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Shipping freight derivatives: a survey of recent evidence

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In an industry that is characterized by highly volatile prices, seasonality, strong business cycles, cyclicality and capital intensiveness, risk management is extremely important. Ship-owners and charterers face enormous risks, which emanate from fluctuations in freight rates, bunker prices, interest rates, foreign exchange rates and vessel values. These risks substantially affect the interplay between revenue and cost. Modern risk management techniques, involve the use of financial derivatives products, some of which have been developed exclusively for protecting (hedging) against the adverse price fluctuations of the aforementioned sources of risk in shipping. By using derivatives products, ship-owners and charterers can secure (stabilize) the level of their future income or costs and thus reduce uncertainty and unforeseen volatility of their cash-flow. To explore the importance of hedging freight rate risk in shipping operations, a survey of recent empirical evidence that has appeared in economic studies has been conducted. Developments over the past 20 years have been fast, with certain amount of research carried, which has helped to understand better the special features of these derivatives markets. They are all summarized in the current study, which can provide the stepping stone for further work in the area of shipping derivatives and risk management in shipping.

1. Introduction

Risk management in an industry that is riddled with cyclicalities in its rates and prices and has made and destroyed millionaires over the years. Since time immemorial, goods and commodities have been transported by sea between countries and around the world. Shipping still represents the life-blood of international trade especially for commodities transported in bulk and is a crucial factor underpinning the health of the global economy.

Shipping markets can be characterized as capital intensive, cyclical, volatile, seasonal and exposed to the international business environment. Shipping derivatives have the potential to offset freight rate risk of the dry-bulk and wet-bulk sectors of the shipping industry and its support industries. During the 1970s and 1980s, derivatives, which were used for commodities, expanded to financial markets, where the underlying assets were fixed-income bonds, foreign exchange, stock indices and equities. Market agents of the shipping industry were using currency swaps to secure against fluctuations in foreign currencies for the payment of new buildings. This exposure to currency risk is due to the fact that ship-owners' income is in

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US dollars, while payments are mostly in the local currency of the shipyard, such as in Japanese yen. Derivatives seem to have become a buzzword in the shipping industry, with the concept often being related to the ever increasing sophistication of the industry to recognize financial risks and the need for risk management in order to stay competitive. A comprehensive and very detailed presentation, with many practical applications, of the use of derivatives for managing all business risks prevalent in the shipping business, may be found in Kavussanos and Visvikis [1].

This paper concentrates on the most important source of business risk in the shipping industry, namely freight rate risk and on the freight derivatives instruments, which are currently used in hedging this risk. They include, freight futures, forward freight agreements (FFAs) and freight options contracts. The aim of the paper, then, is to present a survey of the literature and an analysis of the economic factors underlying the relevant relationships, thus providing a point of reference for researchers working in the area. The study draws together their most important conclusions in a single place, discusses them critically and evaluates their contribution to our knowledge in the subject matter.

The rest of the paper is organized as follows. Section 2 presents the different types of freight derivatives, including freight futures, FFAs, hybrid FFAs and freight options contracts. Section 3 collects together the extant literature on the freight derivatives market, including surveys about their use, forecasting models, the price discovery and hedging functions of freight derivatives, etc. Finally, section 4 summarizes this study.

2. The freight derivatives market

2.1. *Forward freight agreements (FFAs)*

Whenever commodities are traded, someone in the chain, between the supplier (charterer) and the customer that demands these commodities, is required to arrange for its transportation. The volatility observed in freight rates, in the very competitive tramp shipping markets, constitutes a source of risk for both the ship-owner and the charterer.

For the charterer, wishing to hire in vessels for her transportation requirements, increasing freight rates leads to higher costs. For the ship-owner, seeking employment for her vessels, lower freight rates involves less income from hiring out the vessels. FFA contracts can be used to hedge this freight risk. They are principal-to-principal contracts for difference (CFDs), between a seller and a buyer to settle a freight rate, for a specified quantity of cargo or type of vessel, for usually one, or a combination of the major trade routes of the dry-bulk or wet-bulk sectors of the shipping industry. One counter-party takes the view that the price of an agreed freight route, at an agreed time, will be higher than the current level and buys FFA contracts (commonly, the charterer). The other party takes the opposite position, and sells FFA contracts (the shipowner).

In the dry-bulk market, voyage-based contracts are settled on the difference between the contracted price and the average spot price of the route selected in the index over the last seven working days of the month, while time-charter-based contracts are settled on the difference between the contracted price and the average price over the calendar month [2]. If the seller's price is lower than the final settlement price then the seller will compensate the buyer of the FFA contract. For instance, a charterer needs a vessel in four months and wishes to secure the freight cost. He might find a shipowner (through a broker) willing to agree to a specific rate to be paid in four months time. So if the market rate actually increases above the agreed rate, this involves a cash inflow (gain) for the charterer. If it falls below the agreed rate, it involves a cash outflow (loss) for the charterer. In either case, these flows from the FFA, balance the gains or losses of the physical contract.

FFA contracts were introduced in 1992. They are private agreements between two counter-parties, and trade in over-the-counter (OTC) markets. The first freight derivatives contracts actually appeared in 1985 with the establishment of the Baltic International Freight Futures Exchange (BIFFEX) [3] contract. This constituted a freight futures contract whose underlying asset, upon the level of which settlement took place, was the Baltic Freight Index (BFI). In recognition of the market segmentation of the bulk shipping industry into distinct sub-sectors, see for instance Kavussanos [10, 15, 16], a number of distinct sub-indices of the BFI have been introduced gradually, in order to track better developments in each sub-market.

Thus, the Baltic Panamax Index (BPI) in 1998 (table 1), the Baltic Capesize Index (BCI) in 1999 (table 2), the Baltic Handymax Index (BHMI) in 2000 (table 3) and the Baltic Supramax Index (BSI) in 2005 (table 4) have been introduced. These indices are baskets of spot freight rates designed to reflect the daily movement in rates across dry-bulk spot voyage and time-charter rates. No specific cargo or tonnage requirements are represented, but each route is given an individual *weighting*

Table 1. Baltic Panamax Index (BPI) composition, 2006.

Routes	Vessel size (dwt)	Cargo	Route description	Weights
P1	55,000	Light grain	1–2 safe berths/anchorages US Gulf (Mississippi River not above Baton Rouge) to ARA	10%
P1A	74,000	T/C	Transatlantic (including east coast of South America) round of 45/60 days on the basis of delivery and redelivery Skaw–Gibraltar range	20%
P2	54,000	HSS	1–2 safe berths/anchorages US Gulf (Mississippi River not above Baton Rouge)/1 no combo port to South Japan	12.5%
P2A	74,000	T/C	Basis delivery Skaw–Gibraltar range, for a trip to the Far East, redelivery Taiwan-Japan range, duration 60–65 days	12.5%
P3	54,000	HSS	1 port US North Pacific/1 no combo port to South Japan	10%
P3A	74,000	T/C	Transpacific round of 35/50 days either via Australia or Pacific (but not including short rounds such as Vostochy (Russia)/Japan), delivery and redelivery Japan/South Korea range	20%
P4	74,000	T/C	Delivery Japan/South Korea range for a trip via US West Coast—British Columbia range, redelivery Skaw–Gibraltar range, duration 50/60 days	15%

Source: Baltic Exchange

- The vessel size is measured by its carrying capacity (dwt—deadweight tones) and includes the effective cargo, bunkers, lubricants, water, food rations, crew and any passengers.
- Each shipping route is given an individual weighting to reflect its importance in the world-wide freight market.
- Routes P1A, P2A, and P3A refer to time-charter (T/C) contracts, while P1, P2, P3 and P4 refer to voyage contracts.
- HSS stands for heavy grain, soya and sorghum.

Table 2. Baltic Capesize Index (BCI) composition, 2006.

