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Shipping Markets and Freight Rates: An Analysis of the Baltic Dry Index

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Abstract

Shipping, although a crucial component of the transportation of commodities worldwide, is hardly present in the finance literature at this point. The first and foremost goal of this paper is to describe and explain from an economic perspective the key features of shipping markets; the second one is to analyze the behavior of freight rates, which define the final cost of an imported commodity. We focus on the major index, the BDI (Baltic Dry Index) and propose some diffusion models able to capture the unique features of its trajectories, namely large swings and continuity. Their performance is exhibited on a database covering the period 1988-2010. Such spot models should facilitate the growth of the market of freight rates options, a safe hedging instrument for farmers and cooperatives that ship their grains to distant destinations.

JEL classifications: G19; L91; R41

Keywords: shipping markets; freight rates dynamics; spot models; agricultural commodities

Ships and vessels have developed alongside humankind evolution. The first cargoes were transported by sea more than 5,000 years ago. Moving silks and other precious merchandise across the oceans was already quite active in the 15th century, as evidenced in Shakespeare's Merchant of Venice. And the shipping of gold bullion to Wellington's army in Spain and Portugal was decisive in insuring his victory. Freight has become today an integral part of modern trade, with the transport of commodities by sea becoming cheaper and more reliable over time. For instance, the costs of shipping dry bulk like grains, iron ore, coal, have increased by only 70% (in nominal terms) over the last 50 years, a small number compared to other industrial services and inflation numbers. This is due in particular to important technological innovations that occurred in the maritime sector and made it possible to move commodities over the world at a very competitive price. Shipping markets are recognized today as a key component of the commodity asset class, playing a role in final prices of energy, agriculturals and metals. For those actors who have vessels readily available for various destinations, "geographical arbitrage" may be achieved when the locational spread is greater than the cost of shipping. As for the originators and merchant houses who sell the commodity under a CIF (Cost of Insurance and Freight) label, transportation is such an important component of the revenues/profits that a whole department in the firm is dedicated to the shipping activity and its risk- management.

Our goals in this paper are firstly to describe in a comprehensive manner the economic drivers of the shipping markets; secondly to study and model the dynamics of dry bulk shipping rates over the last two decades, and particularly their leading indicator, the Baltic Dry Index (BDI), whose value is daily reported in the financial press. Our mathematical analysis of the behaviour of the spot values of the BDI is in the spirit of the 'spot models' for interest rates, as developed in the seminal papers by Vasicek [1977] and Cox- Ingersoll- Ross [1985] where the term structure of forward rates is derived from spot rates; the liquidity, in our view, is quite insufficient in the forward freight market at this moment to (in)validate a model.

In the next section we provide some fundamentals on the shipping markets and different types of freight rates. We then describe some stylized features of the BDI, as daily quoted by the Baltic Exchange. It is shown that freight rates trajectories are not only different from those of stocks and bonds, but also from most commodities, electricity being the one that exhibits some similar features, such as volatility higher than 60%. The BDI price behavior reflects the inelasticity of supply to shocks in demand in absence of inventory, resulting into large swings in trajectories. We then test a family of diffusion processes, with or without mean-reversion and a CEV (Constant Elasticity of Variance, Cox [1975]) exponent meant to account for a possibly stochastic volatility. We calibrate them to a database covering the years 1988 - 2010 during which all commodities and the BDI as well, exhibited a break in the price trajectory. Finally we conclude, in particular on the usefulness of spot price models for the future growth of options on freight rates, a very valuable instrument for grain producers and merchants.

Shipping Markets and Shipping Rates

The first sea trade network that can be traced was developed 5,000 years ago between Mesopotamia, Bahrain and Western India. The Mesopotamians exchanged their oil and dates for copper and ivory (see Stopford [2009]). The maritime code developed by the Mesopotamians was remarkably similar to the one prevailing today: Ships were hired at a fixed tariff, proportional to the capacity of the vessel, and freight costs were paid in advance. The so-called Baltic Exchange was established as early as the mid-eighteenth century, prior to the Chicago Board of Trade (1848) or the London Metal Exchange (1877). It was known in 1744 as the Virginia and Baltic Coffeehouse and gathered the trading interests of merchants and ships' captains who frequented its premises and negotiated terms for the shipment of cargoes. It was registered as a primitive limited company with shares in 1900 (see Barty-King [1994] for a history of the Baltic Exchange). Today the exchange is owned by its members and operated by a Board of Directors. It is the world's single independent source of maritime information. The year 1985 saw the creation of the Baltic Freight Index (BFI) as a benchmark for the world freight market, against which derivatives contracts would be financially settled. The original BFI was defined as a weighted average of spot rates covering 13 voyage routes related to a variety of dry-bulk vessels with cargoes ranging from 14,000 to 120,000 metric tonnes. Each major route incorporated in the BFI referred to a vessel size, a certain cargo and a route description. The weights were assigned according to the importance of the route in the dry-bulk sector. For instance, the routes from the US Gulf of Mexico to Rotterdam and Japan were the most important ones, followed by the US Pacific Coast to South Japan.

The BFI underwent several restructurings since its inception, with addition of new routes such as South America to Far East, while less popular routes were withdrawn. Following these changes in the BFI and the increasing segmentation of the dry-bulk industry, a number of sectorial indexes were gradually introduced over time by the Baltic Exchange, such as the Baltic Panamax Index (BPI) launched in 1998; the Baltic Capesize Index (BCI) in 1999; the Baltic Handymax Index (BHMI) created in 2000 and the Baltic Supramax Index (BSI) in 2005. The Capesize vessels, the largest ones, represent 10% of the world fleet and 62% of dry bulk traffic; the next largest ones, Panamax, 19% of the fleet and 20% of the tonnage (their name reflecting the fact that they fit the locks of the Panama Canal) . The criterion most used in the shipping industry to categorize dry bulk carriers is their size, which obviously impacts in which ports the vessel will potentially operate (draught, handling gear etc...). Coal is the most widely traded dry commodity and represents 38% of the dry bulk volume. It is interesting to note that, despite the signature of the Kyoto protocol, the amount of coal in the world energy consumption has increased by 24% during the period 2000-2004, compared to 10% for natural gas and 7.4% for crude oil. Moreover, despite its large production, China became two years ago a net importer of coal, both coking coal to produce steel from iron ore and thermal coal for its power plants since new ones continue to be built, in parallel to nuclear plants. Coal travels very well, and a possible shipping accident would not be damaging for the environment like the Exxon Valdez in Alaska, but would only send for ever this heavy commodity to the bottom of the ocean[1].

