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Statistical arbitrage in the freight options market

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ABSTRACT
We investigate whether there are consistent misspecifications of volatility in the freight options markets that can be exploited in profitable trading strategies. We derive smooth forward freight rate curves from observed market prices and convert these to term structures of historical volatility for the Capesize, Panamax and Supramax segments of the drybulk shipping market. The differences between the historical and implied volatility term structures form the basis for executing option trading strategies. We find that there exist statistical arbitrage profits in the freight option markets, suggesting a degree of market inefficiency.

KEYWORDS
Freight options; forward freight agreements; dry bulk; volatility term structure; volatility trading

1. Introduction

The launch of freight futures trading on the Baltic International Freight Futures Exchange (BIFFEX) in 1985 enabled shipowners, charterers, and investors to hedge or speculate on future spot freight rates. The future contract ceased trading in 2002, having gradually been replaced by an over-the-counter (OTC) market for Forward Freight Agreements (FFAs) since 1992 (Kavussanos and Nomikos 2003). FFAs were designed as Contracts-for-difference on the freight rate for a specified quantity of cargo or type of vessel for a specific route or basket of routes (Alexandridis et al. 2018).

Freight options are Asian-style options where the payoff at settlement depends on the arithmetic average spot freight rate over a calendar month, or basket of months (see, Koekebakker, Adland, and Sødal (2007), for a detailed discussion of freight option features). The averaging approach makes the options less susceptible to potential manipulation of the underlying prices in a thinly traded market (Nomikos et al. 2013) and is an attractive feature for 'consumers' of freight, who demand a continuous flow of a transportation service (Koekebakker, Adland, and Sødal 2007).

In practice, freight options are priced based the assumption of log-normal spot freight rate distributions (Koekebakker, Adland, and Sødal 2007). Conditional on a particular option pricing model, the market's expectation of future spot freight volatility can be derived from quoted options prices, resulting in the term structure of 'implied volatility'. The implied volatility term structure describes the expected volatility of the underlying forward freight rates for the traded range of option maturities. While the level of implied volatility is ultimately a result of supply and demand for freight options with a particular maturity, the term structure of implied volatility should, on average, reflect the dynamics of the underlying term structure of forward freight rates. If there are consistent differences between the two (i.e. backward-looking historical volatility and forward-looking implied volatility) then this could be a sign of mispricing in the freight option market that

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could potentially be exploited economically. It is important to note here that such differences would not represent an arbitrage opportunity in the pure sense (i.e. a riskless, certain profit), but rather statistical arbitrage opportunities (an expected profit over time).

The objective of this paper is to study whether discrepancies between the implied and historical volatility term structure of freight rates can be exploited using volatility trading strategies that aim to take advantage of temporal changes in volatility (both within and across instruments and markets). Aside from being the first academic work on volatility trading in the freight option market, an additional contribution is to expand the literature on freight market efficiency to the freight options market. Our findings are of direct and practical relevance to any traders and companies that consider entering the freight derivative market.

The remainder of this paper is structured as follows: Section 2 provides a review of related literature. Section 3 describes the data. Section 4 presents the theoretical framework of our approach. Section 5 estimates the historical volatility structure. Section 6 covers trading strategies, and Section 7 concludes.

2. Literature review

The academic literature on freight derivatives has focussed on the different aspects of market efficiency, initially in the BIFFEX freight futures market and later in the OTC FFA market. Kavussanos and Nomikos (1999, 2003) and Kavussanos, Visvikis, and Menachof (2004) utilized cointegration techniques to explore whether freight futures and FFA prices were unbiased estimates of future realized spot freight rates. They found that the unbiasedness hypothesis holds for maturities up to two months. Similarly, Alizadeh, Ådland, and Koekebakker (2007) find that implied forward time charter rates are unbiased estimates of future spot rates.

The hedging effectiveness of the original freight futures was investigated by Kavussanos and Nomikos (2000a,2000b,2000c). In the FFA market, Kavussanos and Visvikis (2004) compare the hedging performance of time-varying and constant hedge ratios in the Capesize segment. Out-of-sample tests lead to the conclusion that the highest variance reduction is achieved by matching freight rate exposure with forward contracts of equal size. The interaction between the spot and the forward markets has also been subject to much research. Kavussanos and Visvikis (2004) explore the lead-lag relationship between forward and spot freight markets and find that, despite the non-storable nature of freight, FFA prices are important factors in the price discovery of spot prices. Li et al. (2014) investigate spillover effects between spot and FFA prices and find evidence of unilateral spillovers from one-month FFA returns to spot rate returns and a bilateral spillover effect between the one and two-month ahead FFA markets. Additionally, they find bilateral volatility spillover effects between spot and FFA markets. Alexandridis, Sahoo, and Visvikis (2017) extend the research of spillover effects by including freight options when they examine the interaction between freight futures, time charter rates, and freight options. Their study concludes that there is significant information transmission in both volatility and returns between the markets. Interestingly, they find that freight options lag behind freight futures and physical freight rates, a result they assign to the lower liquidity in the options market.

The freight option literature started with Tvedt (1998), who proposed a pricing model for the then-existing European options in the BIFFEX market. More relevant to current markets, Koekebakker, Adland, and Sødal (2007) derive an analytical pricing formula for Asian type freight options by approximating the FFA rate dynamics as a log-normal process. Nomikos et al. (2013) suggest that the risk-adjusted spot freight rates should follow a jump-diffusion model as an improvement to the pricing of freight options. This jump-diffusion pricing formula is then extended by Kyriakou et al. (2017), who incorporate the mean-reverting property of freight rates. The extension of the log-normal assumption of the freight rate returns to include mean reversion is shown to provide significantly lower errors in the pricing of the options.

The pricing of options is highly dependent on reliable estimates of the volatility structure of the underlying asset. Koekebakker and Ådland (2004) investigate the dynamics of the term structure of forward rates in the physical timecharter market and find a 'strange volatility structure' in the data, with volatility reaching a peak for forward freight rates with roughly one year to maturity and low or even negative correlations between different parts of the term structure. Alizadeh and Nomikos (2011) apply augmented EGARCH models and concludes that the volatility of freight rates is affected by the shape of the term structure, in particular, that volatility is higher when the market is in backwardation compared to when it is in contango. Lim, Nomikos, and Yap (2019) investigate the fundamental drivers of volatility in the freight market using panel regression. Their findings indicate that expectations of general economic growth and increasing spot freight rates reduce implied volatility, a result that supports the notion of a leverage effect in freight rates. Another interesting finding is that the slope of the implied volatility curve follows that of the forward curve, meaning that generally, when the slope of the forward curve gets steeper—so will the slope of the implied volatility curve.

