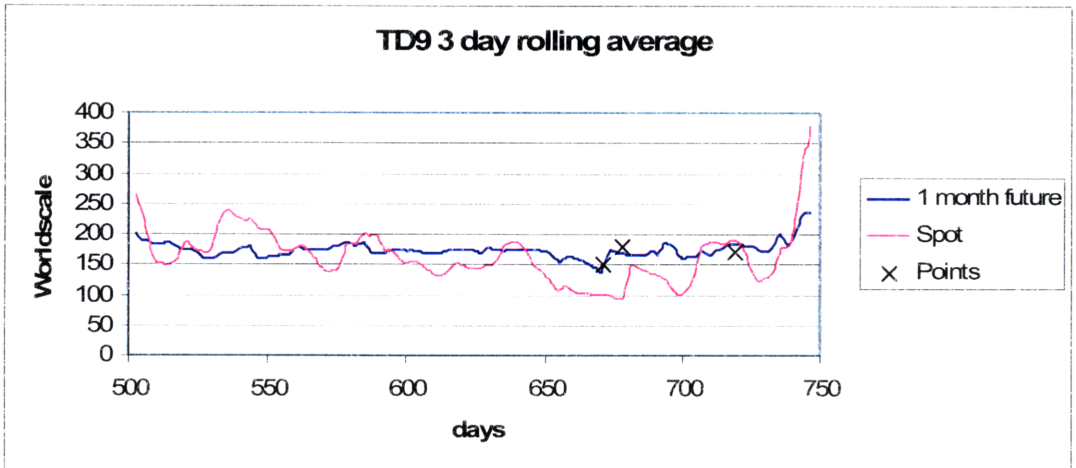

Fig 27 Rolling average for TD9 market for 501-747 days

Overall, only 10 points were identified having the desired lag characteristic that we are looking for. The fluctuations observed in the spot market were not reflected in the futures and that is the main reason there are so few points. Additionally, we could observe that even when the two markets were having the same trend, the slope of their graphs was much different.

3. Cross-Correlation Function

3.1. Introduction

In this part of thesis, we will analyze the lead-lag relationship of the spot and derivatives market by calculating the cross-correlation between the two time series. Although, in the general case, correlation does not imply necessarily causality, we will argue later that in our case a strong correlation between the two markets could mean that there is some information hidden in the behavior of the future contracts regarding the spot prices.

3.2. Correlation

In probability theory and statistics, correlation indicates the strength and direction of a linear relationship between two random variables. In general statistical usage, correlation denotes the dependence of two variables. There are several different coefficients used for different situations but the most frequently used is the Pearson product-moment correlation coefficient, which is obtained by dividing the covariance of the two variables by the product of their standard deviations.

$$r = \frac{Cov(X,Y)}{\sigma_X \sigma_Y}$$

Some useful properties of the Pearson correlation coefficient are:

1. The value of r is dimensionless and therefore does not depend upon the units of measurement. It does not also depend upon which variable is labeled X and which variable is labeled Y.

2. $-1 \leq r \leq 1$ A positive value of r means a positive linear relationship while a negative value of r means a negative linear relationship. If r=1 means that the variables are perfectly correlated positively correlated and, therefore, they fluctuate together. On the other hand when r=-1, when the one variable increases, the other always decreases. Finally, when r=0 there is no dependence between the variables.
3. r measures only the *linear* relationship between X and Y.

Another very important characteristic of correlation is its strength. As it ranges from -1 to 1, we should know when there is strong, moderate or weak correlation between the two variables. We can generally define the strength of correlation as follows:

- Strong: $|r| \geq 0.8$.
- Moderate: $0.5 \leq |r| \leq 0.8$
- Weak: $|r| \leq 0.5$.

3.3. Correlation and causality

There is a big discussion whether correlation implies causality. Generally, the answer is that it does not. Nonetheless, correlation is a necessary feature of a causal relation, but it is not sufficient to demonstrate causality. Whether the relation is interpreted as causal, one should depend not just on the correlation of two variables but also on some rational link between them – on the extent to which the relationship makes sense within some sort of conceptual framework or, ideally, on one conceptual structure plus the elimination of alternative possibilities.

The most important characteristic of our analysis is that we do not try to prove a causal relationship between the physical and the paper market. We try to test if there is a moderate or strong strength of correlation between some time lagged periods which could act as a predictor. Additionally, the two markets are driven from the same players and more or less the same parameters by which supply and demand are, by far, the most important.

3.4. Cross-correlation

Cross-correlation is a signal processing function which is used to measure the similarity of two signals, commonly used to find features in an unknown signal by comparing it to a known one. The CCF (Cross correlation function) provides a statistical comparison of two sequences as a function of the time-shift between them. It reflects the various frequency components held in common between the two sequences Xn, Yn. From a practical point of view the CCF is useful when there are timing differences between two sequences. For example, if x[n] and y[n] are identical white noise sequences which differ only in the time origin, their CCF will then be zero for all values of m, except the one which corresponds to the timing difference.

In our case we will calculate the CCF of the time series of the physical and paper market in order to examine the correlation of the two markets for different time shifts. There could be, for example, a case in which the two markets have low correlation for zero time shift but higher if the spot lagged the futures.

As mentioned above, the cross-correlation is a function of the time shift between the two variables-time series. Its mathematical formula is given below:

$$r_{xy}(k) = \frac{C_{xy}(k)}{S_x S_y}$$

$$C_{xy}(k) = \begin{cases} \frac{1}{n}\sum_{t=1}^{n-k}(x_t - \overline{x})(y_{t+k} - \overline{y}), k = 0,1,2... \\ \frac{1}{n}\sum_{t=1}^{n+k}(x_{t-k} - \overline{x})(y_t - \overline{y}), k = 0,-1,-2... \end{cases}$$

$$S_x = \sqrt{\frac{1}{n}\sum_{t=1}^{n}(x_t - \overline{x})^2}$$

$$S_y = \sqrt{\frac{1}{n}\sum_{t=1}^{n}(y_t - \overline{y})^2}$$

where $r_{xy}(k)$ is the cross-correlation function of lag k, $C_{xy}(k)$ is the covariance of the two variables as a function of k and S_x, S_y are the standard deviations of the variables which are divided with the covariance in order to give the correlation coefficient.

A simple example of the comparison of two signals is given below with its respective graph in order to visualize the CCF. Suppose we have Signal 1 which goes from 0 to 1 in 1 sec, then remains constant for 3 seconds and drops to 0 again in 1 sec. On the other hand, Signal 2 goes from 0 to 1 after 3 seconds than Signal 1 did, then remains constant for 3 seconds and then drops to 0. The plot of these signals is shown in Fig 28.

The correlation of these two signals is 0. It is obvious though that these signals would be identical if we time-shifted the first signal by 3 sec ahead. The bold line of figure 28 is the plot of the CCF for different lags. The function is zero for zero lag but it gets its maximum 1 for lag of 3 sec having a linear behaviour. We can also see that for lags over 6 sec, the function has negative value indicating that if we time shift Signal 1 more than 6 sec, when Signal 1 increases, Signal 2 decreases.

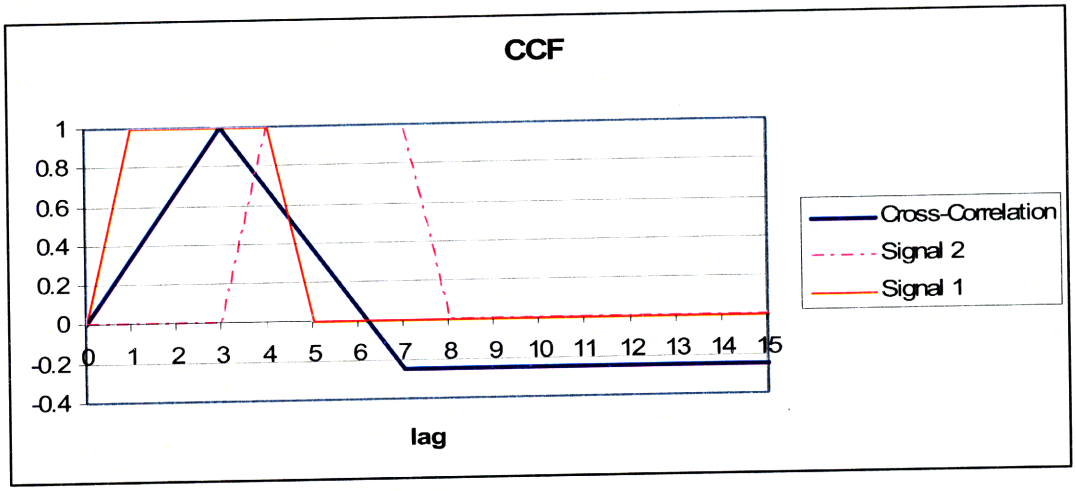

Fig 28 Two signals and their cross-correlation function

We applied the CCF on the time series of the spot and futures market to examine the correlation between them for different time shifts. A strong correlation between the two time series for different lags would indicate that as the one market changes the other follows with similar changes after the lag period. As mentioned above, correlation does not necessarily imply causality.

3.5.Methodology

In order to have reliable results we did not calculate only the cross-correlation of the two time series for each route and market. The trading of freight futures increased significantly during 2006-2007 and therefore the cross-correlation function of each year is also interesting to be examined.

It is argued by market experts that the behavior of futures prices creates momentum to the spot freight rates. To test this assumption we decided to make some additional calculations. We separated the two time series (spot and futures) in smaller pieces in which the spot market was rising or falling for more than 15 days. That means that for a part of the time series that had the sequence given below, we kept only the highlighted elements.

261.59
272.95
272.50
271.36
256.82
248.38
242.95
241.14
231.14
227.73
223.18
219.77
191.36
192.73
180.23
152.73
138.41
118.41
116.59
122.73
122.95

Due to the high volatility of the markets which do not allow prices to have a constant trend for many days, some parts of the time series were ignored for that part of calculations. The result of this separation was a group of smaller time series, usually about twenty. By excluding some of the data which did not belong in any long, with the same trend, sequences, we filtered some data which would not add to our study. The cross-correlation function of these time series was calculated and the average of the results will be presented below. As we will see, each market and each route gave completely different results and, therefore,e we had to examine and comment each case separately. In all cases, positive lags stand for futures leading while negative lags stand for the opposite.