In fact, in major energy companies, coal and shipping are often traded in the same department. The difference between the API-#2, a major coal index traded out of Rotterdam and including the cost of freight (CIF index), and the API-#4, a FOB index ('Free on Board') traded in Richards Bay -South Africa, is called the `implied' freight rate and may lead to the identification of locational arbitrage strategies. In the dry bulk shipping, coal is followed by iron ore (28%), another fundamental commodity entering into the production of steel and sent to steelmaking plants, in China, Japan and India as first destinations. Grains come third, with 7% of the volume.

The Baltic Capesize Index (BCI) is calculated on the shipping costs on ten available routes for a Capesize dry bulker. Each route is weighted according to its importance relative to the nine others. The Baltic Panamax Index (BPI) is computed on the four available routes for a Panamax dry bulker, each route having the same weight (25%). Supramax vessels have six trip charter routes and three voyage charter routes but the Baltic Supramax Index (BSI) is only based on the six trip charter routes: two routes (S_2 and S_3) each account for 25% of the index and the other four have each a weight of 12.5%. Lastly, the Baltic Handysize Index consists of six routes, out of which two (HS_2 and HS_3) each have a weight of 25% and the four others 12.5%. The Baltic Dry Index (BDI), the one that is the flagship today for dry bulk shipping costs, is computed as an arithmetic average of the Baltic Capesize, Panamax, Supramax and Handysize indexes. Over the years 2009 and 2010, the conversion factor of the BDI rate into dollars has been 1/0.113473601; hence, on a day when the BDI value is 2269 for instance, the average charter price is $12672/day (To be adjusted to the size and voyage of a specific vessel). Details on all these elements can be found in Alizadeh and Nomikos [2009].

[1] An anecdote about iron ore is the famous case of the SS Edmund Fitzgerald, an American Great Lakes freighter that carried for seventeen years taconite ore pellets from mines in Minnesota to iron works in Detroit, Toledo and other ports. On November 9, 1975 the vessel was caught in a massive winter storm and suddenly sank in Canadian waters with her cargo.

The major actors in the dry shipping world are the long- established shipping companies based in Oslo, London, Athens, Singapore; the commodity houses and merchants such as Cargill or Louis Dreyfus; banks involved in physical commodity trading like Morgan Stanley and others; oil and energy companies which need to be present in the coal market. In order for the indexes to be reliable, unbiased and accurate reflections of the global spot market, the Baltic Exchange appoints panel companies which are assigned the task of reporting freight rates to the Exchange on a daily basis. These panelists have to be members of the Exchange, and represent broking firms (rather than shipowners or charterers) that are able to estimate how much it would cost to move various cargoes of raw materials on various routes: for instance 100,000 tonnes of iron ore from San Francisco to Hong Kong or one million tonnes of rice from Bangkok to Tokyo. Once the panelists have submitted their figures, the London-based Baltic Exchange is responsible for calculating the final index figures, which are published at 1 p.m. for the dry cargo. The BDI and the other major freight rates can be accessed from the Baltic Exchange or major news services such as Thomson-Reuters or Bloomberg.

The expansion of commodity markets during the years 2000s due to the double- digit growth of the developing countries has contributed to an amazing boom in maritime transport and shipbuilding. Orders for new vessels placed in 2007 totalled 4900 ships, compared to less than one third of this number in 2005. In fact, 2007 was the fifth consecutive remarkable year for the maritime industry. All records were shattered in the dry bulk market, with an unprecedented interest in bulk carriers. Moreover, the concomitant rise in bunker prices persuaded operators to reduce speeds, which in turn required the addition of more vessels to maintain the schedules. Interestingly, the congestion of major harbors plays such a key role in the supply-demand balance for shipping that options written on congestion indexes have been traded for a number of years among the major actors; all of them send "spies" to watch at all times the length of the queue of vessels in the Sydney harbour or the Suez Canal gates.

Recently, the building of strategic commodity inventories by some countries or large firms has been added to the list of unobservable sources for vessel demand changes. For instance, now that the

Chinese agency "China Exploration" has decided to acquire iron ore mining companies in Brazil, the iron output will be redirected to be transformed into steel in mainland China - maximizing the gains for the latter country and giving it the option to keep the raw material or transform it at any optimal time. The supply of cargo ships, on the other hand, is inelastic under market conditions that can only be changed in the short term by changing vessels speeds, a costly solution in terms of bunker fuels. In the longer term, more permanent changes can take place by building new ships and/or scrapping older ones. In the present times, it takes one to three years to build and deliver new ships, influencing essentially the longer term supply for freight services.

The volume of international seaborne trade has increased from 1,750 million tonnes in 1965 to more than 7,000 million tonnes, representing an average annual growth rate of 3.5 per cent. As said before, this growth has been paralleled by a huge expansion of the shipping fleet, both in terms of numbers and sizes of vessels (e.g., Handymax and Supramax). Dry-bulk carriers, the subject of our analysis, constitute 40% of the world fleet, compared to 38% for tankers (crude oil, oil refined products and Liquefied Natural Gas), and the remainder for container ships. Note that at times when there is an excess of oil tankers available, these can be cleaned and refitted to transport dry bulk, an optionality that shippers are aware of (the converse does not hold because of the double hull required today for tankers by international maritime laws).

We chose in this paper to investigate the features of shipping markets through the analysis of the Baltic Dry Index. The BDI used to be mentioned by commodity analysts as an early indicator of the state of the economic growth worldwide because of its link to the demand for transportation, itself related to the demand for raw commodities, the latter in turn connected to many strategic sectors of the world industry like construction or car manufacturing. This property does not always hold, especially in our era of segmented world economy prosperity and growing fleets of vessels of all sizes, and its thorough analysis is outside the scope of this paper. Its importance in the world economy is highlighted by the fact that its value is daily quoted, together with the three strategic commodities:

crude oil, copper and gold prices in the financial press and regular newspapers. Exhibit 1 displays the trajectory of the BDI over the period 1988 to 2010.