Routes	Vessel size (dwt)	Cargo	Route description	Weights
C2	160,000	Iron ore	Tubarao (Brazil) to Rotterdam (The Netherlands)	10%
C3	150,000	Iron ore	Turabao/Beilun and Baoshan (China)	15%
C4	150,000	Coal	Richards Bay (S. Africa) to Rotterdam	5%
C5	150,000	Iron ore	W. Australia/Beilun-Baoshan	15%
C7	150,000	Coal	Bolivar (Columbia)/Rotterdam	5%
C8	172,000	T/C	Delivery Gibraltar–Hamburg range, 5–15 days ahead of the index date, transatlantic round voyage duration 30–45 days, redelivery Gibraltar–Hamburg range	10%
C9	172,000	T/C	Delivery ARA or passing Passero, 5–15 days ahead of the index date, redelivery China–Japan range, duration about 65 days	5%
C10	172,000	T/C	Delivery China–Japan range, 5–15 days ahead of the index date, round voyage duration 30–40 days, redelivery China–Japan range	20%
C11	172,000	T/C	Delivery China–Japan range, 5–15 days ahead of the index date, redelivery ARA or passing Passero, duration about 65 days	5%
C12	150,000	Coal	Gladston (Australia) to Rotterdam	10%

Source: Baltic Exchange

- See also notes in table 1.
- Route C1, which involved a 120,000 dwt vessel carrying coal from Hampton Roads (US) to Rotterdam (The Netherlands) was introduced on 1 March 1999, but ceased being published on 1 April 2004.

Table 3. Baltic Handymax Index (BHMI) composition, 2006.

Routes	Vessel size (dwt)	Route description	Weights
HM1A	45,500	Delivery Antwerp–Skaw range for a trip about 60–65 days redelivery Singapore–Japan range including China	12.5%
HM1B	45,500	Delivery passing Canakkale for a trip about 50–55 days redelivery Singapore–Japan range including China	12.5%
HM2	45,500	Delivery South Korea/Japan for 1 Australian or trans Pacific round voyage, one laden leg, redelivery South Korea–Japan range	25%
HM3	45,500	Delivery South Korea–Japan range for a trip about 60–65 days redelivery Gibraltar–Skaw range	25%
HM4A	45,500	Delivery Antwerp–Skaw range for a trip about 30–35 days redelivery US Gulf	12.5%
HM4B	45,500	Delivery US Gulf for a trip about 30–35 days redelivery Skaw–Passero	12.5%

Source: Baltic Exchange

- See also notes in table 1.
- Handymax vessels carry bulk cargos, grain and coal.

to reflect its importance in the world-wide freight market. These routes are regularly reviewed to ensure their relevance to the underlying physical market. Given the estimates of the routes on a daily basis, FFA contracts (and freight futures contracts) on individual routes or on basket of routes of these indices exist, which can be used by market agents for risk management and investment purposes.

Table 4. Baltic Supramax Index (BSI) composition, 2006.

Routes	Vessel size (dwt)	Route description	Weights
S1A	52,000	Delivery Antwerp–Skaw range for a trip of 60–65 days redelivery Singapore–Japan range including China 5% commission total. Laycan (laydays cancelling) 5–10 days in advance	12.5%
S1B	52,000	Delivery passing Canakkale (Turkey) for a trip of 50–55 days redelivery Singapore–Japan range including China 5% commission total. Laycan 5–10 days in advance	12.5%
S2	52,000	Delivery South Korea–Japan range for 1 Australian or trans Pacific round voyage, for 35–40 days trip, redelivery South Korea/Japan range 5% commission total. Laycan 5–10 days in advance	25%
S3	52,000	Delivery South Korea–Japan range for a trip of 60–65 days redelivery Gibraltar–Skaw range 5% commission total. Laycan 5–10 days in advance	25%
S4	52,000	Delivery Gibraltar–Skaw range for one trans-Atlantic round voyage of 45–50 days, redelivery Gibraltar–Skaw range, 5% commission. Laycan 5–10 days in advance	25%

Source: Baltic Exchange

- See also notes in table 1.
- Supramax vessels carry bulk cargos, grain and coal.
- Laycan refers to the time interval into which the vessel must be in port ready to pick up/deliver cargo.

In the tanker market, a tanker FFA contract is an agreement between two parties to fix a freight rate in World scale units on a predetermined tanker route, over a time period, at a mutually agreed price. Settlement takes place at the end of each month, where the fixed forward price is compared against the monthly average of the spot price of the tanker route selected. These tanker route values are published by the Baltic Exchange and they are classified under the Baltic Dirty Tanker Index (BDTI) routes (see table 5) or the Baltic Clean Tanker Index (BCTI) routes (see table 6). They were launched in January 1998.

FFA contracts, initially, were traded in OTC derivatives markets, where two parties agreed to do business with each other. That means that each party accepted credit-risk from the other party [17]. The institutions that facilitate this market are major shipbrokers, investment banks, and other financial intermediaries in the fund management industry. The primary advantage of an OTC market is that the terms and conditions of the contract are tailored to the specific needs of the two parties. This gives investors flexibility by letting them introduce their own contract specifications in order to cover their specific needs. The OTC market is unregulated and because it is unregulated its participants quickly respond to changing needs and circumstances by developing new variations of old contracts – see Kavussanos and Visvikis [18, 19]. For further analysis regarding the above issues in the FFA and other shipping derivatives markets see Kavussanos and Visvikis [1].

2.2. *Freight futures*

Besides the OTC FFA contracts, market agents in the shipping industry can use freight futures, which are traded in organized exchanges. They include the International Maritime Exchange (IMAREX) and New York Mercantile

Table 5. Baltic Dirty Tanker Index (BDTI) composition, 2006.

Routes	Vessel size (mt)	Type of vessel	Route description
TD1	280,000	VLCC	Middle East to US Gulf: Ras Tanura (South Arabia) to Loop (US)
TD2	260,000	VLCC	Middle East Gulf to Singapore: Ras Tanura to Singapore
TD3	250,000	VLCC	Middle East Gulf to Japan: Ras Tanura to Chiba (Japan)
TD4	260,000	VLCC	West Africa to US Gulf. Off Shore Bonny (Nigeria) to Loop
TD5	130,000	Suezmax	West Africa to USAC. Off Shore Bonny to Philadelphia (US)
TD6	135,000	Suezmax	Black Sea/Mediterranean
TD7	80,000	Aframax	North Sea to Continent. Sullom Voe (UK) to Wilhelmshaven (Germany)
TD8	80,000	Aframax	Kuwait to Singapore. Mena al Ahmadi (Kuwait) to Singapore
TD9	70,000	Panamax	Caribbean to US Gulf. Puerto La Cruz (Venezuela) to Corpus Christi (US)
TD10	50,000	Panamax	Caribbean to USAC. Aruba (Antilles) to New York
TD11	80,000	Aframax	Cross Mediterranean/Banias (Syria) to Lavera (France)
TD12	55,000	Panamax	ARA to US Gulf. Antwerp (Belgium) to Houston (US)
TD14	80,000	Aframax	South East Asia to Australia. Seria to Sydney
TD15	260,000	VLCC	West Africa to China. Serpentina and Off Shore Bonny to Ningpo
TD16	30,000	Handysize	Black Sea to Mediterranean. Odessa to Augusta
TD17	100,000	Aframax	Trial – Baltic to UK Continent. Primorsk to Wilhelmshaven
TD18	30,000	Coaster	Trial – Baltic to UK Continent. Tallinn to Rotterdam

Exchange (NYMEX). IMAREX is a professional freight derivatives exchange for the maritime industry, founded in spring 2000. It provides a marketplace for freight derivatives (freight futures and FFAs) and in partnership with the Norwegian Options and Futures Clearing-House (NOS) offers clearing services for these derivatives. Trading for market participants can be facilitated directly on the IMAREX trading screen, via their broker teams in Oslo and Singapore or via an authorized third-party freight derivatives broker (e.g. Clarksons, Simpson Spence & Young, Freight Investors Services, etc.). A list of freight futures and FFA contracts available at IMAREX may be found on the IMAREX website and in Kavussanos and Visvikis [1].

