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Zusammenfassung / Abstract

In this paper, information processing in spot and forward freight markets with respect to the Organization of the Petroleum Exporting Countries (OPEC) output announcements is investigated. We use the event study methodology to study returns in tanker freight spot and forward markets around OPEC conferences from 2003 to 2014. Significant abnormal returns indicate that the output decisions are informationally important for the pricing of crude oil transportation services. We consistently find patterns of positive abnormal returns around production increase announcements and negative abnormal returns around announcements of production cuts. Our analysis also suggests that market participants appear to trade three to five days prior to the final announcement based on their anticipation of the actual output announcements. This is consistent with findings from related studies on crude oil returns. Persistence of abnormal returns in the post-event period indicates incomplete initial reactions or at least slow adjustment to disseminated information.

JEL-Klassifikation / JEL-Classification: F10,G13, G14

Schlagworte / Keywords: Tanker Freight Rates, Freight Forwards, OPEC, Informational Efficiency, Event Study

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"Die durch die OPEC bedingte leicht reduzierte Ölfördermenge bei gleichbleibendem Tonnageangebot hat im abgelaufenen Jahr einen Preisverfall am Frachtratenmarkt für Tankschiffe bewirkt.“

Wirtschaftsblatt, 25.02.2003

1 Introduction

Crude oil is one of the central sources of energy and may literally be considered as the lubricant of the global economy. However, since natural deposits of crude oil are often not located at the places of demand, transportation of the commodity is required. This is substantially accomplished by crude-oil-carrying commercial vessels. The value of these transportation services is reflected in maritime freight markets, which are characterized by extreme volatilities, causing commercial business risk for market participants in the capital-intensive shipping industry. Historically, freight rate risks have been managed by contracting vessels for longer periods with fixed freight rates (i.e. time-charter contracts). However, from a risk management perspective, this instrument may not be optimal, for instance due to the inherent connection to the physical operation of the vessel (Kavussanos and Visvikis, 2006). For this reason, among others, Forward Freight Agreements (FFAs) were introduced into the industry in the early 1990s as a new risk management instrument. FFAs are principal-to-principal financial derivative contracts which set forward prices for the transportation service by sea (i.e. the underlying commodity) of a specified quantity and type of cargo, on a particular standardized trading route and at a future point in time. Upon maturity, buyers and sellers of the FFA settle the difference between the agreed forward rate and the spot settlement rate in cash (contract for differences). Apart from speculators, buyers of FFA contracts in the tanker segment of the shipping industry, on which our paper is focused, are, for example, oil companies or oil traders, while sellers may be ship-owners. While FFAs were traditionally traded as pure Over-the-Counter (OTC) instruments, trading is nowadays facilitated through clearing houses, which diminishes counterparty risk and may increase liquidity and transparency in the market.[1]

Despite the evident importance of the shipping industry for the global economy, tanker freight markets have so far gained comparatively little attention in financial economics research. Apart from their economic significance, (tanker) freight rates show certain characteristics that make them interesting from a research perspective: first, demand for transportation is a derivative of

[1] Cleared FFAs are sometimes referred as to “hybrid FFAs” due to their similarity to future contracts (see Kavussanos & Visvikis, 2006).

the demand for the transported good, partially explaining the high volatility in shipping markets. Second, in contrast to the vast majority of other commodities, sea-borne transport is a non-storable service and thus spot and FFA prices are not linked by a cost-of-carry relationship. Instead, both spot and forward freight rates are presumed to be determined by respective demand and supply expectations upon maturity.[2] In this context, this paper aims at fostering the understanding of price formation in freight and freight forward markets by studying the efficiency of information processing.