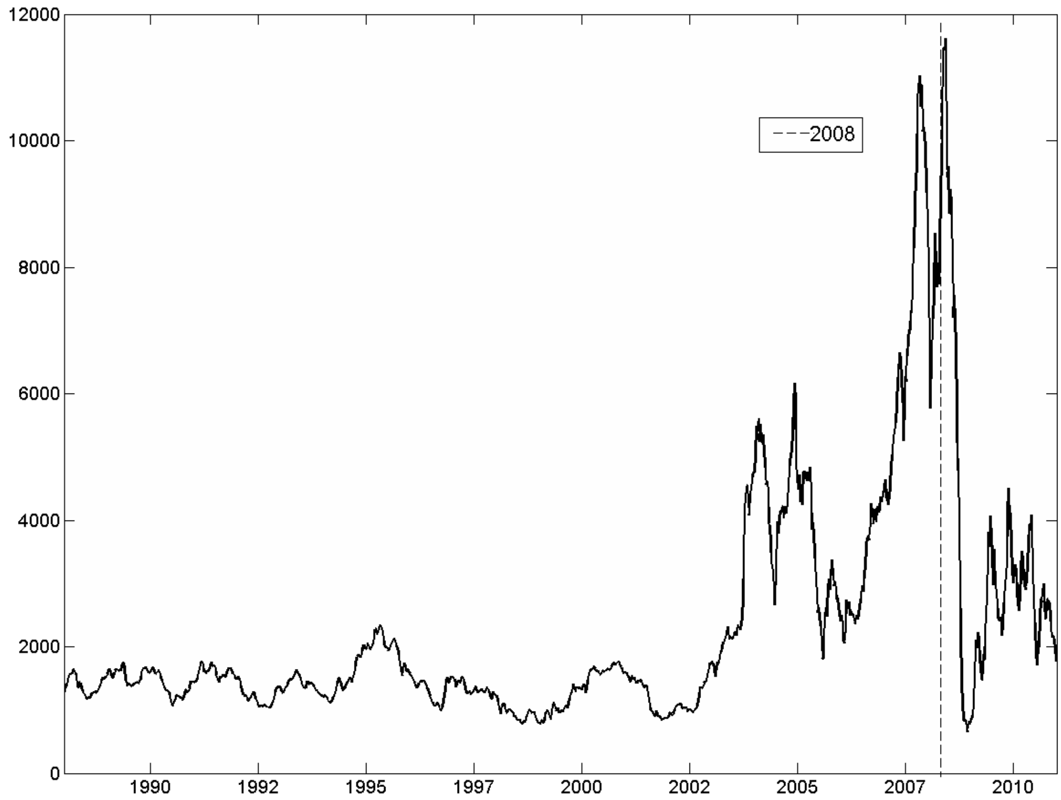

Exhibit 1: The BDI trajectory over the period 1988 - 2010

The argument from economic theory for the natural occurrence of large swings in shipping markets goes as follows: if 100 vessels are available for 99 cargoes of grains to be shipped, freight rates remain moderate or low. Now, if the number of cargoes which have to rapidly depart goes to 101, i.e., a small shock in demand, freight rates will experience a sharp increase as new vessels cannot be built within days (Note that the terms "price" and "rate" will be used in an equivalent manner throughout the paper). In other words, small fleet changes and logistical matters can crash rates, and conversely. In contrast to copper or aluminum, the "storage" of vessels to act as a buffer against shocks in supply and demand is far too expensive: even when freight rates fell dramatically from 12,000 points in May 2008 to 670 in December 2008, (see Exhibit 1), ship-owners preferred to make their ships available at just bunker fuel costs rather than letting them idle and pay the cost of insurance. This full absence of storability is essentially shared with another commodity, namely electricity. However, electricity - for which no standard and affordable technique of storage exists at this date (except for hydro), exhibits during heat waves for instance, sharp spikes of very short duration of the order of a few days and heights which can be ten times the usual price (see Geman and Roncoroni [2006]), as illustrated below. Exhibit 2 also shows that the spikes in electricity prices discussed by the previous and other authors in the case of US markets are also present in the sterling numeraire since related to the non- storability of electricity.