3.5.1. Capesizes

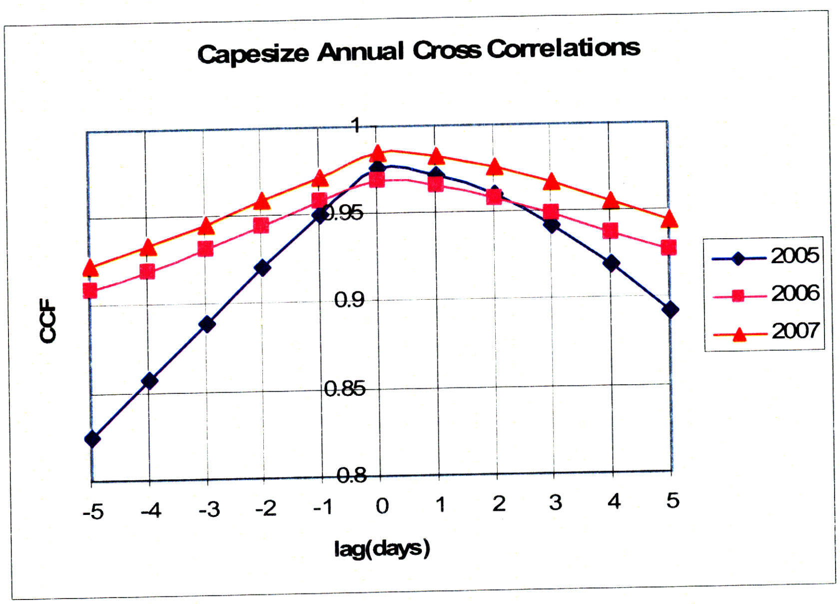

Fig 29 Capesize CCF for 2005-2006-2007

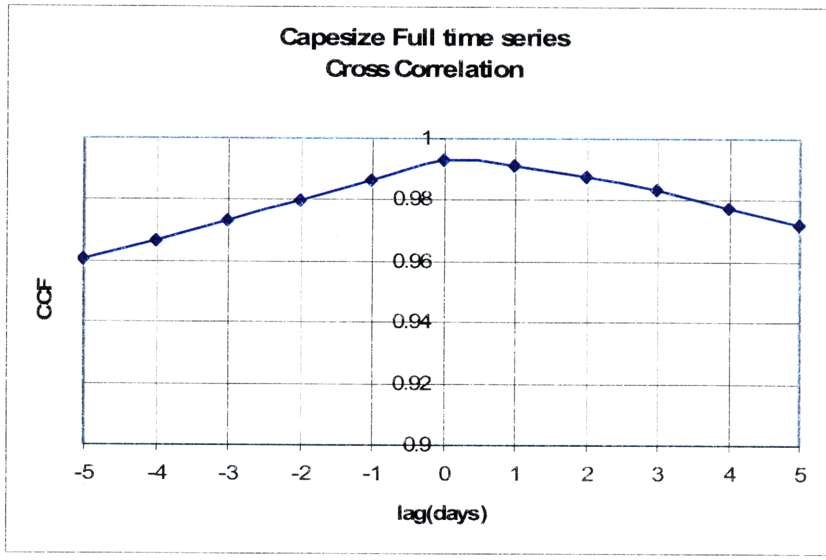

Fig 30 Capesize CCF for the complete time series

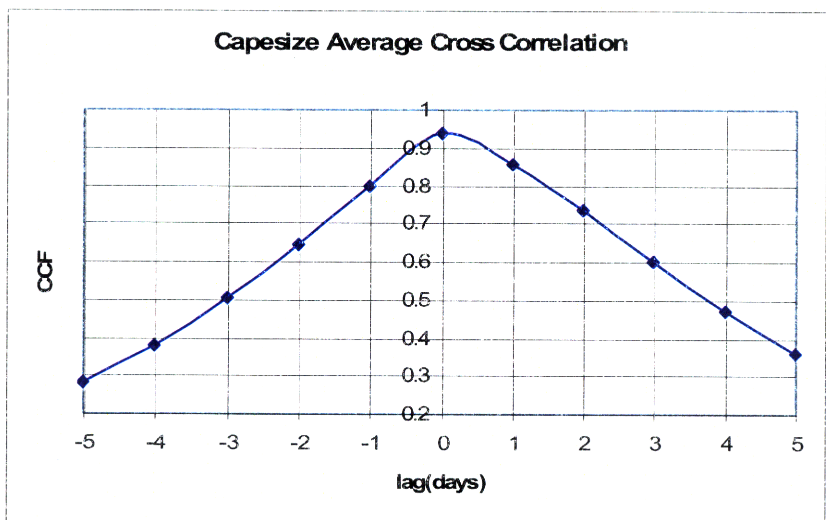

Fig 31 Capesize CCF for the average rising-falling market

What we generally observed in almost all cases was that the correlation for zero lag was maximum. For the Capesizes, zero lag correlation was always over 0.95 indicating the strong linear relation of the two markets. A very interesting finding is that the cross-correlation function was not absolutely symmetrical for positive and negative lags. Although for negative lags (spot leading the futures) the correlation is still high, for positive lags is even greater. This is very visible in Figure 29 for the CCF of 2005 where the plot declines more steeply for negative lags.

3.5.2. Panamax

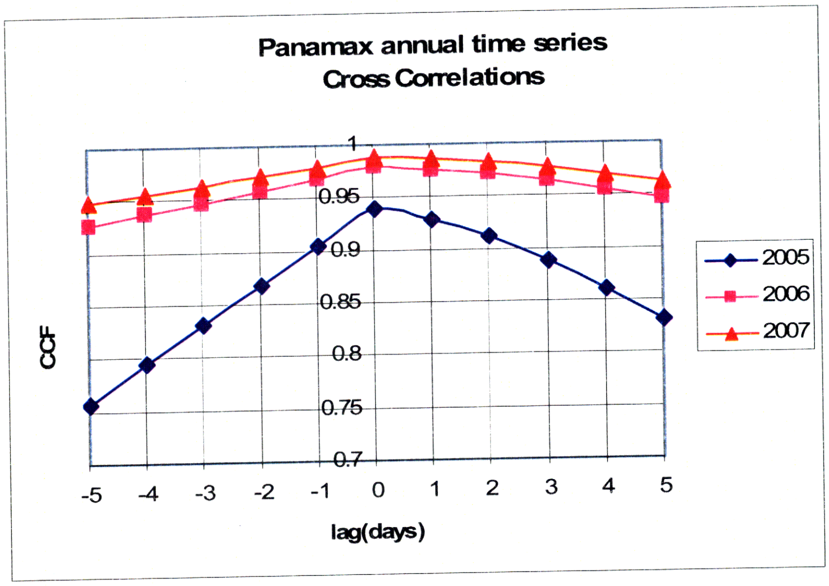

Fig 32 Panamax CCF for 2005-2006-2007

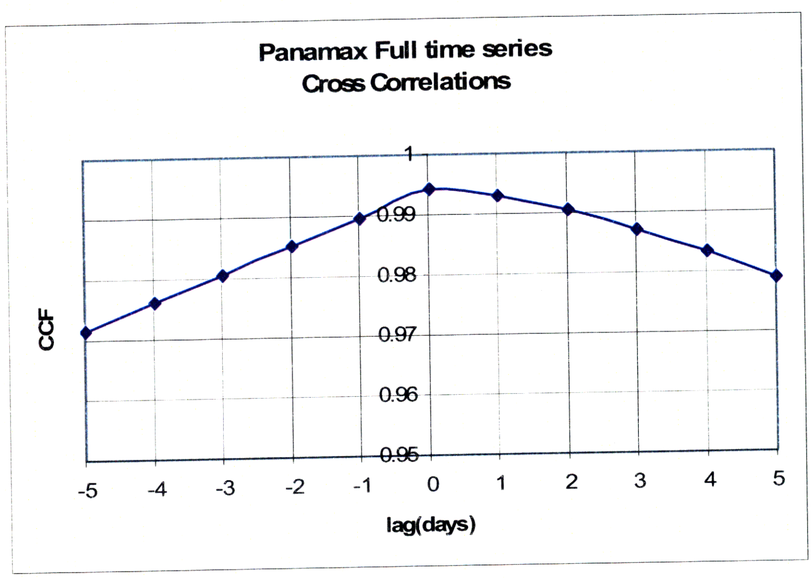

Fig 33 Panamax CCF for the complete time series

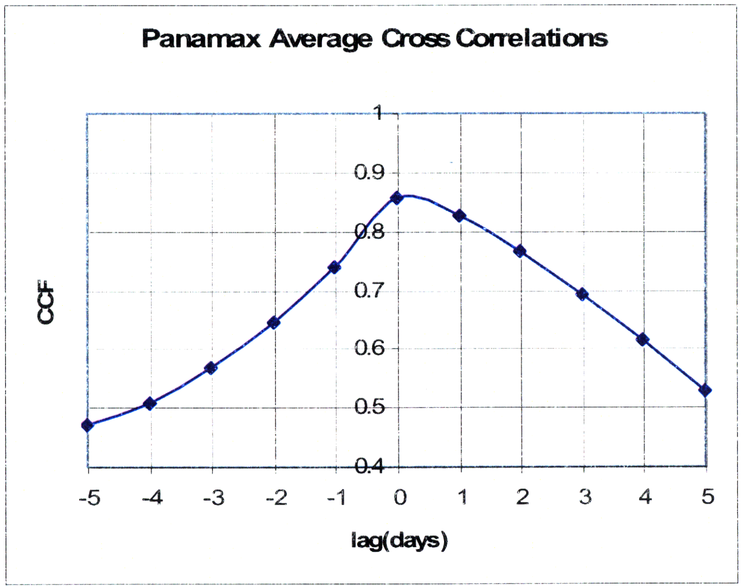

Fig 34 Panamax CCF for the average rising-falling market

In the case of PM4TC basket route, the plots of CCF are very symmetrical with respect to y-axis which means that the correlation for both positive and negative lags is equal. Although this may seem to be a paradox, it is not. It means that if we time shift the one time series over the other for either positive or negative lags, their linear relationship (correlation) is the same.

When analyzing the time series blocks which contained sequences of a rising or falling market, we observed that the correlations were lower than for the "unfiltered" data.

3.5.3. Supramax

In the SM5TC route there was no reason for separating rising or falling market segments because the market was almost always rising during its two years of trading. Some short periods in which the market fell did not play any role in the final results.