While there have been successful attempts to demonstrate profitable trading strategies in the physical chartering market (Adland and Strandenes 2006) and the FFA market (Nomikos and Doctor 2013), to our knowledge, there are no published studies on the profitability of volatility trading in the freight derivative market. The contribution of this paper is therefore be to fill this gap in the academic literature. We first derive a historical volatility structure from observed FFA prices. With the assumption that the historical volatility estimate is an accurate representation of future volatility we then investigate if there is mispricing in the options market that can be exploited by applying option strategies.

3. Data

3.1. Market structure and data sources

Both FFAs and freight options are settled against the monthly average of daily spot freight rate indices provided by the Baltic Exchange.[1] The daily indices represent the average of rate estimates submitted by panels of expert shipbrokers for each route and vessel size. The Baltic Exchange also reports the daily closing prices for all traded FFA contracts and implied volatilities for the freight options used herein. We use LIBOR as the risk-free rate.

Freight derivative contracts are traded in a decentralized OTC market where the matching of buyers and sellers is arranged by specialised FFA brokers through the use of telephone, electronic chat applications and web-based trading screens. Market participants range from shipowners and cargo owners to hedge funds, investment banks and exchange-traded funds, many of which take speculative positions. Once a trade has been executed, it is handed over to a clearing house (SGX or EEX), after which every position is marked-to-market daily as if it was an exchange-traded futures contract. The use of clearing houses effectively removes the counterparty risk, though liquidity risk (i.e. the ability to execute a trade quickly, in the desired volume, and with limited price impact) remains (Alizadeh et al. 2015).

During our sample period, liquidity in the drybulk FFA market has been concentrated in contracts settled against the weighted average trip charter rates for three vessel sizes: *C5TC*—the Capesize time charter average of five routes, *P4TC*—the Panamax time charter average of four routes, and *S6TC*—the Supramax time charter average of six routes. With regard to maturity, quarterly contracts are perceived to be the most liquid (Alizadeh et al. 2015). According to Baltic Exchange trading data for 2018, freight options volumes were heavily focused on the larger vessel sizes, with 68% and 31% of drybulk options in the Capesize and Panamax segment, respectively.

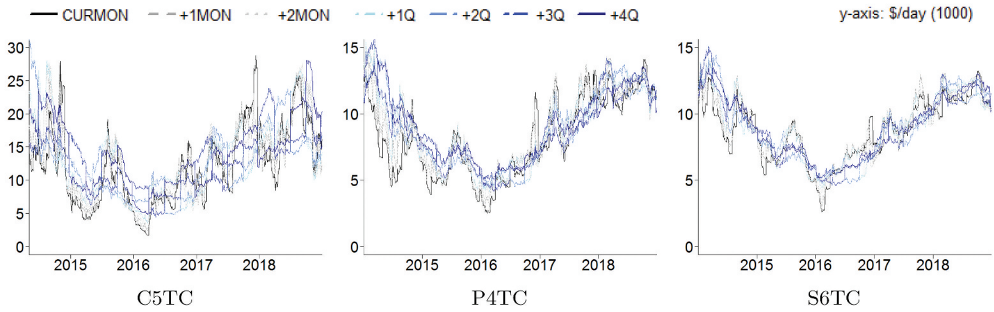

Figure 1. Forward freight agreements.

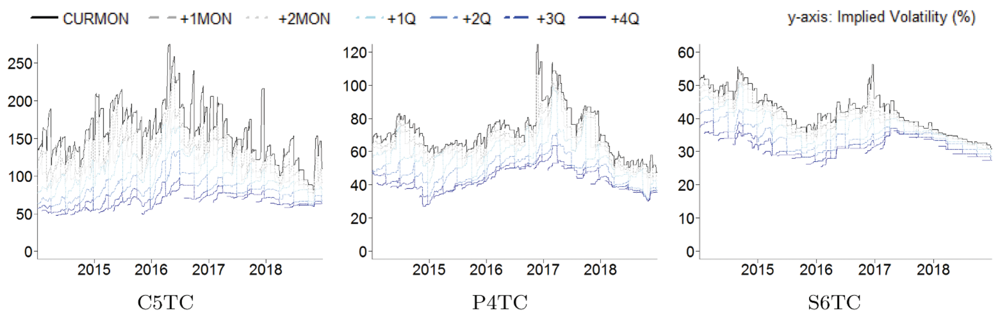

Figure 2. Volatility implied from options prices.

3.2. Descriptive statistics

Time series of FFA prices, as illustrated in Figure 1, suggest that volatility is decreasing with time to maturity.[2] Short-term contracts tend to fluctuate around the levels of the longer-term contracts, and they are higher (a downward-sloping term structure) in strong markets and lower (an upward-sloping term structure) when markets are low. This observation is in line with the notion that freight rates are mean-reverting due to the ability of supply to adapt to changes in demand for transportation through newbuilding and scrapping (Koekebakker, Adland, and Sødal 2006).

The timeseries of implied volatility shown in Figure 2 reflect the expected volatility of the underlying until contract maturity. The volatility is decreasing with time to maturity across all three vessel sizes—a trait that is shared with storable commodities and termed the Samuelson-effect.

Table 1 shows the descriptive statistics for the various contract maturities in our sample. We see that average returns are 0% for all contracts and vessel sizes, while the standard deviation is decreasing with vessel size and with time to maturity. However, we have to be careful to interpret this as proof of volatility decreasing with maturity. If the underlying freight rate follows a mean reverting stochastic process, the volatility of the average of this process over some period will be less volatile than the freight rates themselves. Thus, if we increase the averaging period, the volatility of the average-based contracts will be reduced as well (Koekebakker and Ådland 2004).

Table 1. Descriptive statistics for FFAs—data in log-differences.