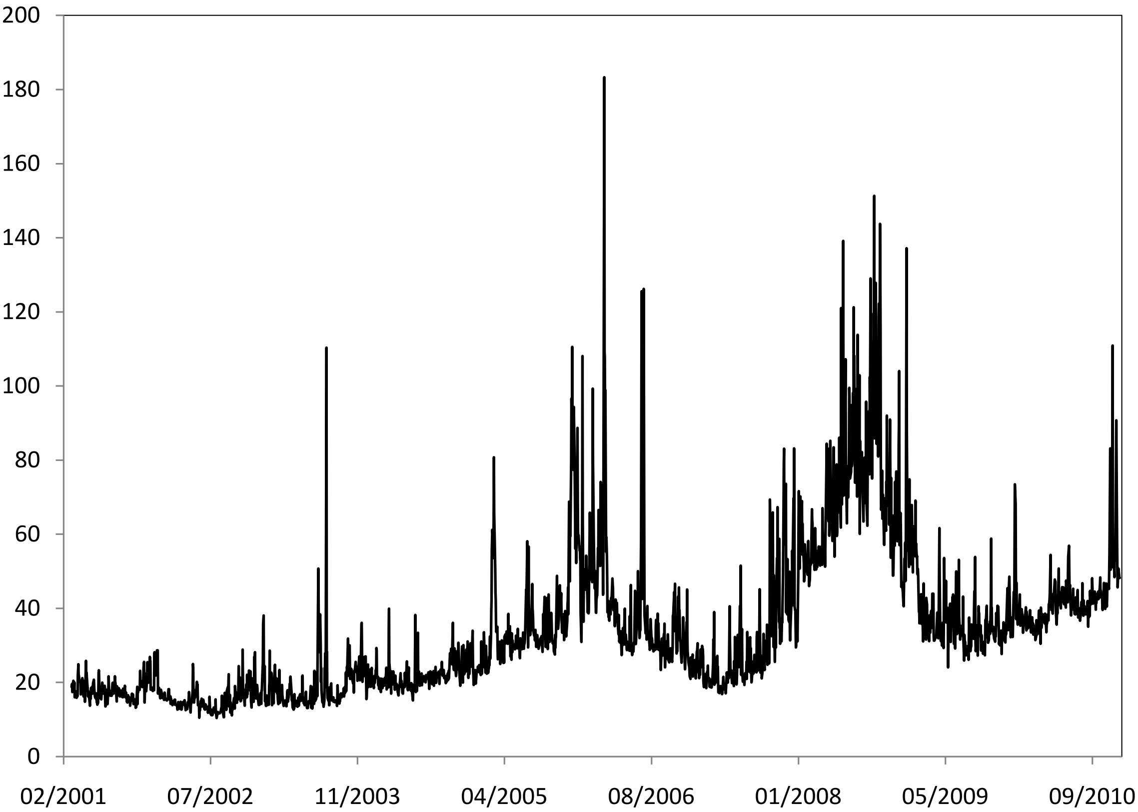

Exhibit 2: UK Electricity spot prices, average daily price (£/MWh), 2001-2010

Shipping rates respond to their unique set of information. For example, the large swings and volatility are related to the cycles in the world economy and commodities consumption (e.g., copper).

Moreover, bunker prices, which represent a significant component of these rates, are quite volatile since they are related to crude oil prices. Lastly, other risks influencing prices include fluctuations in scrap vessel prices, piracy, accidents, weather patterns (that create increased demand for energy producing fossil fuels) as well as bottleneck problems in some ports, as mentioned before.

A first examination of freight rate trajectories

Volatility has been a hallmark of the commodity industry, way before the financial crisis, and is even more extreme in the shipping markets. If we look at the evolution of the Baltic Dry Index during the period August 2002 to December 2005, a long time before the occurrence of any sign of the subprime crisis, we observe that the index was at 1000 in August 2002, rose to 2500 by September 2003, jumped to 4200 a month later to reach in February 2004 a then unprecedented level of 5450, more than double its value a few months earlier. Then, by June of the same year, its value fell to 2900 to return to the even higher level of 5520 in December 2004. By summer 2005, the index was again down at 2200. Upward and downward moves of such amplitude have never been experienced in equity and bond markets and translate the inelasticity in demand for shipping and the long lead times, of the order of several years, in the construction of new vessels to adjust to a rising demand.

We also note the existence of stable periods surrounded by times of extreme volatility. Such periods start with sustained sequences of large rates' increases, followed by a more stable period lasting a few months, as confirmed in Stopford [2009]. A cluster of downward moves will bring the process back to the average upward drift. In the previous example, after the remarkable increasing sequence of October 2003, the rate stayed above the level of 4000 until the beginning of April 2004, then declined in a steady way, returning to the level of 2622 in June 2006. The whole cycle lasted for roughly eight months. Cufley [1972] discussed the sequence of three key events common to shipping cycles: first, a shortage of ships develops, then high freight rates stimulate over-ordering of the ships in short supply, leading finally to market collapse and recession. According to Stopford [2009], a cycle in the shipping markets is defined as a sequence of four stages: a trough, a recovery, a peak and a collapse. Shipping cycles used to average eight years, became shorter recently with the big activity in Korean and Chinese shipyards. In the long-term, the trend is driven by technology. The transition from one technology to another can take 20 years to be completed: over the last century, diesel replaced steam, better boilers were introduced, and more recently the remarkable expansion of the dry bulk market took place, in terms of size and number of vessels (Capesize, Supramax), as well as the enlargement of the locks in the Suez and Panama canals.

Returning to the analysis of the BDI, we can recognize a major difference between its trajectories and those of electricity, the commodity which shares with the BDI an annualized volatility greater than 50%. Electricity exhibits spikes during plant outages or weather events, i.e., sharp upwards jumps followed by downward jumps within hours or days. On the contrary, the BDI paths are remarkably *continuous*, a property that can be explained by the fact that the need for vessels does not present the same emergency as the delivery of electricity to a hospital: grains or coal can wait for a few days in the port! Moreover, the price "stickiness" is naturally created by the averaging procedure used to produce the daily quotes of the index by the Baltic Exchange. As explained in the previous section, the BDI is computed by averaging other sub-indexes, themselves averages of the Baltic Exchange experts' estimates. On the other hand, the remarkable swings of the BDI are mainly due to a particular sequencing of events such as the concomitant need for cargoes to be shipped or congestion in some harbors. For example, the BDI went from a value of 2605 on the 24thof September 2003 to a value of 4049 on the 9th of October 2003. This move represents a steady average increase of 4.1% per day (with a minimal daily increase of 2.6%) leading to a total increase of 55% over the whole period of 11 business days. Kaldor [1939] and Working [1949], in their famous "Theory of Storage" exhibited that low inventory implies a high spot price volatility. In the shipping industry, there is no inventory, hence no buffer effect on prices and price volatility. Interestingly, in the airline industry, the situation is "better": planes which are momentarily unused are parked in the Nevada desert, for instance, in the case of US airlines.

A Class of Continuous Models for Shipping Rates

A first modelling consideration is whether the entire period we study, 1988-2010, is best described with a single set of parameters or whether one or more 'structural breaks' have occurred. Geman and Ohana [2008] test a freight-rate time series from 1988 to April 2008. Using the Bai and Perron [2003] test, their analysis exhibits a break for the BDI in the middle of the year 2003. In addition, Stopford recognizes in the 2009 edition of his reference book on maritime economics, a cycle in the shipping market extending from 1988 to 2002, at which point a new one started. These results, combined with our empirical analysis of both the price and volatility over the study period, support splitting the modelling into two sub-periods, namely 1988 to July 2003 and August 2003 to 2010. We start this Section by examining some statistical properties of the BDI prices over these two sub- periods.