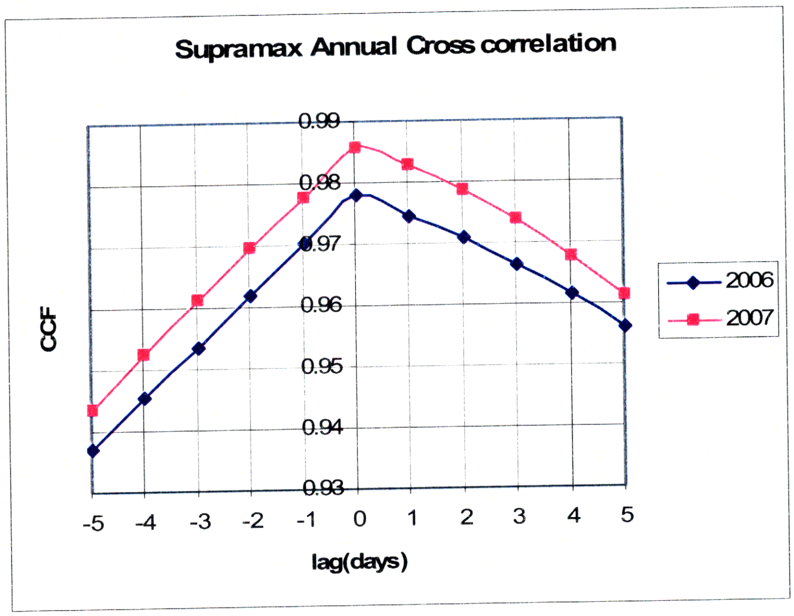

Fig 35 Supramax CCF for 2006-2007

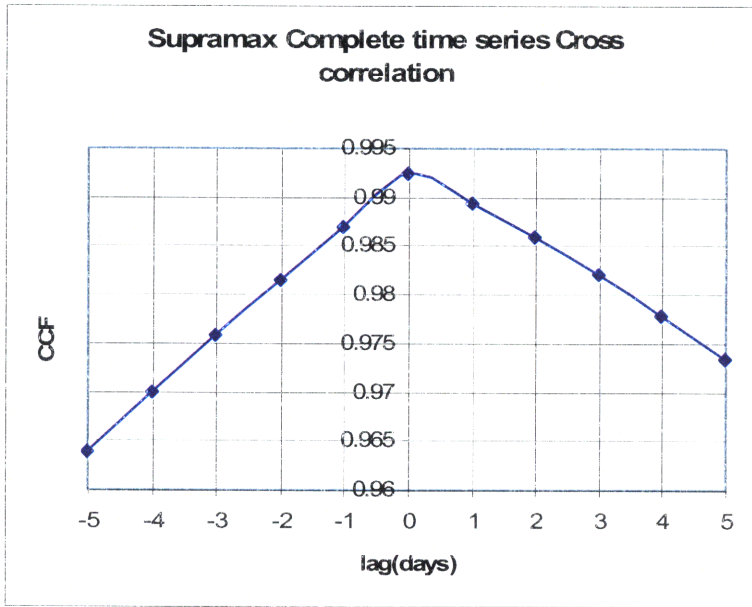

Fig 36 Supramax CCF for the complete time series

From the graphs above we can observe that cross-correlation values are very high for both positive and negative time lags. On the other hand, we can see in both diagrams that the values of the function for positive lags are slightly higher than for negatives. However, the difference is so small that we cannot prove that futures market generally leads the spot but it is an indication that overall futures market could be a better predictor than the opposite case.

3.5.4. TD3

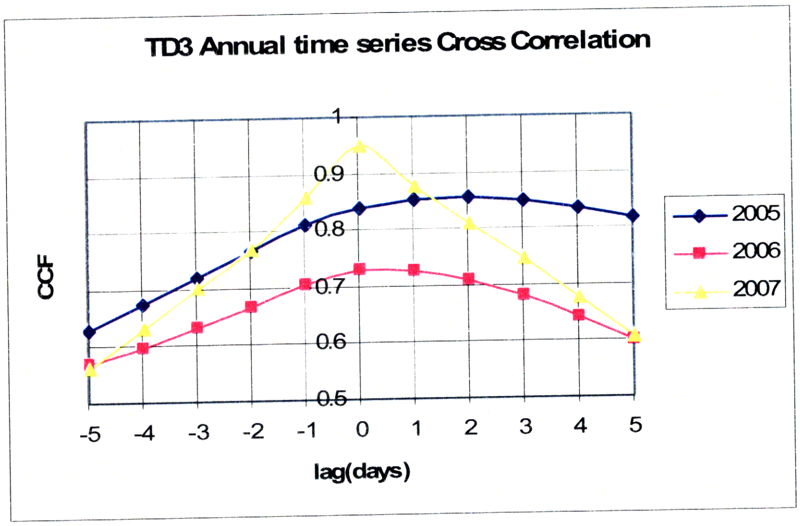

Fig 37 TD3 CCF for 2005-2006-2007

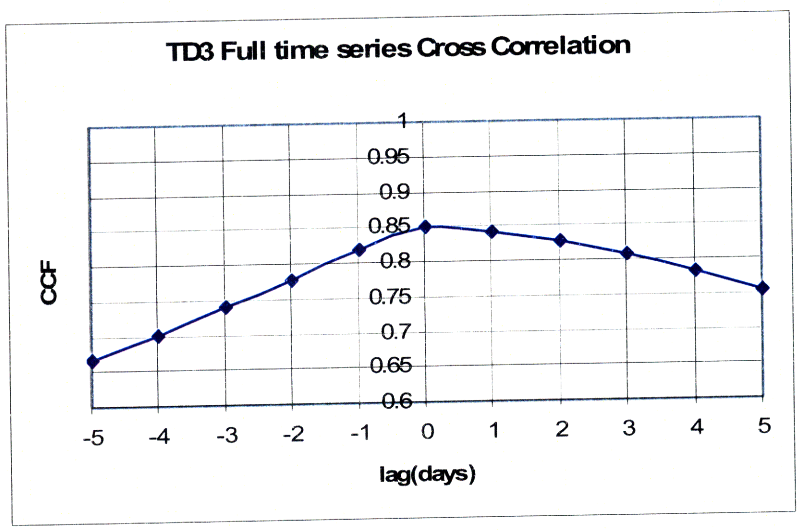

Fig 38 TD3 CCF for the complete time series

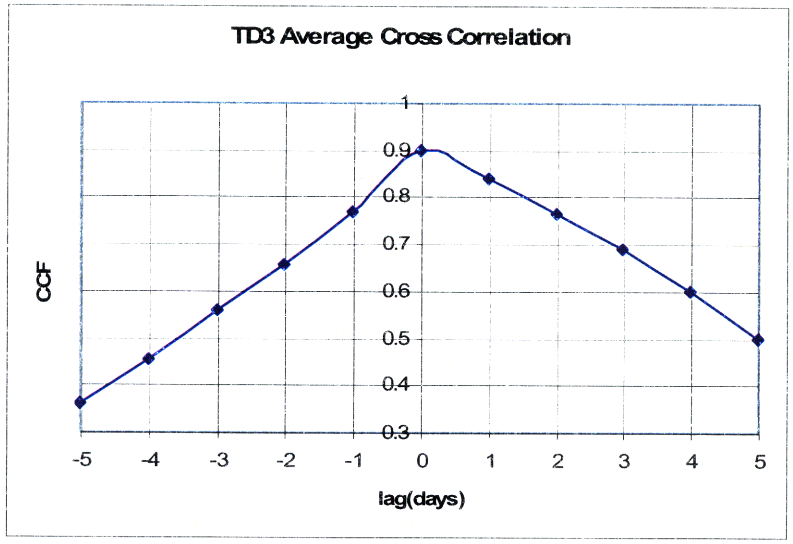

Fig 39 TD3 CCF for the average rising-falling market

Unlike the routes of dry market which proved to have very close cross-correlation values for positive and negative time lags, the tanker market had different behavior.

In Fig 37 we can see that the highest correlation for zero lag occurs for 2007 but then declines rapidly in both directions. The plot of 2007 is quite symmetrical while the plot of 2005 indicates a much higher correlation for positive lags than for negatives. However, we could argue that 2007 is closer to reality since the trading of future contracts in 2007 was much heavier than in 2005.

Another interesting finding comes from the cross-correlation function of the full time series in Fig 38. The values of the function for positive lags are always greater than for negative ones. Unlike the above cases where the values for positive lags were always insignificantly greater than the negative, for TD3 there is difference of 0.1 for ± 5 lags and slightly less for shorter ones.

The same is valid also for the average cross-correlation calculations of the Fig 39. The difference of the correlations for positive and negative values is always greater than

0.1 while for ±3, ±4 and ±5 days is 0.15. Although this may seem to be a small difference, we could not expect to observe any large deviations of the correlations for positive and negative time lags due to the nature of the time series. Therefore, the 0.15 difference indicates that paper market could be a reliable predictor of the physical one in TD3. One who exploits this information should not expect to always predict the spot market from the futures but use it as a long term "investment".