Since May 2005, the NYMEX started offering freight derivatives on nine tanker freight futures contracts on its NYMEX ClearPort(sm) electronic trading and clearing platform. They use as underlying commodities the Baltic Exchange or the Platts' indices and include the five *dirty* tanker routes TD3, TD5, TD7, TD9 and TD10 of table 5 and the four *clean* tanker routes TC1, TC2, TC4 and TC5 of table 6. The Singapore Exchange (SGX) has also announced that during 2006 it will introduce freight derivatives trading.

2.3. *Hybrid FFAs*

In response to demands from market participants to address the issue of credit risk present in OTC FFA contracts, a set of new derivatives contracts appeared. We call them *hybrid* FFAs, as they are OTC agreements, but cleared through the LCH.Clearnet. Thus, they maintain the flexibility of the FFAs and, for a fee, have credit risk eliminated. The LCH.Clearnet then launched, on 13 September 2005, a recording, clearing and settlement service for OTC FFAs, offering the management

Table 6. Baltic Clean Tanker Index (BCTI) composition, 2006.

Routes	Vessel size (mt)	Type of vessel	Route description
TC1	75,000	Aframax	Middle East Gulf to Japan. Ras Tanura to Yokohama (Japan)
TC2_37	37,000	Handysize	Continent to USAC. Rotterdam to New York
TC3_38	38,000	Handysize	Caribbean to USAC. Aruba to New York
TC4	30,000	Handysize	Singapore to Japan. Singapore to Chiba (Japan)
TC5	55,000	Panamax	Middle East to Japan. Ras Tanura (South Arabia) to Yokohama
TC6	30,000	Handysize	Algeria/Euromed. Skilkda (Syria)/Lavera (France)
TC7	30,000	Handysize	Trial – Singapore to East Coast Australia. Singapore to Sydney
TC8	65,000	Panamax	Trial – AG to UK Continent. Jubail to Rotterdam
TC9	22,000	Coaster	Trial – Baltic to UK Continent. Ventspils to Le Havre

Source: Baltic Exchange.
The routes are equally weighted; each of the six routes has a weight of 16.67%.

of margin and cash-flows and becoming the counter-party for each of the parties in the agreement. FFAs cleared at LCH.Clearnet include four tanker FFAs (crude and refined products), four dry voyage FFAs (dry-bulk commodities), three *baskets* of dry time-charter FFAs and two dry trip time-charter FFAs. Benefits of hybrid FFAs include the elimination of counter-party credit risk, multi-lateral transaction netting, and improved operational and capital efficiency across multi-market positions. For full details of these contracts refer to the LCH. Clearnet website and in Kavussanos and Visvikis [1].

2.4. *Freight options*

Besides futures and forward contracts, options contracts are another derivatives tool available to principals for risk management and investment purposes. This type of financial derivatives contracts has been used extensively in finance on a number of underlying instruments, including exchange rates, interest rates, etc. Freight options contracts were introduced in 1991 with a European options [20] contract on BIFFEX, trading at London International Financial Futures and Options Exchange (LIFFE). Trading on these contracts never became popular and they, like BIFFEX, ceased trading in April 2002.

OTC options contracts are now available on individual routes of the Baltic dry and tanker indices, as well as on baskets of time-charter routes of the indices and on the FFA contracts available on them. They are offered by the same brokers that trade FFA contracts. On 1 June 2005 the first cleared tanker IMAREX Freight Option (IFO) contract was launched, on route TD3 (VLCC AG–East), cleared through NOS. The IFOs are available for trading and clearing for all IMAREX and NOS members, are structured as monthly call and put Asian style options [21], with monthly, quarterly and yearly maturities. IFOs are settled against the Baltic Exchange quotes. More specifically, settlement prices for the tanker routes (measured in Worldscale points) and time-charter dry-bulk routes (measured in US$/day) are calculated as the arithmetic average across all trading days in a calendar month and those for dry-bulk voyage routes (measured in US$/ton) are calculated as the average price over the last seven working days of the month.

The standard freight option contract is either a freight put option or a freight call option. They settle the difference between the average spot rate over a defined period of time and an agreed strike price. A ship-owner will buy a put option, agreeing thus to sell his freight service in the future at a price agreed today. She would exercise the option to sell at the agreed price if the market freight rate falls below the agreed price. On the other hand, the charterer would buy a call option, which she will exercise (to buy the freight service at the agreed price) if the market freight rate at expiry is higher than the agreed price. Both the charterer and the ship-owner would pay a premium to purchase these options. In contrast to FFAs and freight futures, the downside cost is known in advance and is equal to the option's premium. The upside potential is unlimited, just as in the case of FFAs and freight futures.

3. Research on freight derivatives markets

Very little research work has been conducted on freight derivatives, in comparison to derivatives on other *commodities*. In a recent survey, Kavussanos [10] reports evidence uncovered in research on BIFFEX contracts. These were the contracts listed at LIFFE that served the industry from 1985 to 2002. In these studies it is found that the contracts fulfilled their unbiased role; for instance Kavussanos and Nomikos [12] report that one-month and two-month BIFFEX contracts were unbiased (on average they were accurate) estimators of the rates prevailing in spot markets, while Haigh [13] finds three-month BIFFEX contracts also to be unbiased estimators of spot freight rates. Also, it was revealed that the hedging effectiveness of BIFFEX contracts was very low compared to other markets. A number of attempts to resolve this issue were made by the industry, and involved changing the structure of the underlying index to make it more homogeneous. However, the problem still remained. Partly, this was a cross-hedging problem. That is, the BIFFEX (futures) contract, which was based on the index—the BFI, could not hedge well the rates on individual routes. As a consequence, the volume of trading fell and LIFFE abandoned the trading of the contract; figure 1 reports the volume of trading of BIFFEX contracts during its lifetime.

The appearance of FFAs, as a substitute tool for freight rate risk management purposes, did not help BIFFEX. Market agents switched to them, with the volume of trading in FFAs rising exponentially since their inception in 1992 (see figure 2).

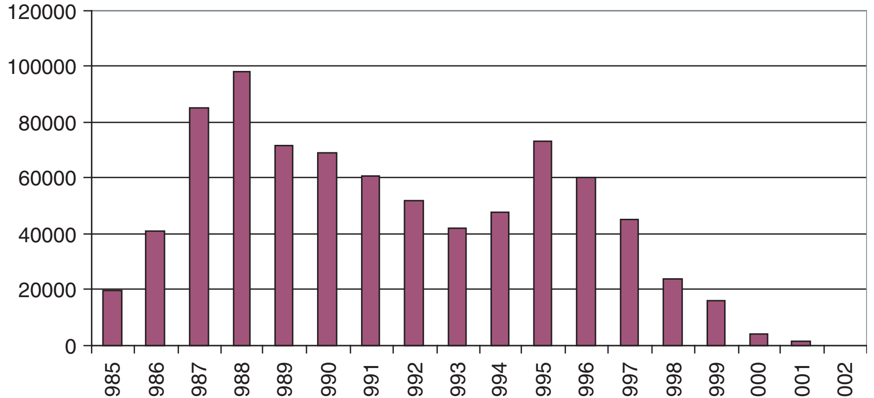

Figure 1. Yearly volumes of the BIFFEX contract (May 1985–April 2002).
Source: LIFFE (2002).