Statistical Properties of the BDI time series

A common feature displayed by many commodities is the non-normality of returns. Specifically, we often see 'fat tails', i.e., more extreme movements than would be expected under a normal distribution. We represent in Exhibit 3 the 'Q-Q' plots for the BDI index returns, sampled weekly, from (a) 1988 to July 2003 and (b) August 2003 to 2010. Observing that the empirical data significantly departs from the theoretical dashed line corresponding to a Gaussian distribution, it is clear that the returns are non-normal. This is confirmed by some statistics intended to test for normality, displayed in Exhibit 4, which also demonstrate that the departure from normality is greater in the second period, as evidenced by the higher kurtosis. We also report in Exhibit 4 the mean and annualized volatility of the BDI over the entire period, as well as the two sub-periods 1988 to July 2003 and August 2003 to 2010. The striking difference between these statistics brings additional justification for a structural break, and argues in favor of two different sets of diffusion parameters for the BDI over the two sub-periods.

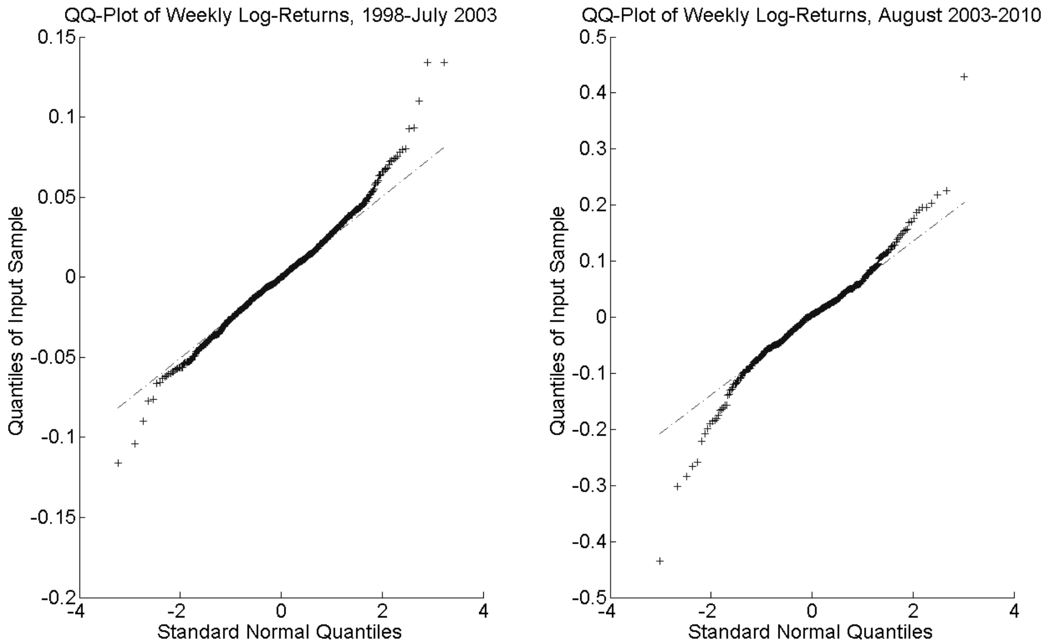

Exhibit 3: QQ Plots of the BDI Index (a) from 1988 to July 2003 (b) from August 2003 to 2010

The BDI mean value went from 1394 points in the first period to a level more than three times higher in the second one, with volatility remarkably exhibiting the same pattern; both features are consistent with the identified break in the trajectory. We can also note that an historical volatility of 61.5% is a number never experienced in the stock market (except for the few days following September 11), nor in other commodities outside electricity.

Period	Mean	Standard Deviation of Annualized Returns	Kurtosis of Returns (Normal Distribution = 3)	Jarque-Bera Statistic (p value)
1988 – 2010	2308	38.9%	13.7	5756 (0.001)
1988 – July 2003	1394	20.9%	4.58	95.2 (0.001)
August 2003 - 2010	4222	61.5%	6.70	226.4 (0.001)

Exhibit 4: Key Statistics of the BDI (weekly sampled) over the 2 periods

The QQ plots confirm the deviations from normality of log- prices in both periods. In agreement with the very large value of 6.70 obtained for the kurtosis in the second period, we can observe that the number of points outside the line is greater during the years 2003 to 2010, an expected feature since this period witnessed the gigantic rise of commodity prices until 2008 (and a value of 12,000 reached by the BDI), then a dramatic fall during the period June 2008 to December 2008 and a recovery since then. As a side note, we recall that oil prices reached a peak of $140 at the end of July 2008 before collapsing. This was an instance when the BDI was indeed an early indicator of commodity price changes; this property essentially lost any relevance as of 2010, with the massive arrival of new vessels manufactured by China to insure its commerce independence.

Returning to modelling considerations, we need to translate the non- normality of the BDI returns in a manner that is consistent with the *continuity* of trajectories and price stickiness

The model

The randomness of the economy is represented by a probability space (Ω, F, P), where P is the real probability measure. No other probability measure will be introduced in the paper as our sole focus here is the analysis of the BDI spot prices. A good understanding of the properties of spot price trajectories is a necessary step for the valuation (hence growth) of derivatives markets or structured products. We denote by S(t) the BDI index value at date and consider the family of processes represented by the stochastic differential equation :

$$dS(t) = a(S,t)dt + \eta S(t)^{\gamma} dW(t) \tag{1}$$

where $(W(t))_{t\geq 0}$ is a P- Brownian motion and gamma a strictly positive parameter. This formulation is as powerful as it is flexible and simple, while encompassing different behaviors of the freight rates. The price process is a continuous function of Brownian motion, hence, has continuous trajectories. The model exhibits stochastic volatility when the exponent gamma is different from 1.

Returning to our model, we recognize that the drift term a(S,t) and the diffusion term $\eta S(t)^{\gamma}$ are linked but observe that the volatility is estimated on the quadratic variation embedded in the trajectory and focus on its estimation in a first stage. The calibration procedure is applied to weekly BDI spot rates over the period January 1988 to December 2010. The data were obtained from Data Stream.