3.5.5. TD5

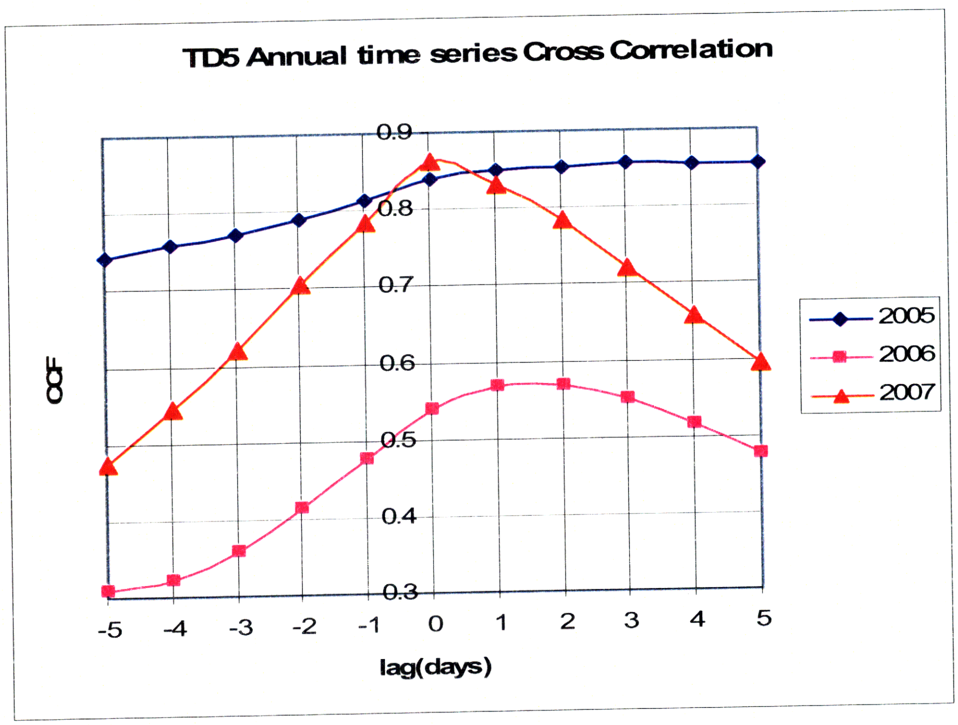

Fig 40 TD5 CCF for 2005-2006-2007

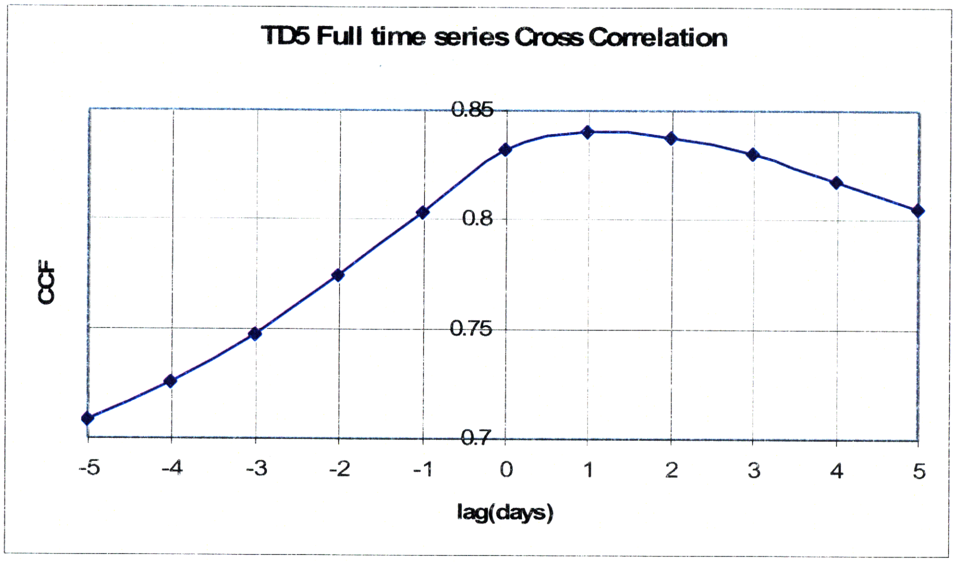

Fig 41 TD5 CCF for the complete time series

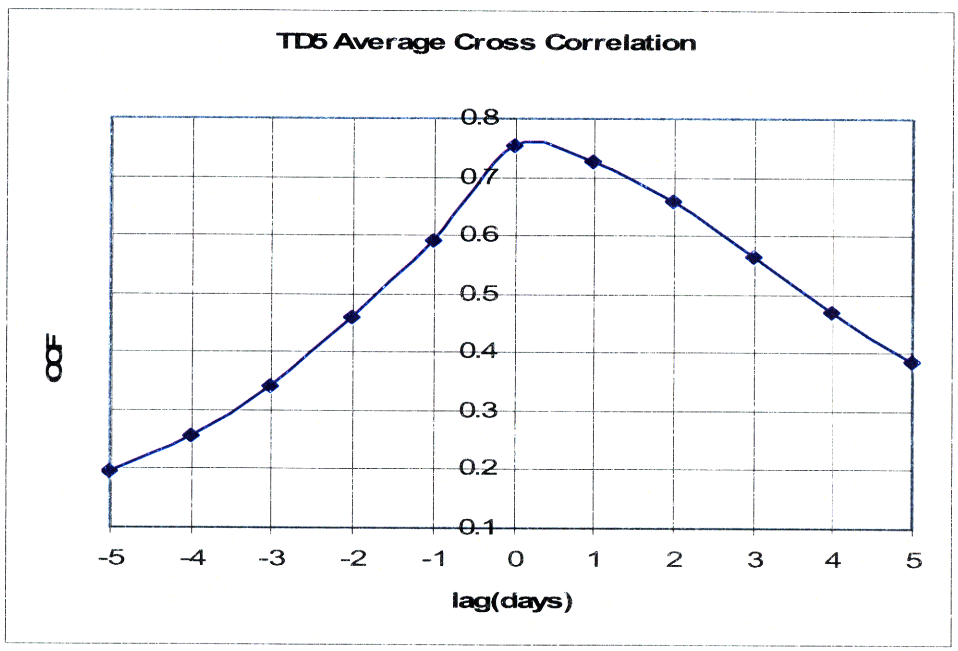

Fig 42 TD5 CCF for the average rising-falling market

In TD5 we also had interesting and valuable results as in TD3 route. In the annual cross-correlation Fig 40, we can clearly see the asymmetry of the values for positive and negative time lags. Although 2005 is quite symmetric, 2006 and 2007, which are of higher interest because they are more recent, have significantly higher values for positive lags. More specifically, for 2006 the values for the positive lags are always (except for the case of +5 which is slightly lower) greater than 0.5 which characterizes the correlation between the two time series as moderate. On the other hand, the CCF for negative time lags is always lower than 0.5 which means that there is weak correlation between the two markets. In 2007, the values of the CCF are significantly greater than those in 2006 but the difference between the values of positive and negative time lags is slightly smaller. However, it is always about 0.1 which cannot be neglected. Therefore, from Fig 41 we can conclude that the futures do lead the spot for TD5.

We can have the same conclusion if we examine Figs 41 and 42. The difference between them is that in Fig 41 we have moderate to strong correlation while Fig 42 implies moderate to weak. The most noticeable finding comes from Fig 42 in which we observe for the first time that the correlation of the two markets is higher for 1 and 2 day positive lags than for zero. That is an even better indication that futures are a reliable predictor, especially for a 1-2 day lag, for the spot prices.

3.5.6. TD7

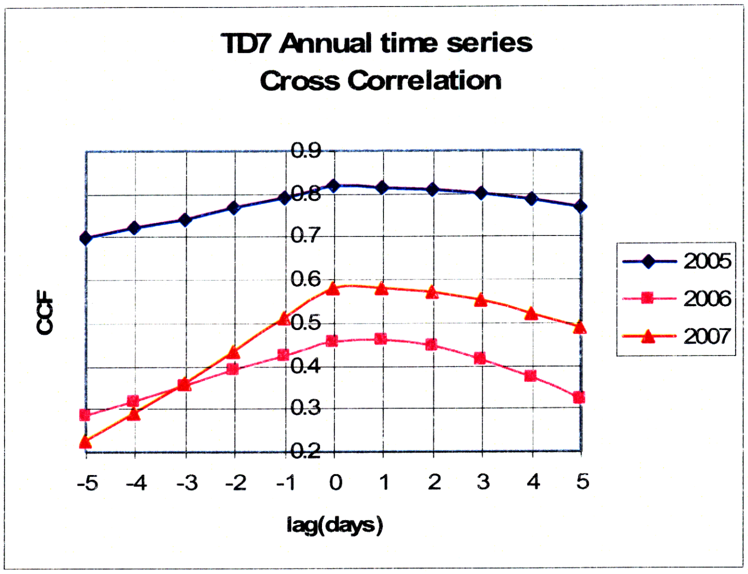

Fig 43 TD7 CCF for 2005-2006-2007

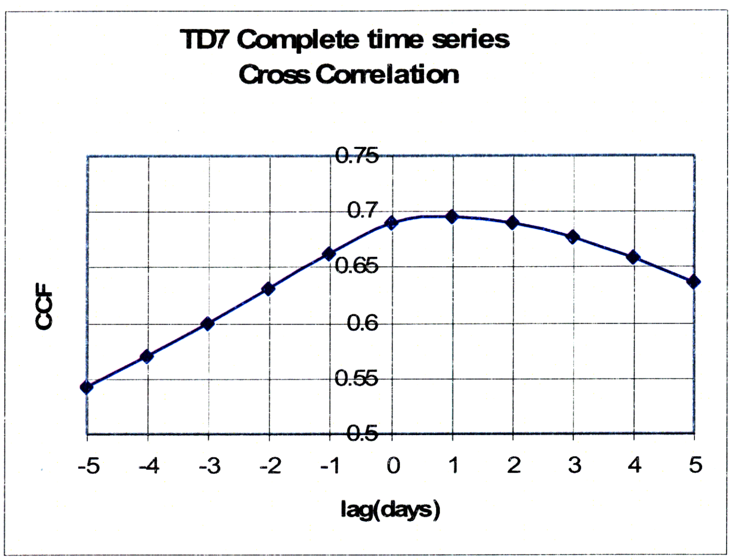

Fig 44 TD7 CCF for the complete time series

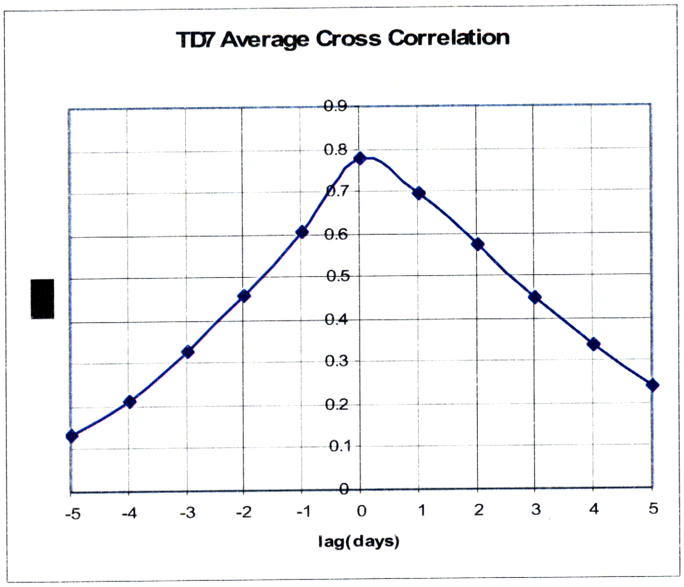

Fig 45 TD7 CCF for the average rising-falling market

Like TD3 and TD5, TD7 gave also some interesting results. The time series of 2005 demonstrates again great symmetry for positive and negative time lags while 2006 gives low correlation coefficients, under 0.5, for all lags. However, 2007 time series contains some valuable information. For positive lags, i.e. for paper leading the spot, the CCF is always greater than 0.5 while its plot is relatively flat compared to the negative lags side which declines rapidly to 0.2. The plot of the CCF of the complete time series in Fig 44 is also quite flat for positive lags while it declines steeply for negative ones. Although, the plot in Fig 45 is not flat in any direction, we can observe that for 1 and 2 days lag, the values in the positive side are greater by at least 0.1 of the other side. For greater lags the correlation becomes less than 0.5 and, therefore, is weak and we cannot use it.

From the analysis above, we can conclude that for TD7, the futures market could be a reliable predictor of spot prices.