	CURMON	+1MON	+2MON	+1Q	+2Q	+3Q	+4Q
C5TC obs.	1177	1177	1177	1177	1177	1177	1177
mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00
std. dev	0.07	0.07	0.06	0.06	0.05	0.04	0.04
median	0.00	0.00	0.00	0.00	0.00	0.00	0.00
min	−0.55	−0.52	−0.48	−0.68	−0.68	−0.58	−0.55
max	0.65	0.35	0.26	0.55	0.35	0.43	0.36
skew	1.51	0.13	−1.30	−2.22	−5.46	−1.39	−2.48
kurtosis	24.37	4.96	14.28	50.87	81.85	62.63	72.83
P4TC obs.	1262	1262	1262	1262	1262	1262	1262
mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00
std. dev	0.04	0.04	0.03	0.03	0.02	0.02	0.02
median	0.00	0.00	0.00	0.00	0.00	0.00	0.00
min	−0.47	−0.22	−0.22	−0.26	−0.22	−0.21	−0.14
max	0.36	0.37	0.29	0.42	0.23	0.27	0.24
skew	1.27	1.58	0.45	1.51	−0.17	0.29	3.09
kurtosis	39.56	10.99	10.24	39.63	23.24	40.51	43.27
S6TC obs.	1262	1262	1262	1262	1262	1262	1262
mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00
std. dev	0.03	0.02	0.02	0.02	0.02	0.02	0.01
median	0.00	0.00	0.00	0.00	0.00	0.00	0.00
min	−0.25	−0.20	−0.30	−0.33	−0.28	−0.18	−0.12
max	0.34	0.16	0.19	0.20	0.19	0.19	0.12
skew	2.86	−0.16	−1.29	−3.43	−3.04	0.43	0.96
kurtosis	46.40	10.60	29.98	57.97	56.91	46.50	25.28

4. Theoretical framework

4.1. The forward freight rate function

We model forward freight rate dynamics directly in the framework developed by Heath, Jarrow, and Morton (1992). Consider a market where the uncertainty can be described by a Wiener process, W, defined on an underlying probability space $(\mathbf{\Omega}, \mathbf{F}, \mathbf{Q})$, with the filtration $\mathbf{F} = \{F_t \in [0, T^*]\}$ satisfying the usual conditions and representing the disclosure of market information. The probability measure Q represents the risk-adjusted pricing measure. See Duffie (1996) for technical details on the Brownian motion and related definitions.

Let the forward freight market be represented by a continuous forward price function, where $f(t, T_N)$ denotes the forward price at date t for the spot rate upon maturity at time T_N, where $t < T_N < T^*$. Given constant interest rates, it can be shown that forward prices are by construction martingales under Q. We model the dynamics of the forward freight rate in line with Koekebakker and Ådland (2004), where

$$\frac{df(t, T_N)}{f(t, T_N)} = \sum_{i=1}^{K} \sigma_i(t, T_N) dW_i(t), \quad t \le T_N \tag{1}$$

with the solution

$$f(t, T_N) = f(0, T_N) exp\left(\frac{-1}{2} \sum_{i=1}^{K} \int_0^t \sigma_i(s, T_N)^2 ds + \sum_{i=1}^{K} \int_0^t \sigma_i(s, T_N) dW_i(s)\right) \tag{2}$$

and the distribution of the natural log of the forward price is given by

$$lnf(t, T_N) \sim \mathcal{N}\left(lnf(0, T_N) \frac{-1}{2} \sum_{i=1}^{K} \int_0^t \sigma_i(s, T_N)^2 ds, \quad \sum_{i=1}^{K} \int_0^t \sigma_i(s, T_N)^2 ds\right) \tag{3}$$

$\mathcal{N}(s, v)$ denotes a normally distributed variable with mean s and variance v.

By the definition of the forward rate, we can describe the spot freight rate as

$$S(t) = f(t,t) = \lim_{T_N \to t} f(t, T_N) \qquad t \in [0, T^*] \tag{4}$$

which implies that the forward freight rate converges to the spot rate, in the limit.

Let $F(t, T_1, T_N)$ be the FFA price at time t for the duration $[T_1, T_N]$, where T_1 and T_N are the first and last day of the averaging period, respectively. When $R(t, T_N)$ is the value at t of entering into a forward freight contract, the profit/loss of the contract at T_N will be the difference between the agreed FFA price and the average spot freight rate over the period $[T_1, T_N]$. At maturity, the profit/loss can be formulated as

$$R(T_N, T_N) = \frac{1}{T_N - T_1} \int_t^{T_N} e^{-r(u-t)} (f(u,u) - F(t, T_1, T_N)) du \tag{5}$$

As the forward price is set to be the expectation of future spot rates, the initial value of the contract must be zero under Q. Thus, as shown by Koekebakker and Ådland (2004)

$$0 = E_t^Q \left[\frac{1}{T_N - T_1} \int_{T_1}^{T_N} e^{-r(u-t)} (f(u,u) - F(t, T_1, T_N)) du \right] \tag{6}$$

$$0 = E_t^Q \left[\frac{1}{T_N - T_1} \int_{T_1}^{T_N} e^{-r(u-t)} f(u,u) du \right] - \frac{F(t, T_1, T_N)}{T_N - t} \int_{T_1}^{T_N} e^{-r(u-t)} du \tag{7}$$

$$0 = \frac{1}{T_N - T_1} \int_{T_1}^{T_N} e^{-r(u-t)} f(t,u) du - \frac{F(t, T_1, T_N)}{T_N - t} \int_{T_1}^{T_N} e^{-r(u-t)} du \tag{8}$$

which can be rearranged to

$$F(t, T_1, T_N) = \int_{T_1}^{T_N} w(u; r) f(t,u) du \tag{9}$$

where

$$w(u; r) = \frac{e^{-ru}}{\int_{T_1}^{T_N} e^{-ru} du} \tag{10}$$

As noted by Lucia and Schwartz (Lucia and Schwartz 2002), $1/(T_N - t)$ is a good approximation for $e^{-ru} / \int_t^{T_N} e^{-ru} du$ for reasonable levels of the interest rate.