The Volatility Term

We choose a rolling window of 90 business days to compute the realized volatility of BDI prices and represent it in Exhibit 5. We immediately observe that volatility is much greater since 2003 than in the previous period.

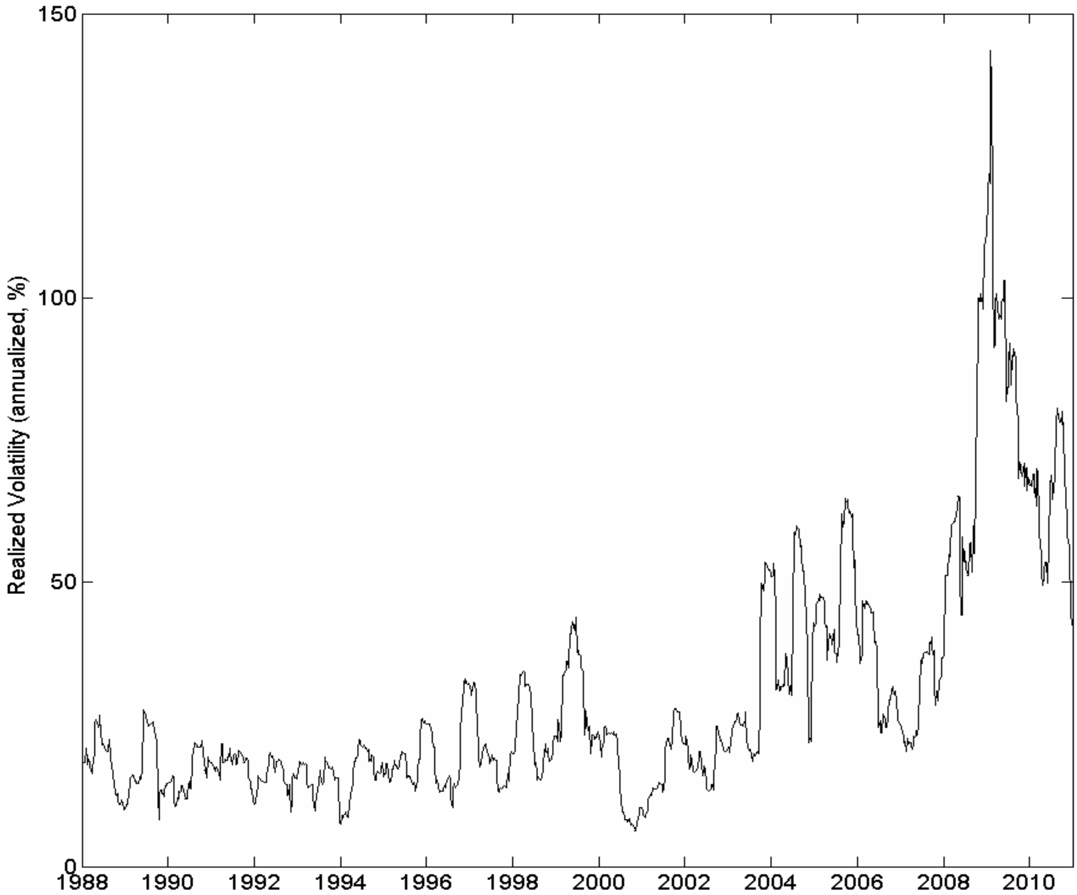

Exhibit 5: Realized Volatility of the BDI over the period of analysis

Gibson and Schwartz [1990], who were the first ones to analyze the valuation of options on crude oil, had represented oil prices by a geometric Brownian motion, probably in the line of the paper by Samuelson [1965]. Various extensions were later on introduced to go beyond the Gaussian distribution of spot prices, and in particular to account for the excess kurtosis which is observed in commodity paths – electricity prices in deregulated markets being an extreme case. Most of them add a Poisson component to the diffusion term, like in Merton [1976]. Our view is that stochastic volatility is a better representation than jumps to account for the high kurtosis of the BDI prices, given the continuity of trajectories due to prices "stickiness" and the benefits of keeping a single[2] source of randomness. The Constant Elasticity of Variance (CEV) model was first introduced in the seminal paper by Cox [1975] in the context of stock prices, in order to account for the leverage effect: stock prices go down with a higher volatility than they rise, creating de facto a non- constant volatility over time. The CEV process was represented by the stochastic differential equation

$$dS(t) = \mu\, S(t)\, dt + \sigma\, (S(t))^{\gamma}.dW(t) \tag{2}$$

where γ is the CEV exponent, assumed to be strictly positive and smaller than 1. This first and remarkable model of stochastic volatility did not introduce volatility as a second state- variable, hence preserved market completeness and the hedging of derivatives using only the underlying stock (an important property for the market of freight rates derivatives where options just start trading and are mostly embedded in the contracts between ship-owners and ship charterers). Emanuel and MacBeth [1982] extended Cox's paper to a model where the CEV exponent was strictly greater than 1 ("inverse leverage effect") and were also able to provide an analytic formula for the European call option price in this case. The case $\gamma = 1$ corresponds to the geometric Brownian motion of the seminal paper by Samuelson [1965]. The suitability of CEV-based processes to modeling commodity prices has been confirmed by Geman & Shih [2009].

Equation (1) may be re-written as

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2 Indeed, Merton had to assume a zero market price of jump risk in order to provide an option pricing formula in the setting of his jump-diffusion model. This assumption rapidly became non realistic, in equity and all other markets. As for the more involved pure jump processes, like CGMY for instance, they were proposed in the context of the S&P 500, where a large number of strikes and maturities allow market completeness to be generated by the plain-vanilla options (see Carr et al [2002]). We are presently far from that situation in the shipping markets.

$$\frac{dS(t)}{S(t)} = \frac{a(S,t)}{S(t)}\,dt + \frac{\eta S(t)^{\gamma}}{S(t)}\,dW(t) \tag{3}$$

Then, noting that the coefficient of $dW(t)$ is the realized volatility of returns usually denoted $\sigma(t)$, and taking logs in Equation (3), we obtain

$$\ln(\sigma(t)) = \ln(\eta) + (\gamma - 1)\ln(S(t)) \tag{4}$$

We can then obtain η and γ from a linear regression given $\sigma(t)$, which we perform using the rolling window of 90 business days mentioned before.