3.5.7. TD9

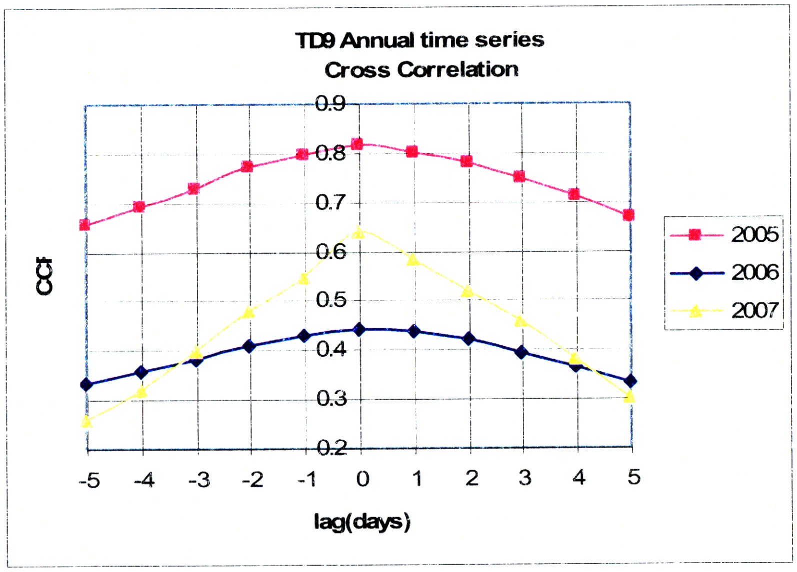

Fig 46 TD9 CCF for 2005-2006-2007

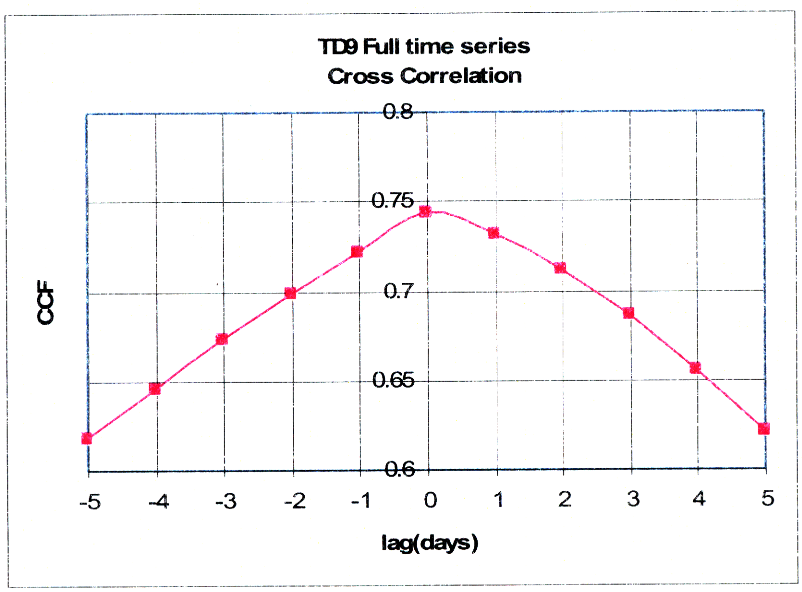

Fig 47 TD9 CCF for the complete time series

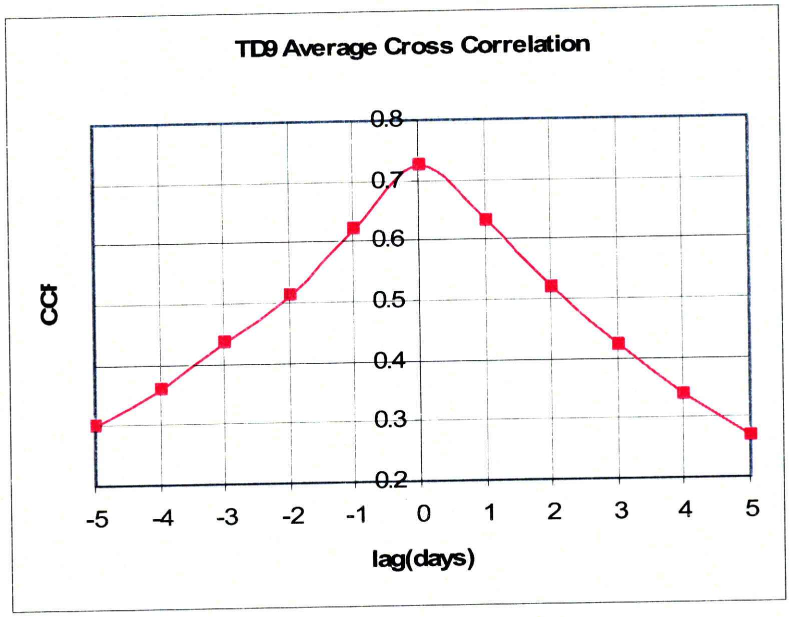

Fig 48 TD9 CCF for the average rising-falling market

Unlike TD3, TD5 and TD6, TD9 did not give results that could lead to valuable conclusions. All the obtained graphs show a perfect symmetry between the correlations of the two markets for positive and negative time lags. Excluding the CCF of 2006, the other plots indicate moderate correlation strength between the two markets which is also very symmetrical. That means that neither futures nor spot prices could be used to predict from one the other. We have to note again that it is very normal for two time series to have symmetrically distributed cross-correlation functions, as in TD9, because it simply means that if you shift one time series forward or backward for a given time lag, then the linear relation between the two series is equal.

3.6. Conclusion

Cross-correlation function gave us a very good indication on the linear relationship of the two markets when we time shift the one with respect to the other. The results in dry market do not allow us to get any safe conclusions. The correlations for either positive or negative time lags are usually equally high. Some slight differences of the correlations in Panamax and Supramax markets cannot be used as safe indicators of the future.

On the other hand, the wet market gave us some different results which may prove very valuable. The plots of the CCF are not symmetrical with respect to y-axis. The function has higher values for positive lags and in some cases the correlation between the two markets is higher for +1 and +2 lags than for zero. From a statistics point of view, that means that if we time shift the paper market two days ahead it will reach its maximum correlation. Therefore, we can argue that the prices of future contracts can be a reliable predictor of the TD3, TD5 and TD7 spot rates. TD9, as we saw in the rolling average analysis above, results cannot be used any further because the plots of the CCF are very symmetrical.

4. Econometric analysis

4.1. Introduction

The third method that we chose to study the lead-lag relationship of the two markets is through multivariate time series analysis which is part of econometrics. More specifically, we will investigate the relationship of the two markets through a bivariate Vector Error Correction model. The methodology that we applied includes:

- Test the order of integration of the time series, i.e. their stationarity, using Augmented Dickey-Fuller test.
- Investigate the co-integration relationships that exist between the two series.
- Determine the coefficients of the Error Correction model in order to decide the lead-lag relationship of the two time series.

4.2. Theoretical background

The first thing that we have to do is to determine the order of integration of each time series in order to test if they are stationary or not. The most frequently used test is the Augmented Dickey-Fuller. To better explain it we would better have a look on the standard Dickey-Fuller test and non-stationary time series.

4.2.1. Testing for unit roots

Testing for difference stationarity was a major concern of econometricians in the 1980s as if a series is difference stationary the effect of any shock is permanent. In the autoregression model:

$$y_t = y_{t-1} + \varepsilon_t$$

where ε_t is zero mean stationary process. If at any time period there is a jump in ε_t then y_t will also increase and stay there. The effect is permanent. But with

$$y_t = \beta y_{t-1} + \varepsilon_t$$
$$|\beta| < 1$$

any shock will fade away over time.

To test for a unit root we test $|\beta|=1$ in:

$y_t = \alpha + \beta y_{t-1} + u_t$

If $|\beta|=1$ then the model is non-stationary. It is even more non-stationary when $|\beta|>1$ The regression model can be written as $\Delta y_t = (\beta - 1) y_{t-1} + u_t = \delta y_{t-1} + u_t$, where Δ is the first difference operator. This model can be estimated and testing for a unit root is equivalent to testing $\delta = 0$. Since the test is done over the residual term rather than raw data, it is not possible to use standard t-distribution as critical values. Therefore this statistic τ has a specific distribution simply known as the Dickey Fuller table.

There are three main versions of the test:

1. Test for a unit root:

$\Delta y_t = \delta y_{t-1} + u_t$

2. Test for a unit root with intercept:

$\Delta y_t = \alpha_0 + \delta y_{t-1} + u_t$, α_0 the drift

3. Test for a unit root with drift and deterministic time trend:

$\Delta y_t = \alpha_0 + \alpha_1 t + \delta y_{t-1} + u_t$, $\alpha_1 t$ the trend and α_0 the drift

Each version of the test has its own critical value which depends on the size of the sample. In each case, the null hypothesis is that there is a unit root, δ = 0. The tests have low power in that they often cannot distinguish between true unit-root processes (δ = 0) and near unit-root processes (δ is close to zero). This is called the "near observation equivalence" problem.

4.2.2. The Augmented Dickey-Fuller (ADF) Test

The simple Dickey-Fuller unit root test described above is valid only if the series is an AR(1) process. If the series is correlated at higher order lags, the assumption of white noise disturbances is violated. The Augmented Dickey-Fuller (ADF) test constructs a parametric correction for higher-order correlation by assuming that the series follows an AR(p) process and adding p lagged difference terms of the dependent variable y to the right-hand side of the test regression:

$$\Delta y_t = a y_{t-1} + x_t' \delta + \beta_1 \Delta y_{t-1} + \beta_2 \Delta y_{t-2} + \ldots + \beta_p \Delta y_{t-p} + u_t$$

This augmented specification is then used to test α=0 using the t-ratio:

$$t_\alpha = \alpha / (se(\hat{\alpha}))$$

where $\hat{\alpha}$ is the estimate of α and $se(\hat{\alpha})$ is the coefficient standard error.

An important result obtained by Fuller is that the asymptotic distribution of the t-ratio for α is independent of the number of lagged first differences included in the ADF regression. Moreover, while the assumption that follows an autoregressive (AR) process may seem restrictive, it can be demonstrated that the ADF test is asymptotically valid in the presence of a moving average (MA) component, provided that sufficient lagged difference terms are included in the test regression.

Performing an ADF test requires the solution of the following two issues. First, we must choose whether to include exogenous variables in the test regression. We have the choice of including an intercept, an intercept and a linear time trend, or neither in the test regression. One approach would be to run the test with both a constant and a linear trend since the other two cases are just special cases of this more general specification. However, including irrelevant regressors in the regression will reduce the power of the test to reject the null of a unit root. Although we chose to include both in our model, the results obtained from the test were very safe due to very negative value as we will see later on.