4.2. Freight rate options

From equation 9, we can interpret the FFA contract $F(t, T_1, T_N)$ as today's t price for the average spot freight rate in the period $[T_1, T_N]$ at date T_N. As noted by Koekebakker, Adland, and Sødal (2007), this implies that we can value an Asian option on the spot freight rate as a European option on the forward contract. By the law of one price, we can argue that the price of the forward contract at T_N equals the price of the underlying in the corresponding period. Thus, the payoff for an Asian call option at T_N with strike K and maturity T_N can be formulated as

$$D \times max[F(T_N, T_1, T_N) - K, 0] \tag{11}$$

similarly, a put option can be formulated as

$$D \times max[K - F(T_N, T_1, T_N), 0] \tag{12}$$

where D denotes the number of days the FFA contract covers.

The value of a contingent claim can be expressed as the expected payoff at maturity under Q discounted by the risk-free rate. The value at time t of the Asian call and put option, with maturity T_N can be written as

$$C(t, T_N) = e^{-r(T_N - t)} D \times E_t^Q[max[F(t, T_1, T_N) - K, 0]] \tag{13}$$

and

$$P(t, T_N) = e^{-r(T_N - t)} D \times E_t^Q[max[K - F(t, T_1, T_N), 0]] \tag{14}$$

Applying the Black-Scholes framework on the above Asian option we can, as shown by Koekebakker, Adland, and Sødal (2007), formulate the price at time t for the call option as

$$C(t, T_N) = e^{-r(T_N - t)} D(F(t, T_1, T_N)N(d_1) - KN(d_2)) \tag{15}$$

where

$$d_1 = \frac{ln\left(\frac{F(t,T_1,T_N)}{K}\right) + \frac{1}{2}\sigma_F^2}{\sigma_F}, \quad d_2 = d_1 - \sigma_F \tag{16}$$

and where σ_F is the volatility of the forward contract, and $N(x)$ is the cumulative normal distribution function. Applying the put-call parity, we can derive the price of the put as

$$P(t, T_N) = e^{-r(T_N - t)} D(KN(-d_2) - F(t, T_1, T_N)N(-d_1)) \tag{17}$$

We price the Asian option on spot freight rates as a European option on the FFA. However, our data on freight options are quoted by the implied volatility of an Asian style option on the spot freight rate. Therefore, in order to get a meaningful comparison between the two, we have to establish a linkage between the two volatility measures. As described by Koekebakker, Adland, and Sødal (2007) we can define the volatility of FFA contracts as a function of the volatility of the spot rate and the time specifications of the FFA contract

$$\sigma_F^2 = (T_1 - t)\sigma^2 + \frac{1}{3}(T_N - T_1) \tag{18}$$

where the $1/3$-term is a result of continuous settlement.

5. Methodology

5.1. Smoothing of the forward freight rate curve

To derive the volatility structure of the forward freight rate function, we first compute a continuous forward price function from each day's FFA price curve. The smoothing procedure is based on the principle of maximum smoothness suggested by Van Deventer (Adams and Van Deventer 1994). The smoothness criterion for the forward rate function minimizes the functional

$$min \int_0^T f''(t, s)^2 ds \tag{19}$$

while simultaneously fitting the observed market prices. Here, f(t,s), denotes the forward freight rate at time t with maturity at time s.

To find the parameters of the spline function

$$x^T = [a_1, b_1, c_1, d_1, e_1, a_2, b_2, c_2, d_2, e_2, \ldots, a_n, b_n, c_n, d_n, e_n] \tag{20}$$

we solve the linear equation

$$\begin{bmatrix} 2H & A^T \\ A & 0 \end{bmatrix} \begin{bmatrix} x \\ \lambda \end{bmatrix} = \begin{bmatrix} 0 \\ b \end{bmatrix} \tag{21}$$

where A is the constraint matrix ensuring connectivity and smoothness of derivatives at the knots, j = 1, . . ., n-1

$$(a_{j+1} - a_j)t_j^4 + (b_{j+1} - b_j)t_j^3 + (c_{j+1} - c_j)t_j^2 + (d_{j+1} - d_j)t_j + e_{j+1} - e_j = 0 \tag{22}$$

$$4(a_{j+1} - a_j)t_j^3 + 3(b_{j+1} - b_j)t_j^2 + 2(c_{j+1} - c_j)t_j + d_{j+1} - d_j = 0 \tag{23}$$

$$12(a_{j+1} - a_j)t_j^2 + 6(b_{j+1} - b_j)t_j + 2(c_{j+1} - c_j) = 0 \tag{24}$$

$$\int_{T_i^s}^{T_i^e} a_i t_i^4 + b_i t_i^3 + c_i t_i^2 + d_i t_i + e_i = FFA_i * (T_i^e - T_i^s), \quad i = 1, \ldots, n \tag{25}$$

and the boundary condition

$$f'(t_n) = 4a_n^3 + 3b_n^2 + 2c_n + d_n = 0 \tag{26}$$

making the forward rate curve flat at the long end, a common assumption in financial modeling (Van Deventer, Imai, and Mesler 2013).

For H we have

$$H = \begin{bmatrix} h_1 & & \\ & \ddots & \\ & & h_n \end{bmatrix}, h_j = \begin{bmatrix} 144/5\Delta_j^5 & 18\Delta_j^4 & 8\Delta_j^3 & 0 & 0 \\ 18\Delta_j^4 & 12\Delta_j^3 & 6\Delta_j^2 & 0 & 0 \\ 8\Delta_j^3 & 6\Delta_j^2 & 4\Delta_j^1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

and

$$\Delta_j^l = t_{j+1}^l - t_j^l, \quad l = 1, \ldots, 5$$

The solution $[x^\star, \lambda^\star]$ is found through QR factorization.

We compute smooth forward freight curves for each of the N days in our sample period. Every day, seven contracts are used; *CURMON, +1MON, +2MON, +1Q, +2Q, +3Q* and *+4Q*. Hence, our forward curve includes FFA prices up to 15 months into the future.