Following the classical efficient markets hypothesis, spot and forward freight markets are considered semi-strong form informational efficient if the respective market prices adjust completely and instantaneously to shocks induced by the dissemination of new price-relevant, public information. Market participants would thus not be able to systematically earn abnormal returns by trading on publicly available information (Fama, 1970). Thus far, research on informational efficiency in freight (derivative) markets, which we selectively review below, has, for the most part, focused on time-series analysis, studying the adjustment of market prices to successively changing informational sets. We aim at complementing this work by studying the speed and efficiency of adjustment of freight rates to the release of specific information packages, which we do by employing the event study methodology. To the best of our knowledge, this is the first study to apply and adapt the event study methodology to maritime freight markets. Specifically, we investigate the behavior of crude oil tanker spot and forward freight rates around periodic crude oil production announcements by the Organization of the Petroleum Exporting Countries (OPEC). Our analysis is based on the assumption that crude oil production levels significantly affect crude oil trade volumes, in turn inducing demand side shocks for sea-born transport of crude oil. This underlying assumption is supported by existing empirical evidence: Tham (2008) finds that crude oil production levels in the Arabian Gulf are a significant determinant of the state of the tanker freight market in the Middle East, and Lauenstein (2016) provides evidence that oil production volumes Granger (1969)-cause tanker freight rates. Accordingly, increased (decreased) production levels would be expected to trigger

[2] This concept is known as the expectations theory, where forward prices are viewed to be a function of expected spot prices upon maturity and a premium (see Fama & French, 1987, and for discussions of this issue in the context of freight rates, see Kavussanos & Alizadeh, 2002, as well as Batchelor et al., 2007). Other applications of the expectations theory include interest rate and electricity derivative markets.

positive (negative) returns in the tanker freight market. To be sure, this paper does not cover in-depth discussions on the economic role of the OPEC in the global crude oil market and its ability to effectively work as a cartel (see Kaufmann et al., 2004, among others). We merely view OPEC output announcements as a potential source for news about the development of demand for sea-born transport of crude oil.

The remainder of this paper is structured as follows: first, we give a brief overview of existing related research on freight rate derivatives, the impact of OPEC announcement of crude oil markets, and dynamic linkages between freight markets and the respective transported goods. Section 3 provides a description of the data, preliminary statistics, and a detailed event definition. The research methodology is discussed in section 4. The empirical results are presented and discussed in section 5. The final section gives a concluding summary.

2 Literature Review

In this paper, we study the efficiency with which the information content of OPEC output announcement is processed in tanker freight and freight forward markets. Several streams of research are related to this issue: first, we present evidence on returns in crude oil markets around OPEC output announcements, from which the demand for sea-transport is commonly argued to be derived (Zannetos, 1966; Alizadeh and Talley, 2011). Second, empirical findings on the linkage between commodity markets and the corresponding freight markets are reviewed. Third, existing empirical studies on freight forwards are presented, focusing on evidence related to informational efficiency.

2.1 OPEC Announcements and Crude Oil Returns

A number of empirical studies have examined the behavior of oil returns around OPEC output announcements.[3] Deaves and Krinsky (1992) are early to investigate the reaction of oil future returns (both crude oil and refined products) to OPEC announcements between 1983 and 1990. They perform a classification of "good" and "bad" news conveyed by the announcement based on the sign of abnormal returns of the first day after the event and find that the information

[3] For sake of methodically comparability, we focus on studies that employ event study techniques.

content of the meetings is anticipated by market participants. Persistence of abnormal returns after the event indicates incomplete initial information processing in case of bullish news. In a more recent study, Demirer and Kutan (2010) explore crude oil spot and future returns around OPEC announcements.[4] Having grouped the OPEC conferences between 1983 and 2008 according to their actual output decision, as is done in our paper, they find that, on the one hand, the market reacts incompletely to output reductions, showing statistically significant abnormal returns after the announcement date. On the other hand, no significant reactions to production increase announcements are observed. In addition, market reactions are found to be most pronounced in the spot market as compared to the futures market. Covering a similar sample observation period (1982 to 2008), Lin and Tamvakis (2010) find that OPEC announcements affect crude oil returns, but the degree of impact depends on the relative level of crude oil prices (price bands) at the time of the announcement. In contrast, Bina and Vo (2007), who study the impact of OPEC announcements on crude oil spot and future returns from 1983 through 2005, argue that the OPEC's ability to influence crude oil prices is transitory and limited to short time windows around announcements. In summary, empirical evidence with respect to the behavior of crude oil prices around OPEC announcements remains somewhat ambiguous. Although significant price reactions are mostly confirmed, the degree of reaction and the efficiency of information processing depend, among other factors, on the decision to increase, maintain, or reduce the OPEC's output.