The second issue that we had to deal with was the specification of the number of lagged difference terms (which we will term the "lag length") to be added to the test regression (0 yields the standard DF test; integers greater than 0 correspond to ADF tests). The usual (though not particularly useful) advice is to include a number of lags sufficient to remove serial correlation in the residuals. We used the Schwarz Information Criterion to decide the optimal number of lags to be included. SIC is an asymptotic result derived under the assumptions that the data distribution is in the exponential family. The mathematical formula of SIC is:

$$SIC = -2 \cdot L_m + m \cdot ln(n)$$

where n is the sample size, L_m is the maximized log-likelihood of the model and m is the number of parameters in the model. The index takes into account both the statistical goodness of fit and the number of parameters that have to be estimated to achieve this particular degree of fit, by imposing a penalty for increasing the number of parameters. Given any two estimated models, the model with the lower value of SIC is the one to be preferred.

4.2.3. Cointegration Test

The finding that many time series may contain a unit root inspired the development of the theory of non-stationary time series analysis. Engle and Granger (1987) pointed out that a linear combination of two or more non-stationary series may be stationary. If such a stationary linear combination exists, the non-stationary time series are said to be cointegrated. The stationary linear combination is called the cointegrating equation and may be interpreted as a long-run equilibrium relationship among the variables.

The purpose of the cointegration test is to determine whether a group of non-stationary series is cointegrated or not. As explained below, the presence of a cointegrating relation forms the basis of the VEC (Vector Error Correction) specification. Consider a VAR model of order p:

$$y_t = A_1 y_{t-1} + \ldots + A_p y_{t-p} + Bx_t + \varepsilon_t$$

where y_t is a k-vector of non-stationary I(1) (integrated of order 1), x_t is a d-vector of deterministic variables, and ε_t is a vector of innovations that may be contemporaneously correlated but are uncorrelated with their own lagged values and uncorrelated with all of the right-hand side variables. By subtracting this equation by

y_{t-1} we can rewrite this model as below:

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \mathrm{B} x_t + \varepsilon_t$$

where:

$$\Pi = \sum_{i=1}^{p} A_i - I \text{ and } \Gamma_i = -\sum_{j=i+1}^{p} A_j$$

Granger's representation theorem asserts that if the coefficient matrix Π has reduced rank r<k, then there exist $k \times r$ matrices α and β each with rank r such that $\Pi = \alpha\beta'$ and $\beta' y_t$ is I(0) (stationary). r is the number of cointegrating relations (the cointegrating rank) and each column of β is the cointegrating vector. The elements of α are known as the adjustment parameters in the VEC model. For our calculations we used Johansen's method (1991, 1995a). His method estimates the Π matrix from an unrestricted VAR and to test whether we can reject the restrictions implied by the reduced rank of Π.

4.2.4. Vector Autoregression and Error Correction Models

A Vector Error Correction Model (VEC model) can lead to a better understanding of the nature of any non-stationarity among the different component series and can also improve longer term forecasting over an unconstrained model. More specifically:

The VEC model is a restricted VAR designed for use with non-stationary series that are known to be cointegrated. It has cointegration relations built into the specification so that it restricts the long-run behaviour of the endogenous variables to converge to their cointegrating relationships while allowing for short-run adjustment dynamics. The cointegration term is known as the *error correction* term since the deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments.

To take the simplest possible example, consider a two variable system with one cointegrating equation and no lagged difference terms. If the cointegrating equation is:

$$y_{2,t} = \beta y_{1,t}$$

then the corresponding VEC is:

$$\Delta y_{1,t} = \alpha_1 \left(y_{2,t-1} - \beta y_{1,t-1} \right) + \varepsilon_{1,t}$$
$$\Delta y_{2,t} = \alpha_2 \left(y_{2,t-1} - \beta y_{1,t-1} \right) + \varepsilon_{2,t}$$

In the above model, the only right-hand side variable is the error correction term. In long run equilibrium, this term is zero. However, if y_1 and y_2 deviate from the long run equilibrium, the error correction term will be nonzero and each variable adjusts to partially restore the equilibrium relation. The coefficient a_i measures the speed of adjustment of the i-th endogenous variable towards the equilibrium.

In our case the VECM model that is created from spot and futures prices are:

$$\Delta F_t = \sum_{i=1}^{p-1} a_{F,i} \Delta S_{t-i} + \sum_{i=1}^{p-1} b_{F,i} \Delta F_{t-i} + a_F z_{t-1} + \varepsilon_{F,t}$$

$$\Delta S_t = \sum_{i=1}^{p-1} a_{S,i} \Delta S_{t-i} + \sum_{i=1}^{p-1} b_{S,i} \Delta F_{t-i} + a_S z_{t-1} + \varepsilon_{S,t}$$

where $a_{F,i}, b_{F,i}, a_{S,i}, b_{S,i}$ are the short-run coefficients, $z_{t-1} = \beta' X_{t-1}$ cointegration term and $\varepsilon_{S,t}, \varepsilon_{F,t}$ are error terms.

We will decide the relationship between the two markets by the values of the above coefficients. If $b_{S,i}$ coefficients are non-zero or the a_S error-correction coefficient has a significant value, then we can conclude that there is some information in the futures price that will be assimilated in later spot prices. That means that futures lead the spot prices. If the opposite happens, then we could use the spot to predict futures prices. However, there is a chance that all these coefficients have significant values which would lead to a two-way feedback relationship between the two markets, just like the cases of dry sector studied above.

The times series used were the logarithms of the original ones in order to obtain homogeneous variance.

4.3. Results

In the following pages we will present the results of Augmented Dickey-Fuller tests with which we decided the stationarity of the individual time series. The cointegration tests will follow in order to see the cointegrating relations that may exist between the two time series for each market and finally the coefficients of the VEC model will be presented.

4.3.1. Dry market

4.3.1.1. Stationarity tests

	ADF test statistic	
	Capesize Futures	**Capesize Spot**
t-Statistic	-0.434	-0.363
Probability	0.9006	0.9125
Lag Length(Automatic based on SIC)	1	3
Schwarz criterion	-5.62	-7.23

	ADF test statistic	
	Panamax Futures	**Panamax Spot**
t-Statistic	-0.183	-0.308
Probability	0.937	0.921
Lag Length(Automatic based on SIC)	1	2
Schwarz criterion	-5.693	-8.139

	ADF test statistic	
	Supramax Futures	**Supramax Spot**
t-Statistic	-0.5462	-0.5010
Prob.*	0.8791	0.8881

Lag Length(Automatic based on SIC)	1	1
Schwarz criterion	-6.6661	-10.2414

4.3.1.2. Cointegration tests

The first column of the tables below represents the number of cointegrating relations under the null hypothesis and the second column is the ordered eigenvalues of the Π matrix as described above.

- Capesizes

Hypothesized No. of CE(s)	Eigenvalue	Prob
None	0.0392	0.0036
At most 1	0.0009	0.9887

From the third column, which represents the probability of the number of cointegrating relations hypothesis made, of the table we can conclude that there is one cointegrating relation between the two markets.

- Panamax

Hypothesized No. of CE(s)	Eigenvalue	Prob.
None	0.0329	0.0182
At most 1	0.0007	0.9944

Again from the third column we can decide that that there is one cointegrating relation between the two markets.

- Supramax

Hypothesized		
No. of CE(s)	Eigenvalue	Prob.
None	0.037576	0.013600
At most 1	0.000562	0.599000

Without having the same certainty as in the two previous cases, we will consider that there is also one cointegration relation in the Supramax too. The number of cointegrating relations calculated above, are necessary input for the construction of the VEC models.

4.3.1.3. Vector Error Correction model

We will present now the results of VEC models which mainly consist of the calculated coefficients which will let us decide whether there is a led-lag relationship between the two markets.

- Capesizes

a_F (ECT)	-0.013206
$b_{F,1}$	0.146214
$b_{F,2}$	0.026594
$b_{F,3}$	-0.048732
$b_{F,4}$	0.006286
$a_{F,1}$	0.614333
$a_{F,2}$	-0.374258
$a_{F,3}$	-0.264964

$a_{F,4}$	0.213915
a_S (ECT)	0.039310
$b_{S,1}$	0.117183
$b_{S,2}$	0.045682
$b_{S,3}$	0.019519
$b_{S,4}$	0.031457
$a_{S,1}$	0.756949
$a_{S,2}$	-0.159029
$a_{S,3}$	-0.103278
$a_{S,4}$	0.049859

In the previous table we can see that all the coefficients have a statistically significant, non-zero value. Therefore, we can conclude that there is not unidirectional flow of information from one market to the other but there rather is a two way feedback. These results agree with the results of the previous method, used to analyze the lead lag relationship of the two markets, which suggests that we cannot have safe conclusions on whether the one market leads the other.

- Panamax

a_F (ECT)	-0.011332
$b_{F,1}$	0.055815
$b_{F,2}$	0.048222
$b_{F,3}$	-0.03207
$b_{F,4}$	0.013922
$a_{F,1}$	0.485291
$a_{F,2}$	-0.425871
$a_{F,3}$	-0.208539
$a_{F,4}$	0.264977

a_S (ECT)	0.020792
$b_{S,1}$	0.080087
$b_{S,2}$	0.012681
$b_{S,3}$	0.011189
$b_{S,4}$	0.024361
$a_{S,1}$	1.0352
$a_{S,2}$	-0.378046
$a_{S,3}$	0.041903
$a_{S,4}$	-0.007005

- Supramax

a_F (ECT)	-0.048202
$b_{F,1}$	0.20768
$b_{F,2}$	0.092747
$b_{F,3}$	-0.042745
$b_{F,4}$	0.025634
$a_{F,1}$	0.070843
$a_{F,2}$	-0.309914
$a_{F,3}$	0.619431
$a_{F,4}$	-0.023154
a_S (ECT)	0.007499
$b_{S,1}$	0.034795
$b_{S,2}$	0.01789
$b_{S,3}$	-0.003669
$b_{S,4}$	0.004331
$a_{S,1}$	0.872418
$a_{S,2}$	-0.002987
$a_{S,3}$	-0.032521
$a_{S,4}$	-0.002197

As expected, the calculated coefficients for the VEC model did not help us decide if there is a unidirectional relation between the two markets. Additionally, we can observe that the error correction term a_S as well as $b_{S,3}$, $b_{S,4}$, $a_{S,2}$, $a_{S,4}$ are one and two orders of magnitude smaller than the rest coefficients which means that they play a less significant role in our model.

4.3.2. Wet sector

In the tanker sector the process that was followed was not the same because of the different behavior of the time series of the market. Both future and spot prices in all routes, TD3, TD5, TD7, TD9, were found to be stationary after the log transformation. This made the calculations much easier and quicker. After the ADF test which indicated the stationarity of the series, as we will see below, there was no need to search for cointegrating relations or use of VEC model. Instead, we could use directly a vector autoregression model and see if the relevant lag coefficients have significant values.