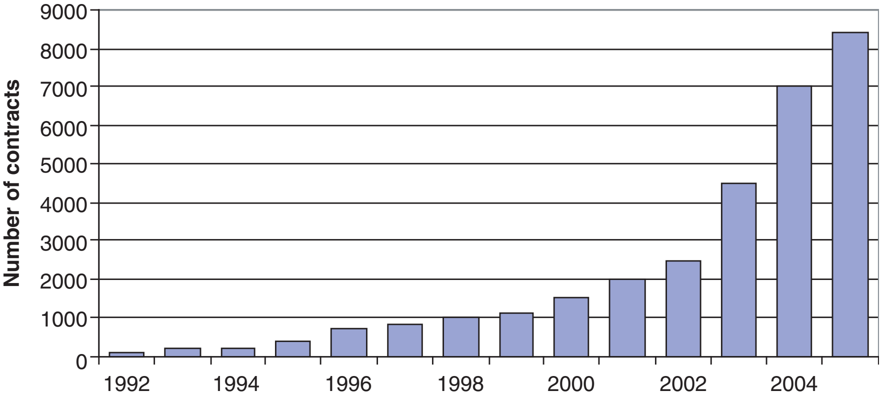

Figure 2. Yearly volumes of dry-bulk FFA contracts (January 1992–September 2005).
Source: Clarksons Securities Ltd.

FFAs can provide the tailor-made product that market players needed, hence their popularity. Research on FFAs is relatively limited. Part of the reason for this situation has been the lack of availability of data, which could be used to support empirical work in these markets. In the early days, research work had to rely on primary data collected from freight derivatives brokers' records (e.g. Kavussanos and Visvikis [22, 23]), often meeting the reluctance of agents in the *secretive* shipping industry to provide data and information for research.

3.1. *Market surveys on the use of freight derivatives*

There have been three studies known to us in the literature that investigate the perceptions of market agents in shipping, as to the use of freight derivatives. Cullinane [24] surveys the attitudes and behaviour of ship-owners with respect to BIFFEX, a few years after its inception. The survey includes questionnaire replies from 85 ship-owners in four countries (Britain, Greece, Hong Kong and Norway). The results of the survey suggest that the shipping community was fully aware of the existence of BIFFEX and that ship-owners were reasonably aware of how to make use of this facility. However, he concludes that a problem existed, in that BIFFEX was not accepted as a viable hedging mechanism by the vast majority of the sample.

Dinwoodie and Morris [25] survey the attitudes of tanker ship-owners and charterers towards freight hedging and their risk perceptions of FFAs. The survey includes questionnaire replies from seven countries over 22 ship-owners and eight charterers. They argue that although FFAs were widely viewed as an important development, some respondents were unaware of their function and the majority had not used them. Most of the participants in this survey were concerned about the risk of payment default on settlement. Many ship-owners also feared that FFAs might expose their risk management policies to counter-parties. The link between freight hedging activity and participants' risk aversion was not clear-cut, but they argue that improved *technical* education is essential for widespread acceptance.

Kavussanos *et al.* [26] conducted a questionnaire survey with 31 replies, to investigate the importance of hedging freight rate risk through derivatives for the Greek ship-owners. The results indicate that: (i) risk management and shipping derivatives are at on early stage of development and understanding in the Greek shipping market, although participants in the sample seem to know about them;

(ii) the traditional ways of thinking must be changed and replaced with modern risk management concepts, which should form part of the overall business strategy of the company; (iii) liquidity and credit (counter-party) risk are considered to be major obstacles in the use of shipping derivatives; (iv) in line with the findings of Dinwoodie and Morris [25], they consider education to be of paramount importance for them; and finally (v) there seems to be a positive view of the future of shipping derivatives in Greece, especially if the banks endorse them.

The success or failure of a derivatives contract is determined by its ability to perform its economic functions efficiently, and therefore, to provide benefits to economic agents, over and above the benefits they derive from the spot market. These economic functions are price discovery and risk management through hedging. If the derivatives market does not perform one or both of these functions satisfactorily, then market agents have no reasons to trade in the derivatives market, which eventually leads to loss of trading interest. Empirical work that has appeared in the literature on these and other issues pertaining to freight rate derivatives are presented next. They include, the impact of the introduction of the FFA markets on the volatility of the freight rates, the relationship between FFA bid–ask spreads and expected volatility, the forward freight rate dynamics and the pricing of freight options.

3.2. *The forecasting performance of freight derivatives*

Cullinane [4] argues that accurate short-term forecasts of spot rates can assist in the development of a forecasting model for short-term BIFFEX speculative strategies. By deriving a Box–Jenkins autoregressive integrated moving average (ARIMA) model of the BFI, covering the period between 1985 and 1988, he argues that predictions of movements in the BFI would go a long way towards providing insight into movement in the value of the nearby BIFFEX contract. More specifically, he finds that an autoregressive (AR) model with three lags is the most appropriate model that fits the data against alternative ARIMA specifications. Using forecasts derived from an AR(3) model with one- and five-day lead times, a simple profitable speculative strategy is constructed. He concludes that an investigation into the precise nature of the relationship between the BFI and the value of the BIFFEX contracts may have an impact not only on the speculative aspect of investing in BIFFEX but also on hedging practice.

Cullinane *et al.* [27], following the work of Cullinane [4], applies the Box–Jenkins ARIMA methodology in order to test whether the exclusion of all Handysize trades from the BFI in November 1993 has altered its underlying behaviour. An ARIMA model is applied to the BFI, covering a period following this index composition change (1993–1996) and comparing the properties of the resulting model to those of the ARIMA model of Cullinane [4] that covered a period before this change (1985–1988). They compare the autocorrelation function (ACF) and the partial autocorrelation function (PACF) of the models before and after November 1993 and report only a very small deviation. The form of the ACF output is the same as that of Cullinane [4], but the characteristics of the PACF differ slightly, pointing to an AR(2) specification instead of an AR(3) as found in Cullinane [4]. They conclude that the exclusion of Handysize trades from the BFI can hardly be termed a revolutionary change. However, it should be noted that the models used in Cullinane [4] and Cullinane *et al.* [27] are not capable in capturing both the short-run dynamics and the long-run relationships between the variables as vector autoregressive (VAR) and vector error-correction model (VECM) models can. The work reported in Kavussanos [10] indicate that, after using overlapping forecast intervals to compare joint VECM forecasts of spot freight rates and BIFFEX futures freight rates with forecasts from ARIMA, VAR and Random Walk models, the VECM generates the most accurate forecasts of spot prices but not of BIFFEX prices.

Batchelor *et al.* [28] compare the performance of multivariate VAR models, VECM, seemingly unrelated regressions estimation—SURE-VECM; and univariate ARIMA time-series models in generating short-term forecasts of spot freight rates and FFA prices. They argue that building forecasting models for the FFA market is interesting for three reasons: First, unlike markets in financial assets and most non-agricultural commodities, the freight market trades a non-storable service. This means that forward rates are not tied to spot rates through a no-arbitrage condition, but are free to be determined by speculative activity—for more details see Kavussanos and Visvikis [1]. Second, there are asymmetric transactions costs between spot and FFA markets. These costs are believed to be higher in the spot freight market as they involve the physical asset, the vessel. Third, the forward freight market is relatively new and, like all forward markets, has developed primarily in response to the needs of hedgers.

Univariate ARIMA(p, d, q) models of the following form are used to generate forecasts of spot and FFA prices:

$$\Delta S_t = \mu_{1,0} + \sum_{i=1}^{p} \mu_{1,i}\Delta S_{t-i} + \sum_{j=1}^{q} \gamma_{1,j}\varepsilon_{t-j} + \varepsilon_{1,t}; \quad \varepsilon_{1t} \sim \text{iid}(0, \sigma_1^2) \tag{1a}$$

$$\Delta F_t = \mu_{2,0} + \sum_{i=1}^{p} \mu_{2,i}\Delta F_{t-i} + \sum_{j=1}^{q} \gamma_{2,j}\varepsilon_{t-j} + \varepsilon_{2,t}; \quad \varepsilon_{2t} \sim \text{iid}(0, \sigma_2^2) \tag{1b}$$

where, ΔF_t and ΔS_t are changes (first-differences) in log FFA and spot prices, respectively, and ε_t is the white noise random error-term. For an ARIMA(p, d, q) model the terms p, d, q refer to the lagged values of the dependent variable, the order of integration [29], and the lagged values of the error-term, respectively, in the specification of the model.