5.2. Deriving the volatility structure

Equation (2) describes the stochastic evolution under an equivalent martingale measure (Q), and not under the real-world measure where observations are made (P). However, from Girsanov's Theorem, we know that the diffusion term remains equal under the two probability measures. This enables us to estimate the volatility function from equation 2 from real-world data, though this is only strictly correct when observations are sampled continuously (Cortazar and Schwartz 1994) and only an approximation for our daily sampling. From our continuous forward freight functions, we construct a data set of *forward freight rates* with weekly maturities $T_1, \ldots, T_m$, which are converted to a set of $X_{(N \times M)}$ forward freight rate returns according to

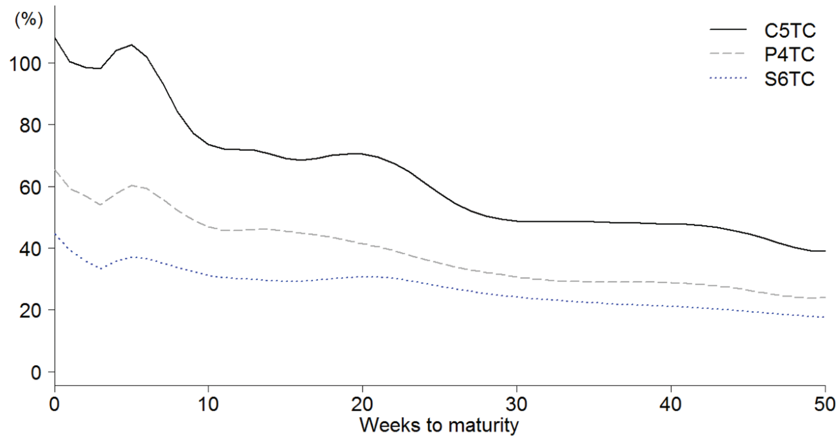

Figure 3. Estimated historical volatility structure of the forward freight function.

$$\ln f(t_n, T_m) - \ln f(t_{n-1}, T_m) = x_{n,m} \tag{27}$$

where n = 1, . . ., N.

$$X_{(N\times M)} = [X_1 \quad X_2 \quad \ldots \quad X_M] = \begin{bmatrix} x_{1,1} & x_{1,2} & \cdots & x_{1,M} \\ x_{2,1} & x_{2,2} & \cdots & x_{2,M} \\ \vdots & \vdots & \ddots & \vdots \\ x_{N,1} & x_{N,2} & \cdots & x_{N,M} \end{bmatrix} \tag{28}$$

From the data set of daily returns, we estimate the historical volatility function as

$$\hat{\sigma}(t, T_M) = s\sqrt{252} \tag{29}$$

where s is a $1 \times M$ vector of historical standard deviations, representing each of our M weekly maturities, annualized by the number of trading days per year.

Figure 3 illustrates how the resulting estimated annualized average volatility function is increasing with vessel size (Kavussanos 1996), but also how—broadly speaking—it is a decreasing function of the maturity of the implied forward freight rates. Given that the long-run freight rate should be highly correlated with newbuilding prices (Strandenes 1984), the volatility of the long end of the term structure of volatility should also converge towards the volatility of newbuilding prices. Data from Clarkson Research Services on newbuilding prices show annualized volatility estimates around 30%, which compares with our one-year maturity estimates of around 25–40% depending on vessel size.

The volatility spike that appears around five weeks to maturity is in line with the elastic expectations hypothesis set forth by Zannetos (1959). Given that both charterers and ship owners have some flexibility in terms of when to enter the market to try to fix their cargo and ship, respectively, the mere expectation of an increase in spot freight rates will move demand forward (i.e. charterers wanting to fix) and push supply (i.e. ships willing to fix) back, thereby generating short-run positive auto-correlation in spot freight rates. Such elastic expectations mean that the volatility of expected near-term spot rates (i.e. FFA prices) must be more volatile than spot rates. In the long run, the expectation of mean reversion dominates such that the volatility structure is overall downward sloping. The fact that our estimate of one month volatility is below that of spot volatility is believed to be a result of the smoothing method, where the spot rate is not accounted for but is merely a result of equation 4. Although not shown here due to space constraints, we also find that these features are stable across time, but that the spread between the term structures of volatility across years is larger for Panamax and Supramax than it is for Capesize. In other words, even though Capesize freight rates are more volatile, the level of volatility is more stable.

6. Trading strategies

6.1. Delta hedging

Ahmad and Wilmott (2005) show that when implied volatility differs from actual volatility, profits can be extracted through delta hedging the option. Delta hedging involves buying or selling an option and hedging its market exposure through an offsetting trade in the underlying asset. The arbitrage is possible in a stylized world with constant volatility, and where we know the future realized volatility —the *actual volatility*. The arbitrage profit is secured through delta hedging using either implied or actual volatility. The difference between hedging with implied and actual volatility becomes apparent in the process of marking to market. Hedging with actual volatility secures a profit equal to the initial mispricing of the options. However, the path required to reach the correct volatility estimate is random—opening up for large losses before gaining. In a time interval $[t, T_N]$ where implied volatility (σ_{IV}) is higher than actual volatility (σ_a) and we hedge with actual volatility, the expected profit is

$$O(t, U; \sigma_a) - O(t, U; \sigma_{IV}) \tag{30}$$

with U representing the underlying asset of the option value O at time t.

Conversely, hedging with implied volatility secures a deterministic daily profit, yet the final profit becomes path-dependent. Ahmad and Wilmott (2005) show that the profit in the time interval $[t, T_N]$ can be formulated as

$$\frac{1}{2}(\sigma_a^2 - \sigma_{IV}^2)\int_t^{T_N} e^{-r(s-t)}U^2\Gamma_{IV}ds, \quad \Gamma = \frac{\partial^2 O}{\partial U^2} = \frac{\partial \Delta}{\partial U} \tag{31}$$

We simulate a delta hedging strategy on real market data. At time t, the first trading day of the contract, we compare the option's implied volatility with the historical volatility as per our estimated volatility term structure. If the implied volatility is sufficiently above/below our historical volatility estimate, we want to sell/buy volatility. We apply a filter (ϕ) to determine what constitutes a sufficient deviation from our estimate. The filter differentiates between the vessel sizes, with the argument being that greater absolute variation in the volatility structure opens up for greater mispricing of the options, and ultimately a lower margin of error when deciding on the direction of the volatility deviation. The filters for Capesize, Panamax, and Supramax contain the trigger values [0,6,12,18,24,30], [0,4,8,12,16,20], and [0,2,4,6,8,10], respectively, where the trigger values are percentage deviations from our historical volatility estimate. Thus, for Capesize with a trigger value of 18%, we need the implied volatility to be 18% higher (or lower) than our historical volatility estimate to take a position. We expose ourselves to the volatility by selling/buying a call and hedging our portfolio through buying/selling $\Delta \times FFA$—establishing a delta neutral position. The delta (Δ) of the call is calculated as

$$\frac{\partial(Call_{Asian})}{\partial FFA} = D \times N(d_1) \tag{32}$$

where D represents the number of calendar days covered by the FFA contract.