- TD3

	ADF test statistic	
	TD3 Futures	**TD3 Spot**
t-Statistic	-2.968	-2.447
Probability	0.038	0.129
Lag Length(Automatic based on SIC)	1	4
Schwarz criterion	-4.603	-5.540

- TD5

	ADF test statistic	
	TD5 Futures	**TD5 Spot**
t-Statistic	-2.660	-3.867
Probability	0.0816	0.0024
Lag Length(Automatic based on SIC)	1	1
Schwarz criterion	-5.36733	-5.052

- TD7

	ADF test statistic	
	TD7 Futures	**TD7 Spot**
t-Statistic	-2.98043	-5.300
Probability	0.0372	0.000
Lag Length(Automatic based on SIC)	1	2
Schwarz criterion	-5.300	-4.947

- TD9

	ADF test statistic	
	TD9 Futures	**TD9 Spot**
t-Statistic	-3.65591	-4.6164
Probability	0.005	0.0001
Lag Length(Automatic based on SIC)	1	2
Schwarz criterion	-5.38694	-4.419

We can clearly see that since the t-statistic is lower than -1, the probability of the time series to be stationary decreases dramatically. Therefore, we can use a Vector Autoregression model to examine the coefficients if each time series. As in the VEC model, if the coefficients which represent the lagged values of the one series in to the other have significant values, then there could be a relationship between the two markets.

The coefficients of the VAR models are presented below:

- TD3

Const(futures)	0.044662
$b_{F,1}$	1.118025
$b_{F,2}$	-0.157295
$b_{F,3}$	-0.008829
$b_{F,4}$	0.019769
$a_{F,1}$	0.262887
$a_{F,2}$	-0.366949
$a_{F,3}$	0.040699
$a_{F,4}$	0.069196
Const(Spot)	-0.000755
$b_{S,1}$	0.139218
$b_{S,2}$	-0.085712
$b_{S,3}$	0.026205
$b_{S,4}$	-0.054794
$a_{S,1}$	1.528782
$a_{S,2}$	-0.619306
$a_{S,3}$	0.1646
$a_{S,4}$	-0.098909

Contrary to the calculations made in the "Cross-correlations" chapter where we had found that there probably is some lagged correlation to the spot market, the above table does not suggest the same thing. $b_{S,i}$ coefficients which represent the effect of the futures market into the spot have significant values but $a_{F,i}$ coefficients, representing the effect of the spot market to the futures, have also significant values. Therefore, we cannot have any safe conclusions regarding the relationship between the two markets, other than two-way feedback.

- TD5

Const(futures)	0.030609
$b_{F,1}$	1.087025
$b_{F,2}$	-0.095169
$b_{F,3}$	-0.002749
$b_{F,4}$	0.001967
$a_{F,1}$	0.023139
$a_{F,2}$	-0.040873
$a_{F,3}$	-0.086893
$a_{F,4}$	0.09934
Const(Spot)	-0.033481
$b_{S,1}$	0.272686
$b_{S,2}$	-0.210007
$b_{S,3}$	0.067033
$b_{S,4}$	-0.047173
$a_{S,1}$	1.321006
$a_{S,2}$	-0.37376
$a_{S,3}$	-0.005128
$a_{S,4}$	-0.098909

Unlike TD3, in this route we can observe that $b_{S,1}$ $b_{S,2}$ (representing the futures coefficients into the spot model) are one order of magnitude greater than $a_{F,1}$ and $a_{F,2}$ (representing the spot coefficients into the futures model). Therefore, we can argue that there is a two day lag of information flow from futures to spot market. Similar conclusions were made for the same route in the cross-correlations calculations.

- TD7

Const(futures)	0.047831
$b_{F,1}$	1.072091
$b_{F,2}$	-0.16328
$b_{F,3}$	0.07142
$b_{F,4}$	0.011151
$a_{F,1}$	0.108073
$a_{F,2}$	-0.1844
$a_{F,3}$	0.077782
$a_{F,4}$	-0.015021
Const(Spot)	0.018716
$b_{S,1}$	0.218042
$b_{S,2}$	-0.137563
$b_{S,3}$	-0.01425
$b_{S,4}$	-0.012741
$a_{S,1}$	1.400938
$a_{S,2}$	-0.375499
$a_{S,3}$	-0.047373
$a_{S,4}$	-0.04033

Similarly to the dry sector, TD7 VAR coefficients did not give us any interesting results. The only conclusion again is that we can get into is the two-way feedback of the two markets, which warns us that we cannot predict the prices of the one from the other.

- TD9

Const(futures)	0.077174
$b_{F,1}$	0.964085
$b_{F,2}$	-0.07703
$b_{F,3}$	0.025321
$b_{F,4}$	0.043616
$a_{F,1}$	0.061668
$a_{F,2}$	-0.009655
$a_{F,3}$	-0.047739
$a_{F,4}$	0.005958
Const(Spot)	0.014212
$b_{S,1}$	0.268915
$b_{S,2}$	-0.233618
$b_{S,3}$	-0.00897
$b_{S,4}$	0.029876
$a_{S,1}$	1.135065
$a_{S,2}$	-0.020331
$a_{S,3}$	-0.073756
$a_{S,4}$	-0.103857

In the above table we can observe again that $b_{S,1}$ and $b_{S,2}$ are one and two orders of magnitude, respectively, greater than $a_{F,1}$ and $a_{F,2}$. That indicates that there is a unidirectional flow of information from futures to spot market with a lag of one or two days. Unlike TD5 where this method and the cross-correlation one agree, TD9's cross-correlation calculations had not indicated a possible unidirectional connection between the two markets.

5. Market Volatility

5.1. Introduction

After examining the possible lead lag relationship between physical and paper market, we made an analysis on the possible relation between the spot market volatility and the trading volume of freight futures.

As seen in the previous chapters, the two markets have a very close relationship. The fact that futures do not always affect the prices of the spot market does not mean that they never do it. Physical market players do get influenced from the daily prices of freight futures even if there is no lead or lag between them. Therefore, one could argue that the spot market has one more parameter to be affected from.

Freight futures are not only a financial tool for risk management but they can also be used for speculative purposes. Although the users of these products should be the players of the shipping markets, charterers and shipowners, independent investors as well as some hedge funds are taking advantage of the volatility. Therefore, the transactions made by this type of investors affect the paper market which in turn affects the physical. That means that the volatility of the spot market may be higher the last year than it used to be because of the tremendous growth of the futures trading.

To test this assumption we plotted the nominal trading value of futures transactions for each market versus the spot market volatility. The calculations were made on a monthly basis. Due to the lack of data concerning the trading values for each route separately, we used the trading values of the tanker and dry market. Capesize and

Panamax markets and TD3, TD5 and TD7 were chosen to be used in the calculations as the most frequently traded routes for freight futures.

5.2. Results

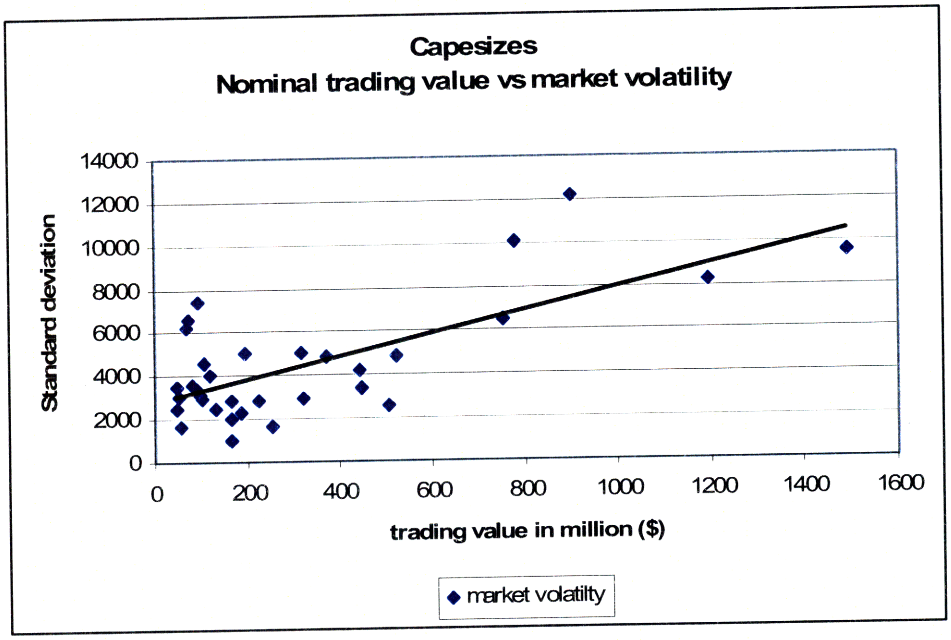

Fig 49 Trading value vs. market volatility for CS4TC

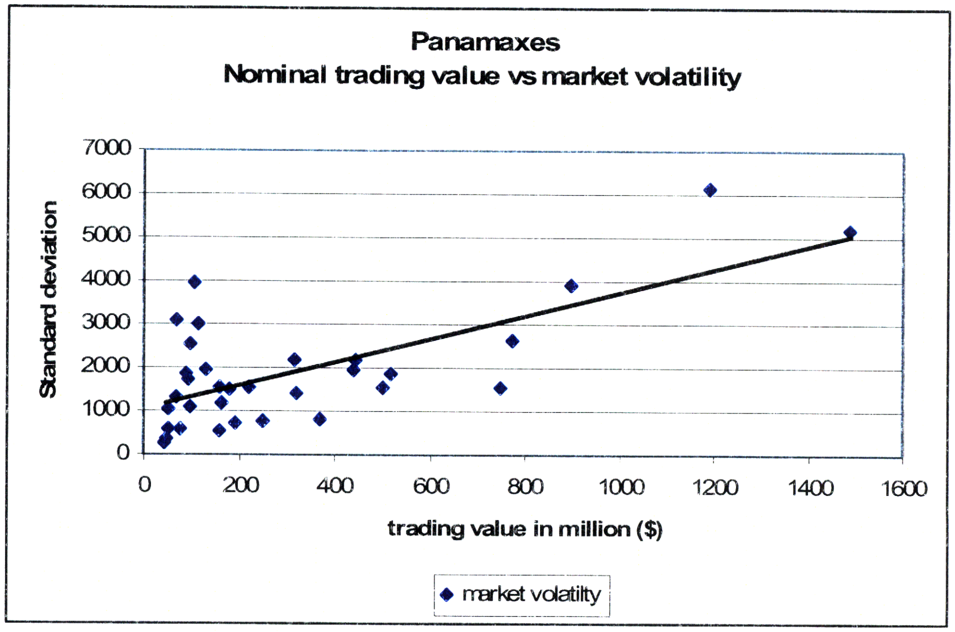

Fig 50 Trading value vs. market volatility for PM4TC

For the dry market calculations shown in Fig 49 and Fig 50, we observe that the assumption made above regarding the increase of market volatility with the growth of trading values of freight futures is valid. The linear regression fitted to the scattered data shows clearly that as the trading value increases, the market volatility does the same. We can see more samples in the lower left side of the graph because we have taken into account data from April 2005 while the big boom in futures trading occurred more recently.