The bivariate VAR(p) model of the following form is also used to produce forecasts of spot and FFA prices in a simultaneous spot-FFA framework:

$$\begin{aligned} \Delta S_t &= \mu_{10} + \sum_{i=1}^{p} \mu_{1,i}\Delta S_{t-i} + \sum_{i=1}^{p} \gamma_{1,i}F_{t-i} + \varepsilon_{1,t} \\ \Delta F_t &= \mu_{20} + \sum_{i=1}^{p} \mu_{2,i}\Delta S_{t-i} + \sum_{i=1}^{p} \gamma_{2,i}F_{t-i} + \varepsilon_{2,t} \end{aligned} \tag{2}$$

Finally, the unrestricted and restricted versions of the bivariate VECM(p) model of the following form is used to generate simultaneous out-of-sample forecasts for spot and FFA prices:

$$\begin{aligned} \Delta S_t &= \mu_{10} + \sum_{i=1}^{p} \mu_{1,i}\Delta S_{t-i} + \sum_{i=1}^{p} \gamma_{1,i}F_{t-i} + \alpha_1(S_{t-1} - \beta_1 F_{t-1} - \beta_0) + \varepsilon_{1,t} \\ \Delta F_t &= \mu_{20} + \sum_{i=1}^{p} \mu_{2,i}\Delta S_{t-i} + \sum_{i=1}^{p} \gamma_{2,i}F_{t-i} + \alpha_2(S_{t-1} - \beta_1 F_{t-1} - \beta_0) + \varepsilon_{2,t} \end{aligned} \tag{3}$$

$$\varepsilon_{i,t}|\Omega_{t-1} \sim IN(0, H_t)$$

where, the term in brackets represents the cointegrating (long-run) relationship between the spot and FFA prices. Alternatively, this error-correction term (ECT) represents the lagged disequilibrium term of the long-run relationship between spot and FFA prices. The error-terms follow a normal distribution with mean zero and time-varying covariance matrix, H_t. The VECM model is argued in the literature to be more appropriate than the univariate ARIMA and bivariate VAR models in modelling the spot and derivatives prices, as it takes into account both the short-run dynamics and the long-run relationship between the variables. In equation (3) the coefficients α_1 and α_2 measure the speed of adjustment of spot and FFA prices to their long run equilibrium.

Independent non-overlapping forecast sets were created by generating N-period ahead multiple forecasts, from recursively estimated model parameters. The results indicate that while conditioning spot returns on lagged FFA returns generates more accurate forecasts of spot prices for all forecast horizons (up to 20 days ahead), conditioning FFA returns on lagged spot returns enhances forecast accuracy only up to four days ahead. For longer forecast horizons, simple univariate ARIMA models seem to be the best models for forecasting FFA prices. Thus, FFA prices can enhance the forecasting performance of spot prices and, consequently, by selecting the appropriate time-series model for forecasting purposes, market agents can design more efficient investment and speculative trading strategies. On the other hand, it seems that spot prices cannot help in enhancing the forecasting performance of FFA prices, which indicates that the forward rate does contain significantly more and different (and maybe better) information than is embodied in the current spot rate. The implication of this is that even if market agents do not use the FFA market for hedging reasons, by collecting and analyzing FFA prices they can obtain *free* information about the future direction of spot freight prices. These results are in line with the work reported in Kavussanos [10] who finds that BIFFEX prices can enhance the forecasting performance of BFI prices but not vice versa.

3.3. *Pricing of freight futures and FFA contracts*

The issue of pricing of derivatives contracts is important for market participants, as identification of mispriced derivatives amounts to identification of investment opportunities. Such arbitrage opportunities are central in the literature in the pricing of derivatives. The cost-of-carry model plays a central role in this. Thus, for a storable commodity, it is argued, the price of a forward contract, written on the commodity, must be equal to the spot price of the commodity today plus the financial and other costs (e.g. storage and insurance) to carry it forward in time. If this is not the case and the forward price is overpriced (underpriced), arbitrageurs/investors can simultaneously sell (buy) the forward contract, buy (sell) the underlying commodity and store it until the expiry of the contract. At expiry, reversing these positions will produce a risk-free profit. These movements by arbitrageurs ensure that correct prices always prevail in efficiently working markets, and they will be

$$F_{t,T} = S_t + C_{T-t} \tag{4}$$

where, $F_{t,T}$ = price of the forward contract at time t, maturing in time period T; S_t = spot price of the underlying commodity in period t; and C_{T-t} = costs of carrying the commodity forward in time between period t and T.

Kavussanos [10] and Kavussanos and Visvikis [22] point out that freight services, as the underlying commodity of FFAs and of freight futures contracts, are non-storable. This feature of the underlying commodity of the derivatives contract violates the usual arbitrage arguments, presented above, that lead to the pricing of futures and forward contracts in storable commodities. In fact, in the above studies and in Kavussanos and Visvikis [1] it is shown that in this case pricing of the futures or FFA contracts with the freight service as the underlying commodity is described through the following relationship:

$$F_{t,T} = E_t(S_T) \tag{5}$$

where, $E_t(\mathrm{S}_T)$ denotes the expected value of S_T, with expectations formed at time period *t*. As observed in equation (5), forward/futures prices are formed in terms of expectations, by the market, of freight rates that will prevail at the maturity of the derivatives contract. This is not an exact pricing relationship and its validity depends, among other things, on how precisely expectations are formed in the market. Assuming rational expectations, equation (5) becomes:

$$F_{t,T} = S_t + u_t; \qquad u_t \sim \mathrm{iid}(0, \sigma^2) \tag{6}$$

Provided the relationship is verified with actual data, it can be argued that the freight forward/futures market satisfies its price discovery function. This is because, futures or forward prices today help as discover spot prices in a future time period, specifically at the expiry of the derivatives contract.

Kavussanos *et al.* [30] and Kavussanos and Visvikis [22] investigate two different aspects of the price discovery function of the FFA market, namely the relationship between current forward prices and expected spot prices—embodied in the unbiasedness hypothesis, and the lead–lag relationship in returns and volatility between spot and forward prices, respectively. They examine the following constituent routes of the BPI: (a) the Atlantic voyage route P1 (US Gulf/Antwerp–Rotterdam–Amsterdam); (b) the Atlantic time-charter route P1A (Transatlantic round to Skaw–Gibraltar range); (c) the Pacific voyage route P2 (US Gulf/Japan); and (d) the Pacific time-charter route P2A (Skaw Passero–Gibraltar/Taiwan-Japan).

More specifically, Kavussanos *et al.* [30] investigate the unbiased expectations property of the forward prices in the market using cointegration techniques. The following VECM framework, proposed by Johansen [31], is used to test for unbiasedness:

$$\Delta X_t = \mu + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + \Pi X_{t-1} + u_t; \; u_t \sim IN(0, \Sigma) \tag{7}$$

where, X_t is the $\mathbf{2 \times 1}$ vector $(S_t, F_{t,t-n})$, μ is a $\mathbf{2 \times 1}$ vector of deterministic components which may include a linear trend term, an intercept term, or both, Δ denotes the first difference operator, u_t is a $\mathbf{2 \times 1}$ vector of residuals $(u_{S,t}, u_{F,t})$ and Σ the variance/covariance matrix of the latter. The VECM specification contains information on both the short- and long-run adjustment to changes in X_t, via the estimates of Γ_i and Π, respectively.