The investment decision at time t is strictly based on information available prior to t. For every trading day prior to roll-over, $[t, \ldots, T_R]$, we adjust our portfolio by buying/selling the underlying FFA to remain delta neutral. On the day, T_R, that the contract rolls-over to a new period, we clear our position. Thus, for monthly contracts, the trading period will span around one month (20 trading days), while quarterly contracts will be traded for approximately one quarter, establishing the time frame of relevance as $[t, T_R, T_1, T_N]$. We assume that we can borrow/place money at the LIBOR risk-free rate. Transaction costs are set at 0.01% for FFAs and 0.25% for options. When short selling, we assume that all positive cash flow will be held as collateral.

Table 2. Descriptive statistics for delta hedging strategy with implied volatility.

		+1MOc				+1Q				+3Q			
Index	Filter(%)	μ(%)	σ (%)	MDD(%)	#	μ(%)	σ (%)	MDD(%)	#	μ (%)	σ (%)	MDD(%)	#
C5TC	0	4.47	3.34	8.14	48	6.92	3.53	3.83	16	5.43	2.32	2.78	16
	6	4.51	3.41	8.14	46	6.92	3.53	3.83	16	5.43	2.32	2.78	16
	12	4.66	3.29	8.14	43	6.92	3.53	3.83	16	5.43	2.32	2.78	16
	18	4.79	3.31	8.14	40	7.35	3.19	3.83	15	6.01	2.10	2.78	13
	24	5.06	3.24	8.14	35	7.35	3.19	3.83	15	6.01	2.10	2.78	13
	30	4.96	3.30	8.14	33	8.18	2.87	3.83	10	7.66	1.39	0.78	6
P4TC	0	1.44	2.01	2.80	48	2.25	1.39	1.81	16	2.50	1.12	0.51	16
	4	1.91	2.01	2.80	32	2.66	1.34	1.81	12	2.60	1.08	0.51	15
	8	2.26	2.13	2.80	24	2.68	1.40	1.81	11	2.72	1.02	0.51	14
	12	2.13	2.17	2.80	22	2.91	1.46	1.81	9	2.86	0.91	0.37	13
	16	2.39	2.14	2.80	18	2.91	1.46	1.81	9	3.25	0.82	0.37	9
	20	2.39	2.21	2.80	17	3.30	1.19	1.81	7	3.56	0.54	0.23	7
S6TC	0	0.08	0.95	2.79	48	0.87	0.61	0.95	16	1.13	0.65	1.36	16
	2	0.15	0.95	2.79	35	0.88	0.63	0.95	15	1.13	0.65	1.36	16
	4	0.25	1.03	2.79	21	0.98	0.56	0.95	12	1.13	0.65	1.36	16
	6	0.39	1.07	2.79	16	1.23	0.48	0.49	6	1.13	0.65	1.36	16
	8	0.71	0.72	1.23	10	1.51	0.09	0.41	2	1.13	0.65	1.36	16
	10	0.89	0.47	0.72	7	1.44	—	0.15	1	1.32	0.52	0.27	13

The results when delta hedging using implied volatility are presented in Table 2. The return (μ) is the total return, from t to T_R, on the absolute value of what we initially buy and sell. The volatility (σ) is the standard deviation of these returns. # is the total number of positions initiated for the specific contract and filter value. Maximum drawdown (MDD), is the maximum observed loss from a local maximum to a local minimum during the time interval $[t, T_M]$ for any contract traded in our sample.

With reference to Table 2, we note that downside risk (MDD), volatility, and return is typically higher for shorter contracts and larger vessels. However, we should keep in mind here that the reported return and volatility estimates are not directly comparable across monthly and quarterly contracts because of the differing holding period. As expected, the number of positions initiated are declining with higher filter values. Furthermore, higher threshold values for initiating a trade generally results in higher returns and lower volatility. We can also observe identical MDD values for different filter values, suggesting that the largest drawdown stems from one specific trade. A closer look at the simulations reveals that the largest drawdown occurs in the same time interval across several contracts. Put differently, there are occasions where all versions of the strategy will fail simultaneously.

For comparison, we also simulate delta hedging based on historical volatility. Here, the expected profit is path-independent and equal to equation 30, provided that the strategy is upheld until T_N, giving the volatility time to reach its expected level. Thus, our trading strategy rests on the assumption that volatility converges towards our historical volatility estimate prior to T_R and that the options are priced according to this information. With reference to the results in Table 3, hedging using historical volatility yields higher returns with higher volatility and downside risk. This reflects how the backward-looking historical volatility measure is unable to reflect (expected) upcoming events that are accounted for in implied volatility.

Figure 4 and 5 show the P&L processes for the simulated delta hedge trades in the Capesize segment. We note that it is not the individual paths that are important here, but the shape of the overall cluster, which says something about risk and return for the strategy as such. We can observe how delta hedging using monthly contracts has a higher risk of negative outcomes and a wider dispersion of returns. Conversely, the use of long-term contracts (+3Q) results in a positive return for all trading periods if the trade is maintained until the roll-over date. This reflects the greater variation in the volatility of short-maturity contracts, and the fact that delta hedging does not account for the impact of the underlying price movement's effect on volatility. Consequently, delta hedging will be more efficient for long-term contracts, which have more stable volatility estimates.

Table 3. Descriptive statistics for delta hedging strategy with historical volatility.