2.2 Linkages between Commodity and Freight Markets

A recent research focus is the market interaction between freight rates (derivatives) and the commodities being carried by the respective ship type. To some extent, this matches the approach taken in this study. In an early work, Alizadeh and Nomikos (2004) identify a long-run relationship between oil prices and tanker freight rates between 1993 and 2001. However, by contrasting standard cost-of-carry relationships, they cannot confirm that tanker freight rates are related to differences between spot and future crude oil prices. In support of the notion that

[4] Demirer & Kutan (2010) perform their analysis both based on the (modified) market model as well as on the Fama-French three-factor model. However, it remains somewhat uncertain how the authors apply the Fama-French three-factor model to the crude oil market. In addition to the OPEC announcements, the authors study U.S. strategic petroleum reserve (SPR) announcements and find that the market reacts efficiently to the SPR announcements.

the demand for tanker sea-transport derives from the demand for crude oil, Poulakidas and Joutz (2008) investigate the dynamic linkage between oil future prices and tanker freight rates in a lead-lag framework and find a Granger-causal link from crude oil future prices to spot freight rates.[5] In addition, Kavussanos et al. (2014) show that dry bulk commodity forward prices informationally lead related freight forward prices both in terms of volatilities and returns. Instead of studying the relationship between crude oil prices and freight rates, Lyridis and Zacharioudakis (2012) show a strong and positive correlation between physical crude oil production volumes and tanker demand. This finding matches the evidence provided by Tham (2008) and Lauenstein (2016), as mentioned above. The notion of tanker demand levels being strongly related to crude oil production volumes is the basis for the empirical analysis performed in this paper.

2.3 Freight Forwards: Hedging Performance, Price Discovery and Informational Efficiency

Existing empirical research on (hybrid) freight forwards is, to a large extent, aligned with the two core functions of financial derivatives: risk management and price discovery. Both functions – however, in particular the latter – are related to informational efficiency of market prices.[6] The *risk management function* of the FFA market is, for instance, studied by Kavussanos and Visvikis (2005) as well as Alizadeh et al. (2015), who empirically confirm a significant hedging performance of freight income risk. However, market risk reductions are lower than typically observed in other commodity derivative markets. Furthermore, Alizadeh and Nomikos (2012) observe that FFAs perform well in hedging ship price risks. The *price discovery function* of freight rate derivatives is tested within a variety of methodological frameworks: making use of cointegration techniques to study the dry bulk market, Kavussanos et al. (2004) find that FFA prices of contracts with one and two months maturities are unbiased predictors of future spot

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[5] Specifically, Poulakidas & Joutz (2008) focus on the link between tanker freight rates for shipments ex West Africa to the U.S. Gulf Coast from 1998 through 2006.

[6] The reader is also referred to Kavussanos & Visvikis (2006) for a detailed review of parts of the research presented in this section. These authors also argue that derivatives need to, at least, fulfil one of the two core functions in order to create additional value beyond the spot market for the underlying; for a general discussion on this issue see Black (1976), among others. For example, the demise of the BIFFEX market, which had been the predecessor of today´s FFA market, was allegedly due to its insufficient hedging performance as its underlying structure caused significant basis risk for hedgers.

rates. Kavussanos and Visvikis (2004) study the lead-lag relationship in returns between dry bulk FFA prices and the underlying spot market and conclude that information is processed faster in the FFA market. Similarly, Batchelor et al. (2007) show that forward rates help to forecast future spot rates but not vice versa, which finds support from Zhang et al. (2014). Bessler et al. (2008) find support for price discovery by FFA contracts in view of the fact that spot prices show a significantly higher autocorrelation than forward prices. In summary, empirical evidence suggests an existing price discovery function of freight forwards. This may be taken as a time series-based indication of efficient information processing in freight forward markets. On the other hand, Goulas and Skiadopoulos (2012) document informational inefficiencies for freight forwards traded on the International Maritime Exchange (IMAREX) because forward prices can be forecasted over the daily horizon. Their findings hold for all underlying freight indexes (dry bulk and tanker) but diminish over the weekly horizon. In this paper, further insight regarding the processing of public information shall be provided by means of the event study methodology to examine the processing of specific information packages.