Period	η (95% confidence level)	γ (95% confidence level)	Regression R^2	Examples of Annualized Volatility for different BDI Levels	
				BDI=1394	BDI=10000
1988-2010	0.00687 (0.0047 - 0.0100)	1.47 (1.42 – 1.52)	0.225	21.4%	54.7%

Exhibit 6: Results of the volatility calibration

We display in Exhibit 7 a scatter plot of the realised volatility $\sigma(t)$ of the BDI against its level S(t). Samples from the first period, 1988-July 2003, are displayed as pluses (+), and samples from the second period as circles (o). We note the concentration of low values, both in price and volatility, of the BDI in the first period. The second period shows greater levels of the BDI, and greater volatility. The CEV parameter calibration over both periods is depicted as the curved line in Exhibit 7. Note that a constant-volatility model, with $\gamma = 1$, would plot the line as horizontal. We thus observe the 'inverse leverage effect', with $\gamma = 1.47 > 1$, widely noted in the commodity asset class. We also display in Exhibit 6 the 'model fit' annualized volatility corresponding to two BDI levels. At a BDI value of 1394 points (the mean in the first period), the model volatility is 21.4% versus a realized volatility of 20.9%; this is clearly a good fit. At high values of the BDI, the volatility rises significantly; for example at the level 10,000 observed in early 2008, the model predicts a volatility of 54.7%.

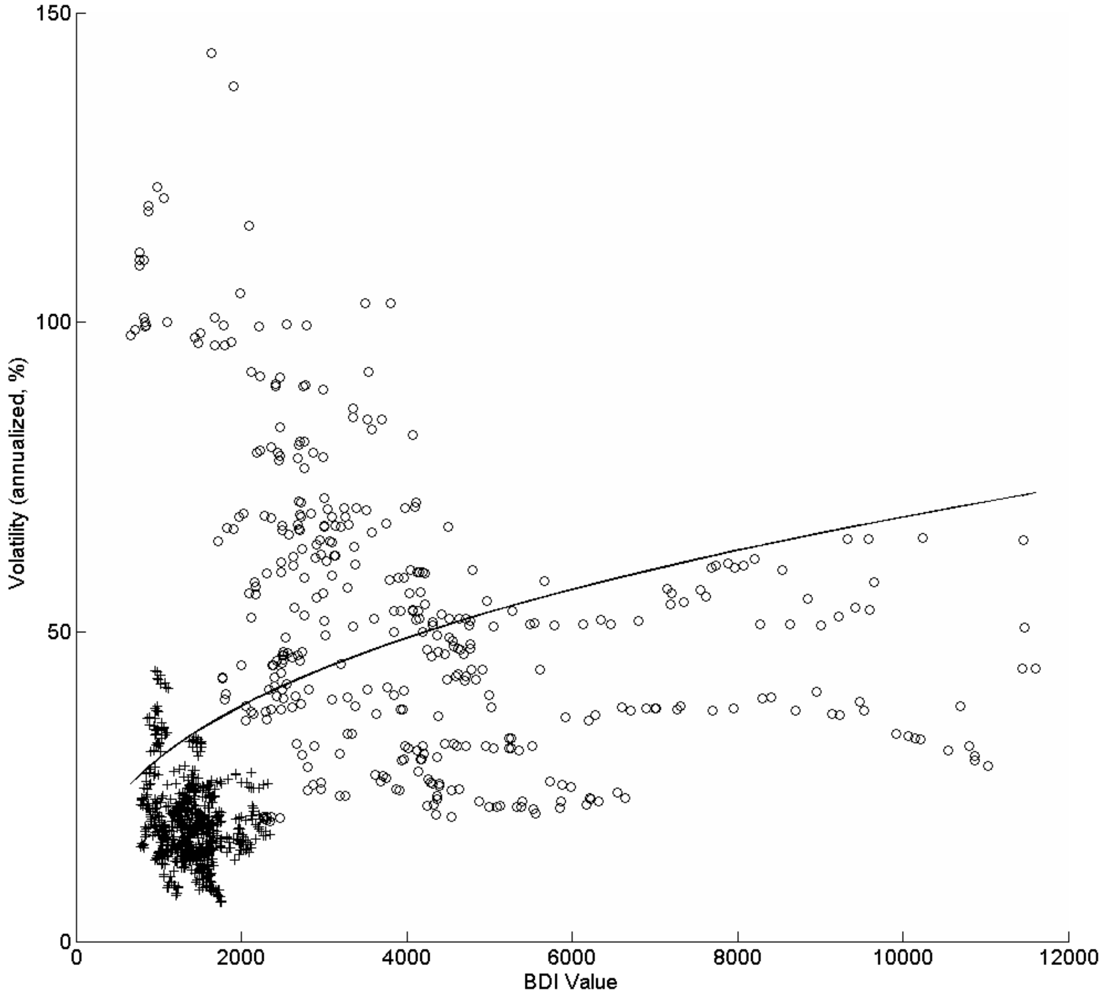

Exhibit 7: Realized Volatility of the BDI against BDI spot price, 1988-2010

The Drift Term

A key decision is whether the BDI is best modeled by a random walk or by a mean reverting (stationary) process. Koekebakker & al [2006] raise the question of the stationarity of the freight rates over the period going from 1985 to 2006 and conclude to its rejection. Considering a 129-years database of bituminous coal and the likes, Pindyck [1999] had analyzed a series of annual data of oil, natural gas and coal prices and concluded that they mean-revert to stochastically changing trends. Supporting the case for mean-reversion in commodity prices is the economic argument that a negative shock in supply moves prices up, generating a profitable return for additional commodity production, inducing in turn prices to go down.