Parameter restriction tests on the cointegrating relationship between spot and FFA prices indicate that FFA prices one- and two-month prior to maturity are unbiased predictors of the realized spot prices in all investigated routes. However, the efficiency of the FFA prices three-month prior to maturity gives mixed evidence, with routes P2 and P2A being unbiased estimators and with routes P1 and P1A being biased estimators of the realized spot prices. Thus, it seems that unbiasedness depends on the market and type of contract under investigation. For the investigated routes and maturities for which unbiasedness holds, market agents can use the FFA prices as indicators of the future course of spot prices, in order to guide their physical market decisions. In accordance with the above results it was mentioned earlier that BIFFEX contract prices one, two, and three-months from maturity provide unbiased forecasts of the realized spot prices.

Kavussanos and Visvikis [22] investigate also the lead–lag relationship between forward and spot markets, both in terms of returns and volatility. This takes account of the second dimension of the price discovery role of derivatives markets; that is, volatilities of rates and prices. By using a VECM model (similar to that of equation 7), to investigate the short-run dynamics and the price movements in the two markets, causality tests and impulse response analysis indicate that there is a bi-directional causal relationship between spot and FFA prices in all routes, implying that FFA prices can be equally important sources of information as spot prices are. However, the results, from further tests on the unrestricted VECM models, suggest that causality from FFA (spot) to spot (FFA) returns is stronger than in the other direction on routes P1 and P2A (on routes P1A and P2). In order to investigate for volatility spillovers between the spot and FFA markets, an extended bivariate VECM-generalized autoregressive conditional heteroskedasticity (GARCH) model is utilized, with the following Baba *et al.* [32] augmented positive definite parameterization:

$$\begin{aligned} H_t = {} & A'A + B'H_{t-1}B + C'\varepsilon_{t-1}\varepsilon'_{t-1}C + S1'u_{1,t-1}u'_{1,t-1}{}'S1 \\ & + S2'u_{2,t-1}u'_{2,t-1}{}'S2 + E'(z_{t-1})^2 E \end{aligned} \tag{8}$$

where, A is a $\mathbf{2} \times \mathbf{2}$ lower triangular matrix of coefficients, B and C are $\mathbf{2} \times \mathbf{2}$ diagonal coefficient matrices, with $\beta_{kk}^2 + \gamma_{kk}^2 < 1$, $k = 1, 2$ for stationarity, S1 and S2 are matrices, which contain parameters of spillover effects, $u_{1,t-1}$ and $u_{2,t-1}$ are matrices whose elements are lagged square error-terms ($u_{1,t-1}$ represents the volatility spillover effect from the spot to the derivatives market and $u_{2,t-1}$ represents the volatility spillover effect from the derivatives to the spot market), $(z_{t-1})^2$ is the lagged squared basis, and E is a $\mathbf{1} \times \mathbf{2}$ vector of coefficients of the lagged squared basis. In this diagonal representation, the conditional variances are a function of their own lagged values (old news), their own lagged error terms (new news), volatility spillover parameters, and a lagged squared basis parameter, while the conditional covariance is a function of lagged covariances and lagged cross products of the ε_t's.

The results indicate that the FFA market volatility spills information to the spot market volatility in route P1. In route P1A the results indicate no volatility spillovers in either market. In routes P2 and P2A there is a bi-directional relationship as each market transmits volatility to the other. The previous results, in routes P1 and P2A, indicate that informed agents are not indifferent between trading in the FFA or in the spot market, as new market information is disseminated in the FFA market before the spot market. Thus, it seems that FFA prices for those routes contain useful information about subsequent spot prices, beyond that already embedded in the current spot price, and therefore, can be used as price discovery vehicles, since such information may be used in decision making. More specifically, market agents who have collected and analysed new information, regarding the expected level of spot and forward prices in routes P1 and P2A, will prefer to trade in the forward market than in the spot market. Furthermore, the FFA contracts for routes P1, P2, and P2A contribute to the volatility of the relevant spot rate, and therefore, further support the notion of price discovery. These results are in line with the work reported in Kavussanos [10] who finds that there is a bi-directional causal relationship in returns between the BFI and BIFFEX prices, and that this relationship is stronger from BIFFEX to BFI prices.

3.4. *The risk management function of freight derivatives*

Kavussanos and Visvikis [23] investigate the risk management function of the FFA market. They examine the effectiveness of time-varying hedge ratios in reducing freight rate risk in the four aforementioned routes of the BPI. Comparison between the effectiveness of different hedge ratios is made by constructing portfolios implied by the computed ratios each week and then comparing the variance of the returns of these constructed (hedged) portfolios over the sample.

The traditional naïve strategy involves adopting a derivatives position equal in magnitude but opposite in sign to the spot position, i.e. an investor who is long in the spot market should sell the equivalent value of the derivative product today and buy the same value of the derivative back when he sells the spot. This strategy, as in all other derivative-based hedge strategies, assumes that derivatives and spot prices and their volatilities move closely together. Indeed, if proportionate price changes in one market exactly match those in the other market, then price risk is eliminated (it is said that there exists a perfect hedge). The portfolio explanation of hedging shows that the hedge ratio that minimizes the risk of the spot position is given by the ratio of the covariance (measuring co-movement) between spot and derivatives price changes over the variance (measuring volatility—spread) of derivatives price changes. The ratio is known as the minimum variance hedge ratio (MVHR). These hedge ratio strategies implicitly assume that the risk in spot and derivatives markets is constant over time. This assumption is too restrictive and contrasts sharply with the empirical evidence in different markets, which indicates that spot and derivatives prices are characterized by time-varying distributions. This in turn, implies that the MVHR should be time varying, reflecting the fact that as new information arrives in the market the information set used by decision makers is updated.

For each trading route, five different hedge ratios were considered: from the simple constant ordinary least squares (OLS), VECM, SURE-VECM to the more complex time-varying ones of VECM-GARCH and VECM-GARCH-X. The variance of the hedged portfolios is compared to the variance of the unhedged position. The greater the reduction in the unhedged variance, the better the hedging effectiveness. In- and out-of-sample tests indicate that, in voyage routes P1 and P2, the relationship between spot and FFA prices is quite stable and market agents can use simple first-difference regression models in order to obtain optimum hedge ratios. In contrast, on time-charter routes P1A and P2A, it seems that the arrival of new information affects the relationship between spot and FFA prices, and therefore, time-varying hedging models should be preferred. Also the hedging effectiveness varies from one freight market to the other. This is because freight prices, and consequently FFA quotes, are affected by different regional economic conditions. For the record, it should be mentioned that similar results hold for the BIFFEX contracts, as reported in Kavussanos [10]. Market agents can benefit from this result by developing appropriate hedge ratios for each route, thus controlling their freight rate risk more efficiently. Ship-owning companies with vessels operating worldwide or trading companies that transport commodities to different parts of the world can use FFA contracts to reduce their freight rate risk, since the variability of their cash-flows can be explained by the price fluctuations of spot routes.

Despite the mixed evidence provided in favour of the time-varying hedge ratios in the FFA market, and despite the fact that FFA contracts provide better hedging opportunities than the BIFFEX contract, the freight rate risk reduction across the four investigated routes is lower than that evidenced in other commodity and financial markets in the literature, such as those reported in Bera *et al.* [33] and in Koutmos and Pericli [34], among others. The low trading volume, the way that shipbrokers estimate their FFA quotes, and the lack of a cost-of-carry arbitrage relationship of storable assets that would keep spot and derivatives prices close together, may provide explanations of the finding that spot price fluctuations of the investigated trading routes are not accurately tracked by the FFA prices.