		+1MON				+1Q				+3Q			
Index	Filter(%)	μ (%)	σ(%)	MDD(%)	#	μ (%)	σ (%)	MDD(%)	#	μ (%)	σ (%)	MDD(%)	#
C5TC	0	4.73	3.67	13.92	48	7.23	3.13	5.84	16	5.62	2.45	3.96	16
	6	4.79	3.75	13.92	46	7.23	3.13	5.84	16	5.62	2.45	3.96	16
	12	4.97	3.64	13.92	43	7.23	3.13	5.84	16	5.62	2.45	3.96	16
	18	5.12	3.68	13.92	40	7.69	2.63	5.84	15	6.19	2.26	3.96	13
	24	5.38	3.73	13.92	35	7.69	2.63	5.84	15	6.19	2.26	3.96	13
	30	5.30	3.82	13.92	33	8.12	2.85	5.84	10	7.94	1.64	0.44	6
P4TC	0	1.50	1.96	2.93	48	2.33	1.47	1.55	16	2.58	1.15	0.44	16
	4	1.99	1.92	2.93	32	2.78	1.39	1.55	12	2.69	1.11	0.44	15
	8	2.36	2.01	2.93	24	2.81	1.46	1.55	11	2.80	1.06	0.44	14
	12	2.23	2.05	2.93	22	3.08	1.48	1.55	9	2.94	0.95	0.36	13
	16	2.44	2.13	2.93	18	3.08	1.48	1.55	9	3.35	0.86	0.36	9
	20	2.45	2.19	2.93	17	3.51	1.21	1.55	7	3.64	0.68	0.36	7
S6TC	0	0.10	0.96	2.81	48	0.88	0.61	0.98	16	1.16	0.64	1.43	16
	2	0.17	0.96	2.81	35	0.89	0.63	0.98	15	1.16	0.64	1.43	16
	4	0.27	1.05	2.81	21	0.98	0.57	0.98	12	1.16	0.64	1.43	16
	6	0.42	1.10	2.81	16	1.25	0.48	0.51	6	1.16	0.64	1.43	16
	8	0.75	0.74	1.28	10	1.56	0.14	0.31	2	1.35	0.48	0.30	13
	10	0.97	0.41	0.60	7	1.46	—	0.16	1	1.35	0.48	0.30	13

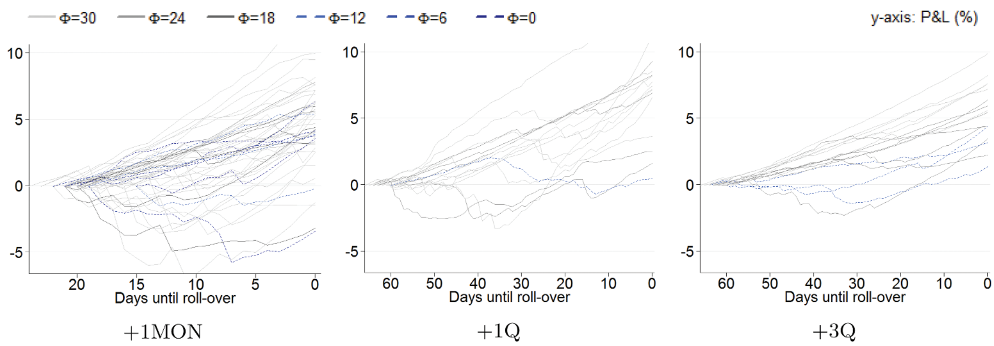

Figure 4. Delta hedging strategy with implied volatility for Capesize.

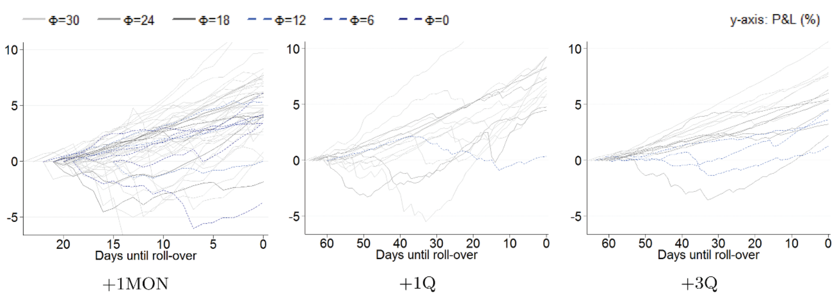

Figure 5. Delta hedging strategy with historical volatility for Capesize.

We can also recognize the slightly better performance of delta hedging strategies based on implied volatility estimates. This is because a portfolio constructed according to implied volatility is delta neutral by definition, while a portfolio where the hedge ratio is based on historical volatility generally is not, and so exposed to price movements (unless implied volatility in the market converges to the historical volatility estimate).

We acknowledge that our model for delta hedging will meet some challenges in real-world implementation. The arbitrage opportunity described by Ahmad and Wilmott (2005) is only attainable in the unlikely case that historical volatility estimates are perfect forecasts of future volatility. Since this is not the case in practice, the resulting delta hedge is imperfect. Combined with the fact that hedging cannot be continuous (neither in time, nor in volume, due to a minimum FFA trade size of five days), this means that there will be an accumulation of replication errors and that increasing the frequency of hedging does not improve the situation. On the contrary, the presence of transaction costs will reduce the P&L. These market imperfections all create a trade-off between variance reduction and hedging frequency (Sepp 2013). While we account for transaction costs and only allow for discrete hedging, the effects of low liquidity in the freight derivative market are not included in our simulation. Low liquidity and an OTC trading environment means that the daily rebalancing of a portfolio is hard and might only be possible at a premium.

6.2. Straddle

A long (short) straddle position is an options strategy involving the purchase (sale) of both a put and call option for the same maturity and strike price. Based on its qualities of being long (short) volatility, having vegas and gammas on the same side of the market, and initially being close to delta-neutral, Taleb (1997) defines the strategy as a first-order volatility trade. The option value will also be sensitive to changes in interest rates (rho, ρ) and time-decay (theta, Θ). We do not formulate a strategy for how to manage these first-order derivatives of the position value.

As in the case of delta hedging, potential excess returns are obtained by recognizing when options are mispriced and exploited the situations where the implied volatility is above/below our volatility estimate. We simulate buying/selling an at-the-money straddle at t and delta hedging the position such that it is approximately delta neutral at this time. We hold the position until the delta of the straddle surpasses $\|0.1\|$ in which case the position is rolled over to a new at-the-money straddle. A threshold of 0.1 is based on what is practically considered delta neutral, as noted by Schmitt and Kaehler (1996). Our estimate of the delta of the portfolio is based on equation 32, accounting for the symmetrical property of the normal distribution when calculating the delta for puts. We use our historical volatility estimate to recognize seemingly cheap and expensive volatility, but the success of the strategy depends on the actual realized volatility over the period. The results of the straddle strategy are reported in Table 4 and Figure 6. The return (μ), volatility (σ), and maximum drawdown (MDD) are calculated in the same way as for the delta-hedging strategy.