To test the BDI for stationarity, we employ the widely used ADF (Augmented Dickey Fuller) test. This test, in its most generic form, consists of testing for the null hypothesis that $\alpha = 0$ against the alternative that $\alpha < 0$ in the following model, with S_t being the BDI value at time *t*, and Δ being the difference operator

$$\Delta S_t = c + \alpha S_{t-1} + \sum_{l=1}^{k} \beta_l \Delta S_{t-l} + \varepsilon_t \tag{5}$$

Note that if $\alpha < 0$, changes in y are inversely related to its level, and we have mean-reversion. The summation term considers lags, possibly necessary in order to ensure that the residuals ε_t are independent. We can alternatively write equation (5) as

$$S_t - S_{t-1} = c + \alpha S_{t-1} + \sum_{l=1}^{k} \beta_l \Delta S_{t-l} + \varepsilon_t \tag{6}$$

$$S_t = c + (\alpha + 1) S_{t-1} + \sum_{l=1}^{k} \beta_l \Delta S_{t-l} + \varepsilon_t \tag{7}$$

The result of the ADF test is a 't-statistic', and the lower the value, the more strongly we reject the null hypothesis of non-stationarity (also termed a 'unit root'). We tabulate in Exhibit 8 these results, for the full date range, and the two sub-periods. We test the *log* BDI price for mean reversion, rather than its actual value, since we would expect that, like for most financial assets, its distribution would be approximately normally distributed (discarding the gamma exponent, both the OU process and the arithmetic Brownian motion for log- prices lead to Gaussian univariate distributions). The number of lags, necessary to remove the effects of autocorrelation, was chosen to minimize the Bayes Information Criterion (BIC).

Period	**Lags Included**	**Daily Data**		**Weekly Data**	
		ADF test t-stat	**ADF test p-value**	**ADF test t-stat**	**ADF test p-value**
1988 – 2010	2 (based on BIC)	-2.76	0.063	-2.843	0.053
1988 – July 2003	3 (based on BIC)	-2.81	0.057	-2.36	0.152
August 2003 – 2010	2 (based on BIC)	-1.88	0.340	-2.74	0.068
Critical Values		1%: -3.43 5%: -2.86 10%: -2.56		1%: -3.44 5%: -2.87 10%: -2.57	

Exhibit 8: Results of the Unit Root Test

In order to get a bigger sample to detect mean reversion, we performed the testing on daily as well as weekly samples. The results indicate evidence of stationarity if we widen our confidence to the 10% level. Analyzing both daily and weekly data confirm stationarity over the whole period. For the separate sub-periods, results are more conflicting: period 1 shows stationarity when analysed at daily but not weekly data, and period 2 shows stationarity for the weekly but not the daily data. Either our data are insufficient numerous to confidently detect an existing stationarity as suggested by Pindyck [1999] in his study of crude oil and bituminous coal, or we are in a borderline situation between stationarity and non-stationarity.

Mean- reverting models have been extensively used for log- prices in the commodity literature since 1995, to represent a situation where supply and demand fundamentals induce mean-reversion to some long-term equilibrium value. The mean-reversion feature has been a central element of discussion in the recent literature on the spot and forward dynamics of commodity prices (see for instance the seminal paper by Bessembinder & al [1995]).

Returning to our model, under the constraints of strict positivity of prices and mean reversion, we adopt for equation (1) the following form:

$$dS(t) = a\left(b - S(t)\right)dt + \eta S(t)^{\gamma} dW(t) \tag{8}$$

In the case of $\gamma = 0$ or $\frac{1}{2}$, closed form solutions exist (Ornstein-Uhlenbeck process, and square-root process, respectively), allowing a log-likelihood function to be derived and the calibration to be performed using maximum likelihood. In the general case, no closed form solutions are available. Instead, we employ the calibration technique and associated software developed by Aït-Sahalia [2002] who builds an approximation to the stochastic differential equation of arbitrary precision, using a polynomial. Using this technique, a likelihood function can be derived for the approximation, which converges to the unknown likelihood function of the equation we wish to solve.

	a (standard error)	b (standard error)
1988-Jul 2003	0.2209 (0.2377)	1666.82 (474.59)
Aug 2003-2010	0.4986 (0.4225)	4128.5 (1730.4)

Exhibit 9: Results of the drift calibration

The results of the calibration are displayed in Exhibit 9. The first parameter 'a', corresponds to the speed of mean reversion, with 1/a the length of the cycle. The value of 0.2209 for the first sub-period corresponds to 4.52 years, which used to be the approximate time required to build a ship. The value of 0.4986 for the second sub-period corresponds to 2.04 years, related to the rapid 'boom and bust' seen in commodity markets during the 2007-2009 period. Besides these unique events, there has been lately a major arrival of new vessels built in China, with a clear goal of becoming self- sufficient for the transportation of its imports of iron ore, coal and grains in particular.

Regarding the parameter 'b', corresponding to the level of mean reversion, we see a huge change between the two sub-periods, with a much higher level in the second period, confirming again the existence of a structural break in mid 2003. The values of 1666 for the first sub-period and 4128 for the second sub-period correspond closely to the arithmetic mean values of the BDI in each case, as displayed earlier in Exhibit 4. This lends support to the accuracy of the calibration.

At this point, several avenues of research are open: either propose a term structure of forward freight rates consistent with this spot rate, or go to the valuation of options, plain- vanilla or Asian, after having adjusted the parameters to incorporate the risk premia and invoke 'risk-neutrality' arguments.

Conclusion

The fascinating features of shipping markets have been, to our view, under-studied in the financial literature so far. The present paper aimed at presenting the key features of these markets and their relationship to the world economy. We also analyzed the freight rates leading indicator, the Baltic Dry Index, whose trajectories exhibit large swings but are still continuous. We proposed a mean-reverting form of the CEV model for the BDI index between the years 1988 and 2010 and exhibited the presence of a structural break in mid 2003 – expressed by the mean values and the volatility in particular, hence the need to calibrate our model separately for the pre and post-break periods.

Our view is that an option freight market is unlikely to grow out of price assessments, but only after a number of models for spot rates have been proposed and tested. Non- financial hedgers, like farmers or small agribusiness companies, often feel more comfortable with purchasing options rather than futures or forwards since the outflows are fully known at inception of the contract.

Endnotes

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