3 Data Description and Event Definition

The sample period of this study ranges from April 1, 2003, to May 30, 2014, yielding 2861 daily observations. The spot freight rates are obtained from the Baltic Exchange and the FFA dataset is provided by Marex Spectron.[7] First differences in the logarithm of daily freight rates and FFAs are used to calculate daily returns.

The analysis in this paper is concentrated on the long-haul crude oil trading route from the Middle East Gulf to Japan, which is serviced by Very Large Crude Carriers (VLCC). The Baltic Exchange classifies this route as benchmark route Tanker Dirty 3 (TD3). This particular route is selected for two reasons: first, in view of the fact that the major oil-producing countries in the Middle East are OPEC member states, the informational relevance of OPEC output announcements is increased by selecting a specific trading route ex Middle East. Second, the TD3 route is considered as the most liquid route among the available freight forward standard

[7] Marex Spectron is a broker and clearing house for a variety of financial instruments. It is the successor of the International Maritime Exchange (IMAREX). Before April 2003, there was no active trading of tanker FFAs on the Marex trading platform. We thank Marex Spectron for providing us with the freight derivative data.

trading routes.[8] Following a common approach in the literature, forward contracts with short times to maturity – in this case, one month and two months – are chosen to represent the derivative market, as these are the most liquid contracts (e.g. Kavussanos et al., 2014). As done by Alizadeh et al. (2015), among others, time series of FFA returns have been constructed by rolling over to the next month five trading days before the first day of the settlement period of the specific forward contract is reached.

Table 1 presents descriptive statistics of the daily spot and forward logarithmic returns of the particular routes and selected maturities for a preliminary analysis of the dataset. Mean returns of both the spot (Panel A) and forward freight rates (Panel B) are essentially zero. Based on sample standard deviations, the volatility of the return series decreases as maturity increases, which yields evidence for the so-called "Samuelson effect" (Samuelson, 1965). That is, short-term prices tend to be more sensitive to the arrival of news about shifts in the underlying demand and supply conditions as compared to prices with longer periods until final settlement of the respective contract.[9] Negative values for skewness indicate that the return distributions of FFAs are slightly skewed to the left, while the opposite holds for the spot return distribution to a lesser degree. Kurtosis values indicate that all distributions are leptokurtic (fat-tailed), which is a common characteristic of daily commodity and freight rate returns (as, for instance, described in Kavussanos, 2003). Accordingly, departures from normality are indicated by the Jarque-Bera test statistic for all return distributions, which is partially accounted for by employing non-parametric significance testing as outlined in section 4. Returns – as opposed to the original time series of freight rate in levels (not reported) – prove to be log first-difference stationary.

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[8] Angelidis & Skiadopoulos (2008) as well Goulas & Skiadopoulos (2012) also base their analysis of the tanker derivative market on the TD3 due to liquidity reasons.

[9] The "Samuelson effect" in spot freight rates and FFAs has been documented and discussed in the literature. Alternatively, the phenomenon of decreasing volatility with increasing time-to-maturity is termed "volatility term structure" (e.g. Alizadeh & Nomikos, 2009).