3.5. *The impact of freight derivatives trading on spot market price volatility*

Kavussanos *et al.* [35] investigate the impact of FFA trading and the activities of speculators on spot market price volatility of the four aforementioned routes of the BPI. They use a GARCH model of the GJR-GARCH type—see Glosten *et al.* [36]. This allows for the asymmetric impact of news (positive or negative) on volatility. Thus, the mean equation of the GJR-GARCH process can be defined as follows:

$$\Delta S_t = \varphi_0 + \sum_{i=1}^{p-1} \varphi_i \Delta S_{t-i} + \varepsilon_t; \qquad \varepsilon_t \sim IN(0, h_t) \tag{9}$$

where, S_t is the natural logarithm of spot prices, Δ is the first-difference operator and ε_t is the regression error term, which follows a conditional normal distribution with mean zero and time-varying covariance, h_t. The conditional variance of the process can be specified as follows:

$$h_t = a_0 + a_1 h_{t-1} + \beta_1 \varepsilon_{t-1}^2 + \gamma_1 \varepsilon_{t-1}^2 D_{t-1}^- \tag{10}$$

where, D_{t-1}^- is a dummy variable that takes the value of unity if the error is negative ($\varepsilon_{t-1} < 0$) and zero otherwise. When the coefficient of D_{t-1}^- is zero (i.e. $\gamma_1 = 0$), the model of equation (10) is the symmetric GARCH model. A negative shock ($D_{t-1}^- = 1$) can generate an asymmetric response on volatility, in comparison to a positive shock. When $\gamma_1 > 0$ ($\gamma_1 < 0$), the model produces a larger (smaller) response for a negative shock compared to a positive shock of equal magnitude.

The results suggest that the onset of FFA trading has had (i) a stabilizing impact on the spot price volatility of all investigated routes; (ii) an impact on the asymmetry of volatility (market dynamics) in routes P2 and P2A; and (iii) substantially improved the quality and speed of information flow for routes P1, P1A and P2. However, after including in the conditional variance equation other explanatory economic variables that may affect spot volatility, the results indicate that only in voyage routes P1 and P2 the reduction of volatility may be a direct consequence of FFA trading. The results do not present a clear answer as to whether reduction in spot volatility, in time-charter routes P1A and P2A, is a direct consequence of FFA trading.

These findings have implications for the way in which the FFA market is viewed. Contrary to the traditional view of derivatives trading and despite the route-specific nature of the FFA contracts, with the different economic and trading conditions of each route, the results indicate that the introduction of FFA contracts has not had a detrimental effect on the underlying spot market. On the contrary, it appears that there has been an improvement in the way that news is transmitted into prices following the onset of FFA trading. We can conjecture that by attracting more, and possibly better informed, participants into the market, FFA trading has assisted the incorporation of information into spot prices more quickly. Thus, even those market agents who do not directly use the FFA market have benefited from the introduction of FFA trading.

3.6. *The relationship between FFA bid–ask spreads and expected volatility*

Batchelor *et al.* [37] examine the relationship between expected volatility and bid–ask spreads in the FFA market, using the four aforementioned routes of the BPI. In order to derive an estimate of the FFA volatility, the following AR(p)-GARCH(1,1) model is employed:

$$\Delta F_t = \varphi_0 + \sum_{i=1}^{p-1} \varphi_i \Delta F_{t-i} + \varepsilon_t; \qquad \varepsilon_t \sim \mathrm{iid}(0, h_t) \tag{11a}$$

$$h_t = a_0 + a_1 h_{t-1} + \beta_1 \varepsilon_{t-1}^2 \tag{11b}$$

where, F_t is the natural logarithm of FFA prices (average mid-point of the bid–ask quotes), Δ is the first-difference operator, and ε_t are the residuals that follow a normal distribution with mean zero and time-varying variance, h_t.

After ensuring that the model is well specified, they construct one-step ahead conditional volatility estimates (h_{t+1}). To analyse the relationship between expected volatility and current BAS_t (bid–ask spread), the BASs are regressed against variables that represent risk, information and a lagged BAS:

$$\mathrm{BAS}_t = \beta_0 + \beta_1 h_{t+1} + \beta_2 \mathrm{BAS}_{t-1} + \beta_3 \Delta F_t + u_t; \qquad u_t \sim \mathrm{iid}(0, h_t) \tag{12}$$

where, risk is defined as the one-step ahead conditional volatility (h_{t+1}) from a GARCH(1,1) model, information effects are accounted for by the logarithmic first-difference of the FFA price series (ΔF_t) and BAS_t is defined as the difference of the natural logarithm of the ask quote minus the natural logarithm of the bid quote. The model is estimated via the generalized method of moments (GMM), avoiding thus any simultaneity bias and yielding heteroskedasticity and autocorrelation consistent estimates.

The results indicate that there is a positive relationship between bid–ask spreads and expected price volatility for routes P1, P2, and P2A, after controlling for other factors. In contrast, on route P1A they do not observe a significant relationship between bid–ask spreads and expected volatility. This finding may be explained by the thin trading of FFA contracts for the latter route. These results provide a better understanding of the movements of FFA prices, and the consequent effect on transactions costs. Market agents using information on the behaviour of bid–ask spreads have a better insight into the timing of their FFA transactions and the future direction of the FFA market, as a widening bid–ask spread corresponds to an anticipation of increased future volatility. More specifically, traders, speculators, hedgers and arbitrageurs alike are interested in extracting information from these variables to know how their reaction to new information can be used in predicting future prices.

3.7. *Forward freight rate dynamics*

Koekebakker and Adland [38] investigate the forward freight rate dynamics by modelling them under a term-structure model. They transform time-charter rates into average based forward freight rates. They then assume that there exists a continuous forward freight rate function that correctly prices the average based forward freight rate contracts. For their analysis, they use time-charter rates for a Panamax 65,000 dwt vessel under three different time-charter maturities; six months, one year and three years. These data are then used to construct, each day, a forward rate function using a smoothing algorithm in order to investigate the factors governing the dynamics of the forward freight rate curve.

Results show that the volatility of the forward curve is bumped, with volatility reaching a peak for freight rates with roughly one year to maturity. Moreover, correlations between different parts of the term structure are in general low and even negative. They conclude that these results are not found in other markets. The authors argue that such a forward freight rate model provides a tool to perform freight rate derivatives valuation and hedging. However, as they argue the empirical results of their study must be interpreted with care, since building a term structure based on only three time-charter maturities is somewhat limited and further research in needed to establish more reliable results.

3.8. *Pricing of freight options*

Tvedt [11] derives an analytical pricing formula for European options on BIFFEX, recognizing the special features related to the freight rate market. Two main characteristics make his formula different from the futures option formula of Black [39]. Due to the possible lay-up of vessels, the BFI is never close to zero. Therefore, it is assumed that the BFI, and also the futures price process, are restricted downwards by an absorbing level above zero. Second, it is assumed that freight rates are mean reverting, due to frictional capacity adjustments to changes in the demand for shipping services. These properties influence the valuation of the options on BIFFEX.

Let λ denote an absorbing level for the BFI process that would be the lay-up level for vessels. Assuming that the BFI less the absorbing level λ is log-normally distributed, the increment of the index is given by the following mean reversion process:

$$dX_t = k[a - \ln(X_t - \lambda)](X_t - \lambda)d_t + \sigma(X_t - \lambda)dZ_t \tag{13}$$

where, X_t is the index value (BFI) at time t, dZ_t is the increment of a standard Brownian motion, and k, a and σ are constants. Generally, the futures price at time t (Φ_t) is the expected value at time t of the spot price at the time of settlement T. Following Black [39], in the case of no risk premium from investing in the futures market, it is argued that the futures price process is given by the expectation of the spot process at the time of settlement. Therefore, the futures price process is given by:

$$d\Phi_t = e^{-k(T-t)}\sigma(\Phi_t - \lambda)dZ_t \tag{14}$$

where, the weight $e^{-k(T-t)}$ determines the degree by which the volatility in the spot rate (the BFI) is transferred over to the futures price process. In many storable financial futures markets it has been observed that the volatility of the futures price process increases as the contract approaches the settlement date, due to mean reversion in spot prices, which is consistent with a no-arbitrage cost-of-carry argument. Tvedt [11] argues that since BFI is an index of prices of shipping services, and since a service cannot be stored, the cost-of-carry argument does not apply. Consequently, he argues that mean reversion in prices can prevail without being smoothed out by storage and can be explained without referring to changes in inventory costs.