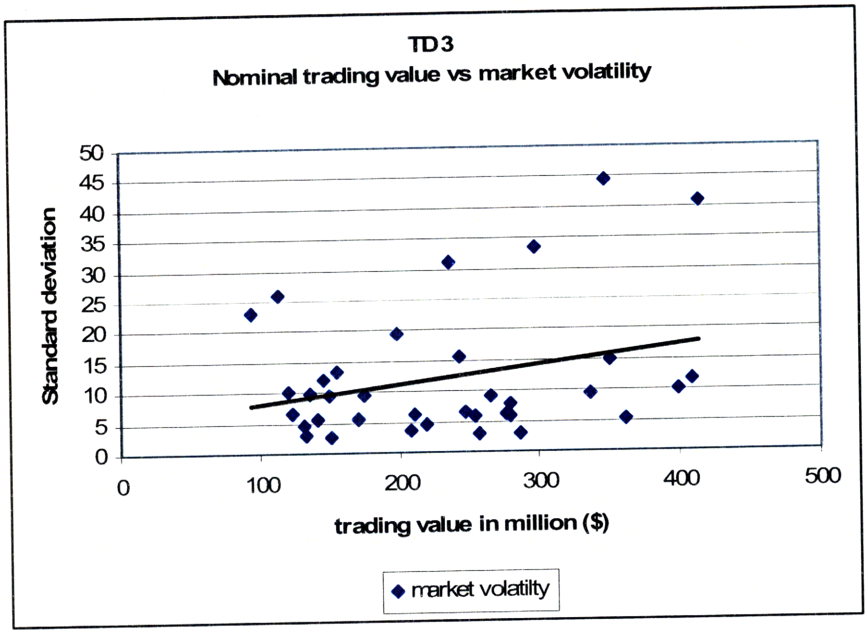

Fig 51 Trading value vs. market volatility for TD3

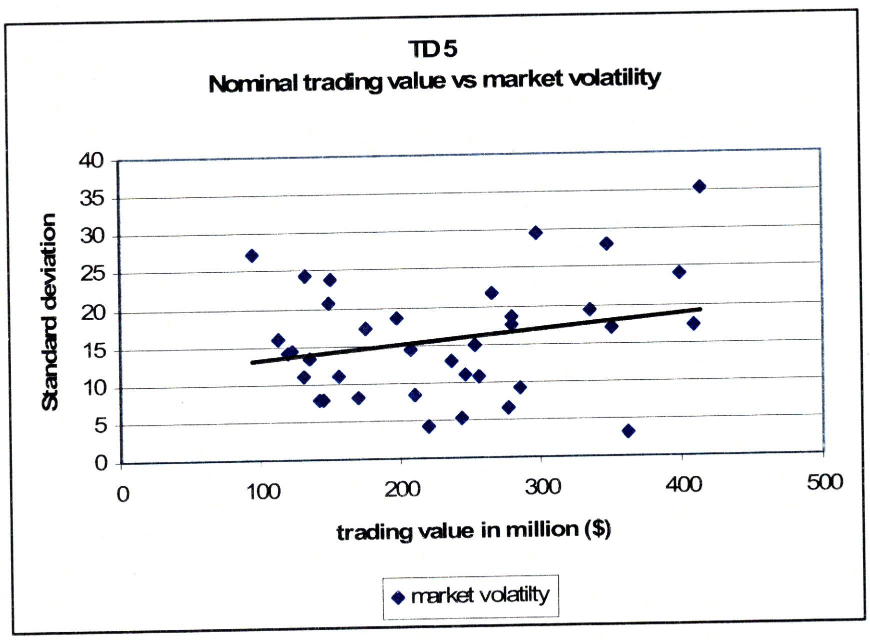

Fig 52 Trading value vs. market volatility for TD5

In Figures 51 and 52, we can confirm the validity of the assumption made above regarding the relation of trading value and market volatility. Contrary to the dry market, the relevant linear fitting has smaller slope, indicating that the tanker spot market is affected less from the trading of freight futures.

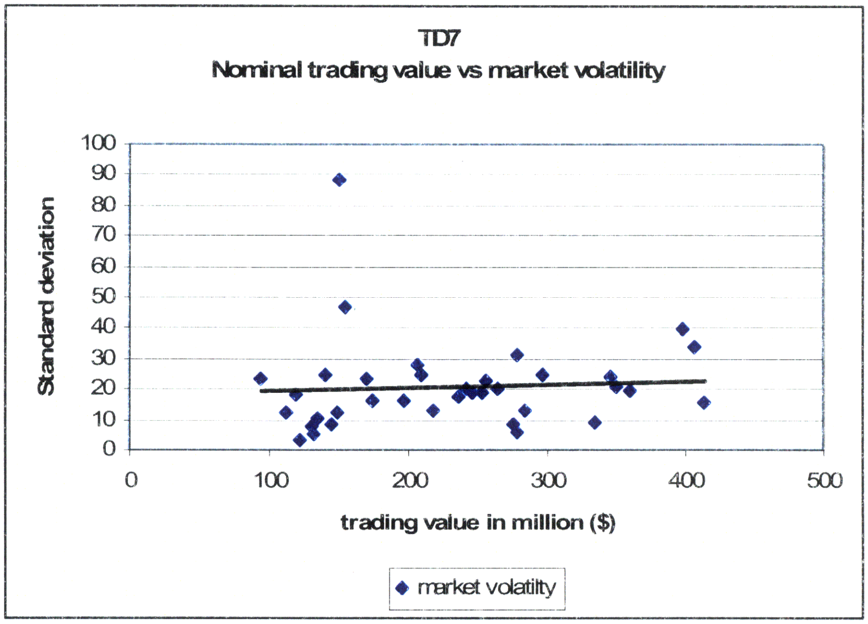

Fig 53 Trading value vs. market volatility for TD7

The only exception in our calculations comes from TD7. Figure 53 shows that the linear fitting on the scattered points is almost flat. That means that TD7 spot prices are not influenced at all from the growth of trading value in freight futures.

6. Conclusions

6.1. General conclusions

Three different methods were used to identify the lead-lag relationship of the physical and paper market. The results of these methods agreed in some cases while in others did not.

The rolling average method gave us a rough estimation of the points that paper market led the spot. This was done only by means of change of direction because we could not examine the change in slope in the two plots. We found out that there were many points where the spot market followed the futures but unfortunately this is not a proof of their true relationship.

The cross-correlation method was more mathematically sophisticated than the rolling average and gave us the opportunity to examine the correlation between the two markets on specific leads and lags. What we found out was that dry sector's cross-correlation graphs were very symmetrical with respect to the y axis. That means that the values of correlations were the same when we time shifted the two markets positively or negatively. On the other hand TD3, TD5 and TD7 did not have symmetric cross correlation functions. When the spot market followed the futures, the correlation was higher than when we were doing the opposite. TD9 had the same behavior as the dry sector.

The last and most complex method used was a Vector Error Correction model. Depending on the coefficients calculated for that model we judged whether there is information flow from one market to the other or if there is a two way feedback. For most of the cases we found that the futures coefficients inside the spot equation and the spot coefficients inside the futures equation were of the same order of magnitude. That indicates a two way feedback relationship which does not have any practical use. The only exceptions were TD5 and TD9 which both provided proofs through their VAR coefficients that the spot market follows the futures.

After all, we could say that the only route which proved to have the same results in both cross-correlation method and VAR model was TD5.

Although the second and third methods are mathematically more sophisticated, the first method gives us a view of the actual markets and not some coefficients which measure their relationship. Therefore, even if the second and third methods deny the leading of futures market, the first one gives us many points in which the physical does follow the paper.

Some reasons why the futures market could lead the spot one are:

- The players of the paper market have the ability to react faster in the arrival of new information regarding the market conditions contrary to the physical which needs some bureaucracy to fix voyages in the new freight rates.
- Low transaction costs and the flexibility of getting in and out of the market attract more people to invest in freight futures than in the physical market. Therefore, the paper market becomes more efficient.
- The effect of the trading of freight futures is immediate to their prices while spot contracts take longer to be completed.

- The players of the physical market may be influenced by the current closing prices of paper market. For example, it is natural for a charterer to ask for a lower rate when he sees that the paper market is moving downwards because he expects that the rates will decline. The opposite happens for a commercial manager of a ship who demands higher rates for his ships when he sees that the paper market gets stronger.

The price discovery that may be done through the derivatives market can have some very useful and profitable applications. In TD7 for example which, from our study, is the route most likely to follow the paper market, the commercial manager of an Aframax can check the paper market before fixing a voyage. If for the past 3 days the prices of the freight futures were falling, it would be very likely that the spot market will have the same behavior in the next day. Therefore, if he wanted to fix a vessel for a spot rate, it would be wise to rush to do it as soon as possible before the market gets lower. On the other hand if the futures indicated a rise in the spot market, the manager should wait before closing a spot contract.

6.2. Further study

So far in this thesis we tried to find methods, either simple or complex, to discover if there is some information hidden in the futures daily trading about the spot market. What we would ideally like to have found is that the physical market follows the paper one by a specific number (or a range) of days. On the other hand, if there was such a phenomenon, market players could have easily identified, taken advantage of and finally eliminated it. What we would realistically like to have found is that the futures market usually leads the spot one, so that a player who used this information could make profits in the long term.

In this thesis, the futures market was represented only from the 1 month contracts in order to avoid significant price jumps from contracts maturing during days in which we took into account for our calculations the prices of the next month. The discussion made below is addressed to someone who wants to study the two markets from one month ahead contracts. Similar techniques can be applied for longer maturities as well. More specifically, month futures mature the 20th day of the month that they are traded for. That means that the maturity date of an August contract is the 20th of August. Our time series took into account from August 1st the September contracts. Therefore, there could be some small price jumps from the difference between the September contract traded in August 1st and the August contract traded in the same day. A researcher could construct a model which during the twenty first days of August will take into account the prices of August contracts as well as the September prices. This could probably be done with a weighted average method which as we reach to the maturity date, the weight of the August contracts will decrease.

The most recent trend in shipping derivatives is the trading of freight options. Calls and puts are traded through IMAREX and provide risk managers and speculators with a powerful financial tool to do their business. If the trading of options becomes significant, a researcher could look for some information flow from options to the spot market or even combine options and futures to find a model which predicts it.

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