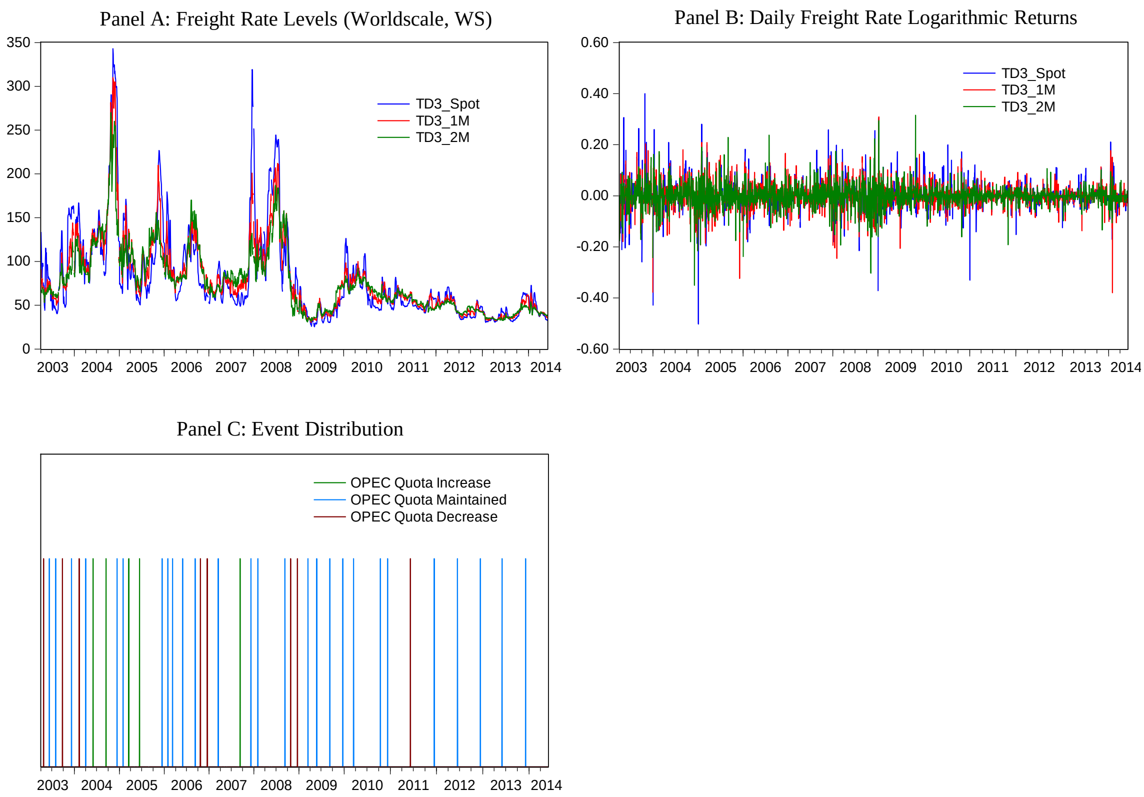
Table 1
Descriptive Statistics (Period: 01.04.2003-30.05.2014, T=2,861)

	Mean	SD	Skewness	Kurtosis	Normality		Stationarity	
					JB	p-Val.	ADF	p-Val.
Panel A: Spot Freight Rates								
TD3_Spot	-0.0005	0.0490	0.0207	17.6884	25,719	0.0000	-23.8184	0.0000
Panel B: Forward Freight Rates								
TD3_1m	-0.0004	0.0475	-0.3754	9.3479	4,871	0.0000	-22.8119	0.0000
TD3_2m	-0.0003	0.0400	-0.2588	13.1401	12,289	0.0000	-22.6068	0.0000

Notes: Preliminary statistics are provided on daily logarithmic first differences. The null hypothesis for the Jarque–Bera (JB) and Augmented Dickey and Fuller (ADF) tests is that the series is normally distributed and has a unit root, respectively.

Heteroskedasticity in return volatilities is a widely known characteristic of commodity (forward) markets, which is also well-documented to hold for tanker freight rate returns (e.g. Alizadeh and Nomikos, 2004; Batchelor et al., 2007; Poulakidas and Joutz, 2008). This is in support of a visual observation of Panel B in Figure 1, which suggests that the spot and FFA return series may exhibit non-constant volatility through time and volatility clustering; that is, large volatilities in returns are likely to be followed by large volatilities and low volatilities are probable to be followed by low volatilities.