As per the performance statistics in Table 4, the straddle strategy shares many of the features of the delta hedging strategy's performance, with generally higher returns for higher filter values, high volatility of trading returns for monthly contracts, and better risk/return ratio for longer-maturity contracts. However, the MDD estimates confirm that this is a strategy with higher risk than our delta hedging strategy.

7. Concluding remarks

In this paper, we have investigated whether volatility trading strategies can be used to economically exploit misspecification of volatility in the freight options market. We derive daily smooth forward rate curves for the Capesize, Panamax and Supramax markets and use these to estimate the segments' respective term structures of historical volatility. The volatility term structure is increasing in maturity over a six-week time horizon before declining towards levels seen in the market for newbuilding prices at maturities of around one year. Volatility levels are also decreasing with vessel size for all maturities. By comparing the historical volatility term structure with the volatility estimates implied by the options market, we simulate the implementation of two volatility trading strategies: delta hedging call options and delta hedging long/short straddles. Only the delta hedging strategy is found to generate consistently positive results across segments and market conditions.

Table 4. Descriptives for buy/sell straddle strategy.

		+1MON				+1Q				+3Q			
Index	Filter(%)	μ (%)	σ(%)	MDD(%)	#	μ (%)	σ(%)	MDD(%)	#	μ (%)	σ(%)	MDD(%)	#
C5TC	0	21.51	24.58	47.24	48	30.14	18.09	19.21	16	29.15	13.84	10.43	16
	6	22.98	22.65	33.40	47	30.14	18.09	19.21	16	29.15	13.84	10.43	16
	12	22.73	23.12	33.40	45	30.14	18.09	19.21	16	29.15	13.84	10.43	16
	18	24.04	23.11	33.40	41	31.84	17.33	19.21	15	32.05	11.77	7.77	13
	24	25.43	22.72	33.40	36	31.84	17.33	19.21	15	32.05	11.77	7.77	13
	30	24.66	23.10	33.40	34	31.11	20.38	19.21	10	37.49	14.12	2.98	6
P4TC	0	8.05	11.87	19.92	48	7.47	8.60	15.54	16	11.43	5.80	3.73	16
	4	10.34	11.96	19.92	34	7.34	9.27	15.54	13	11.52	5.99	3.73	15
	8	11.49	12.15	19.92	24	7.31	9.28	15.54	11	12.21	5.57	3.73	14
	12	10.98	12.57	19.92	22	8.02	9.44	15.54	9	12.38	5.76	3.73	13
	16	12.65	12.82	19.92	18	8.02	9.44	15.54	9	12.86	5.75	3.64	9
	20	12.67	13.21	19.92	17	9.11	10.36	15.54	7	13.52	6.46	3.64	7
S6TC	0	−0.12	7.07	20.24	48	1.92	7.35	11.77	16	5.66	5.68	10.17	16
	2	0.79	7.18	20.24	34	1.41	7.30	11.77	15	5.66	5.68	10.17	16
	4	0.76	7.66	20.24	21	3.57	6.28	9.39	12	5.66	5.68	10.17	16
	6	1.71	8.01	20.24	15	4.14	7.34	9.39	7	5.66	5.68	10.17	16
	8	4.22	4.43	5.78	12	7.65	4.95	2.62	2	5.66	5.68	10.17	16
	10	4.47	3.58	5.66	7	4.15	—	2.36	1	7.82	3.24	2.11	13

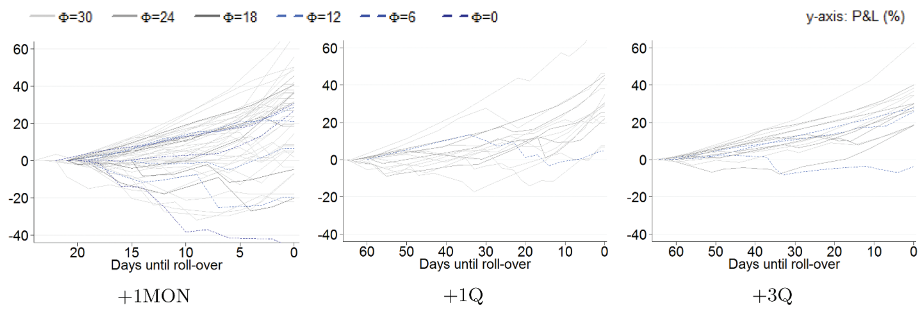

Figure 6. Adjusting straddle strategy.

While our findings can be interpreted as a sign of inefficiency in the freight options market, we acknowledge that our study has certain weaknesses that can change this conclusion. Firstly, our simulations assume a highly liquid market where even small changes in the portfolio can be immediately executed without price slippage and delay. Furthermore, our approach assumes that freight options are priced according to the log-normal spot freight rate processes proposed in the literature. If, in reality, the market is simply accounting for fat tails and skewness in the distribution of freight rate returns, and adapt by adjusting the volatility estimate in the option pricing formula, any identification of mispricing could be a result of incorrect assumptions (Haug and Taleb 2008). Given that the freight derivative market is a zero-sum game, we also have to consider the possibility that such apparent profit opportunities merely represent a compensation to option market makers from those who want to offload price risk. As the volatility trading strategies are risky, they may only be of interest to participants that have a certain risk attitude and have access to substantial trading capital.

Future research should verify whether these results hold under more stringent assumptions regarding liquidity and more sophisticated option pricing models. It is also worth investigating whether the degree of market efficiency in the freight options market has changed over time, as a result of increasing sophistication, liquidity, price transparency and speed of information flow in the market.

Notes

1. Alternative indices produced by price reporting agency S&P Global Platts exist but are currently not used by market participants.
2. Note that CURMON refers to the contract for the current month, +1MON to the subsequent monthly maturity, +1Q to the nearest quarterly maturity, +2Q to the next quarterly maturity, and so on.

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