The present value of a European call option on a BIFFEX futures at time t is given by the expectation of the value of the option at settlement date (C_T):

$$C_T = e^{r(T-t)} E[(\Phi_t - \psi)\chi_A] \tag{15}$$

where, r is a constant risk-free interest rate, χ_A is the indicator function of the event A (that is, the option is only exercised when it is favourable for the option holder) and ψ is the strike price. Black [39] offers a solution to equation (15) in the case that the underlying futures process follows a geometric Brownian motion. Calculating equation (15), using traditional arbitrage arguments and assuming no transactions costs or taxes, the value of a European option on a futures contract in the BIFFEX market is given by:

$$C_T = e^{-r(T-t)}[(\Phi_t - \lambda)N(d_1) - (\psi - \lambda)N(d_2)] \tag{16}$$

where:

$$d_1 = \frac{\ln(\Phi_t - \lambda/\psi - \lambda) + \left[1/2e^{-2k(T-t)}\sigma^2(T-t)\right]}{e^{-k(T-t)}\sigma\sqrt{T-t}},$$

$$d_2 = \frac{\ln(\Phi_t - \lambda/\psi - \lambda) - \left[1/2e^{-2k(T-t)}\sigma^2(T-t)\right]}{e^{-k(T-t)}\sigma\sqrt{T-t}}$$

Koekebakker *et al.* [40] propose a mathematical framework for Asian freight options modelling, which is basically an extension of the framework put forward in Black [39]. Under this theoretical framework the spot freight rate at time t, which is a non-traded asset, is denoted $S(t)$. A future arithmetic average of S consists of N fixings at time points $T_1 < T_2 < \cdots < T_N$. An FFA contract with a price $F(t, T_1, T_N)$ can be interpreted as the price set today at time t to deliver at time T_N the value of the arithmetic average of the underlying spot freight rate during the period $[T_1, T_N]$. Moreover, an FFA is a cash-settled contract that gives the difference between this average and the price $F(t, T_1, T_N)$ multiplied by a constant D. The constant D refers to the number of calendar days covered by the FFA contract or an agreed cargo size for time-charter routes and voyage route, respectively. The value of an FFA can be found by discounting this cash-flow received at time T_N and taking the conditional expectation under the pricing measure Q. Rearranging and solving for the FFA price, it is simply the expected average spot price under the pricing measure:

$$F(t,T_1,T_N) = \frac{1}{N}\sum_{i=1}^{N} E^Q[S(T_i)] \tag{17}$$

It is argued that FFAs are lognormal prior to the settlement period, but this lognormality breaks down in the settlement period. They suggest an approximate dynamics structure in the settlement period for the FFA, leading to closed-form option pricing formulas for Asian call and put options written on the spot freight rate indices in the Black [39] framework. They argue that standard arbitrage arguments can be applied, which imply that the price at time T_N for the average asset price during this interval is equal to the realized average. However, this seems to be in contrast with the analysis by Tvedt [11] and Kavussanos and Visvikis [22] for instance, who recognize that the freight service is a non-storable commodity, and as a consequence standard arbitrage arguments do not apply. Using equation (17), the payoff of a call Asian option with strike price K and maturity $T \leq T_N$ is then derived as:

$$D\left[\frac{1}{N}\sum_{i=1}^{N} S(T_i) - K\right]^{+} = D[F(T, T_1, T_N) - K]^{+} \tag{18}$$

and for a put:

$$D\left[K - \frac{1}{N}\sum_{i=1}^{N} S(T_i)\right]^{+} = D[K - F(T, T_1, T_N)]^{+} \tag{19}$$

Given that the freight options relate to periods that are non-overlapping multiples of the monthly settlement period they are caps and floors. Thus, the price at time $t < T_N$ for a call option is derived as:

$$C(t, T_N) = e^{-r(T_N - t)} D(F(t, T_1, T_N)N(d_1) - KN(d_2)) \tag{20}$$

where:

$d_1 = (\ln(F(t, T_1, T_N)/K) + 1/2\sigma_F^2)/\sigma_F$, $d_2 = d_1 - \sigma_F$, and $N(\mathrm{d}_i)$, $i = 1, 2$, is the standard cumulative normal distribution function.

For the put option the put–call parity for futures contracts is used and the symmetry property of the normal distribution to derive:

$$P(t,T_N) = e^{-r(T_N - t)} D(KN(-d_2) - F(t,T_1,T_N)N(-d_1)) \tag{21}$$

4. Conclusion

This survey has reviewed the developments in freight rate risk management through freight derivatives products. They were introduced in 1985 through freight futures contracts, namely BIFFEX, trading on a basket of freight routes, namely on the BFI. Options were also written on the BFI but both stopped trading in April 2002. In 1992, FFAs provided the alternative OTC, more flexible, tailor-made derivatives tool and have since grown in popularity. According to Clarkson Securities, there are now in excess of 200 players in the market with more than 8,000 deals taking place each year. IMAREX was established in 2000 offering yet more choice of freight derivatives contracts for risk management purposes to market participants. It has provided the trading platform for both FFAs, freight futures and lately options contracts on routes and baskets of routes of the Baltic freight indices. NYMEX and LCH.Clearnet have increased further the choices for interested parties, while announcements have been made about the entry of other market-makers and players in the area of freight derivatives.

According to IMAREX, the shipping derivatives market more than doubled to $8 billion in the first six months of 2004, as banks, ship-owners, oil producers and mining companies sought to profit from record freight rates. Moreover, FFA trading, which is tied to the transport costs of commodities such as oil, coal and iron ore, rose in value to around $17 billion by the end of 2004. For the first time ever, this meant that the value of FFA trading surpassed the turnover of actual freight transactions. This is a sign of maturity for this market, which however still has to reach the several times multiple of the underlying market, as is the case in other more mature derivatives markets.

The high volatility of freight rates in the shipping industry is proving particularly attractive to non-shipping players looking to become involved in shipping markets, without physically exposing themselves to operating the assets—the vessels. Some brokers are reporting that freight derivatives have recently been turning over as much in a month as they used to in a year. As the shipping market becomes more familiar with hedging and risk management techniques, it seems very likely that both ship-owners and charterers will increasingly see a need to safeguard profits against volatile freight market movements. However, caution should be exercised in using freight derivatives, as the sums involved are large and overexposure has lead to spectacular failures in the past. On the research front, no doubt there is room for a considerable amount of research to be carried, and this paper can provide the basis upon which to step and continue.

References and notes

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2. The contract size depends on the vessel type and the route for the voyage-based contracts (around 54,000 tons for a Panamax and 150,000 tons for a Capesize), while for the time-charter-based contracts the contract size is one vessel.
3. Several empirical studies have examined the economic functions of the BIFFEX contract: Cullinane [4] investigates the predictive power of short-term forecasts of the BFI by the use of the BIFFEX contract; Chang and Chang [5] examine the predictability of BIFFEX with respect to the dry-bulk shipping market; Thuong and Visscher [6], Haralambides [7, 8], Haigh and Holt [9], and Kavussanos [10] present studies that have examined the risk management function, through hedging, of the BIFFEX contract; Tvedt [11] derives a pricing formula for European futures options in the BIFFEX market; Kavussanos and Nomikos [12] and Haigh [13] examine the unbiasedness hypothesis in the BIFFEX market using cointegration techniques; Haigh and Holt [14] estimate foreign exchange hedging ratios alongside freight and commodity ratios in a time-varying portfolio framework.
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19. Kavussanos, M. G. and Visvikis, I. D., 2003, FFAs can stabilize revenue. *Lloyd's Shipping Economist (LSE)*, July.
20. European options contracts can only be exercised on the expiry date of the contract. On the other hand, American-type options contracts can be exercised at any time up to their expiry.
21. An Asian option is an option that is exercised against an average over a period of time. Asian options are often used in thinly traded commodity markets to avoid problems with price manipulation of the underlying commodity near or at maturity.
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