Figure 1
Daily Freight Rates, Returns and Event Dates



As outlined earlier, this study focuses on the effect of OPEC production quota announcements on the tanker freight market. The event study methodology is performed under the assumption that the selected events are exogenous with respect to the pricing of the maritime crude oil transportation services (e.g. MacKinlay, 1997). The results provided by Lauenstein (2016) suggest the exogeneity of crude oil production levels to the tanker freight market. Announcement days of the outcome of the OPEC conferences, which are typically at the end of each conference, are obtained from official press releases as published by the OPEC Secretariat. Events are classified as increase, maintain, and decrease in accordance with the effective decision of the OPEC conference to raise, maintain, or reduce the future combined production level of the OPEC countries, respectively. In doing so, no distinction is made between semi-annual regular and occasional extraordinary OPEC conferences for two reasons: first, the dates of both types of meetings are announced in advance for both types of conferences and, for that reason, market participants would equally be able to form expectations about the outcome of the conference. Second, the number of extraordinary meetings in the sample is rather small, which is why a separate empirical investigation of the announcements is not feasible. During the entire sample period of this study, 40 conferences could be observed. 5 (N^I) of these meetings are classified as increase, 27 (N^M) as maintain and 8 (N^D) as decrease of the crude oil production quota. The distribution of the events over the sample period is depicted in Panel C of Figure 1.

4 Methodology

From an informational efficiency point of view, event studies are a standard methodological approach to study how rapidly and completely markets respond to specific new information packages. This information is assumed to disseminate in the market through a specific informational event. Detailed discussions and reviews of the generic event study methodology and its econometric development can be found in MacKinlay (1997), Binder (1998) as well as Kothari and Warner (2006). While the methodology was initially developed to assess the incorporation of firm-specific news into equity market valuations, event studies have recently been applied to a diversity of financial markets. In this context, McKenzie et al. (2004) give a review of the application of event studies to commodity derivative markets.

Following the event study methodology, the impact of events on a freight rate return series is assessed by measuring abnormal (or excess) returns on and around specified event dates. Here, abnormal returns ($AR_{\tau n}$) on event-day τ, around OPEC event n, are defined as:

$$AR_{\tau n} = R_{\tau n} - E(R_{\tau n}), \qquad (1)$$

where $R_{\tau n}$ and $E(R_{\tau n})$ are the observed freight rate or FFA log-returns and the expected log-return, respectively.

In order to account for the fact that OPEC announcements may partially be anticipated and processing of the information may take longer than one day, the abnormal return behavior is studied over a multi-day event window around the announcement day (τ = 0). We choose the event window (with length L_2) to range from $\tau_1 = -8$ to $\tau_2 = +8$, yielding $L_2 = 17$ event days. This event window appears long enough to analyze the full event-induced changes in freight rates, yet not too long in order to avoid excess contamination of the event period with non-event information.[10]

4.1 Estimation Procedures

The principal challenge in any event study is, by implication, the estimation of expected returns. However, short-term event studies are found to be less sensitive to the choice of return-generating models (Kothari and Warner, 2006). Based on the analysis by McKenzie et al. (2004), we employ both the mean-adjusted return model as well as the market model to estimate expected returns. Besides the fact that Brown and Warner (1980) show that these two approaches perform similarly well in detecting event-induced abnormal returns, selecting multiple methodological approaches is expected to enhance the robustness of our empirical results. This may be considered as a partial remedy to the "joint hypothesis problem" (Brenner, 1977).

[10] In comparison, Bina & Vo (2007) employ an 11-day event window while Lin & Tamvakis (2010) and Demirer & Kutan (2010) use 21 days and 41 days, respectively. The event study presented in this paper was also performed based on 11-day and 21-day event windows, which produced results similar to the ones presented in this paper.

a) *Mean-Adjusted Returns:* The mean-adjusted return model is based on the assumption that the expected return during the event window equals a constant rate of return ($\overline{R}_{\tau n}$), which is estimated as the mean freight rate return during the estimation period preceding the event window:

$$E(R_{\tau n}) = \overline{R}_{\tau n} = \frac{1}{L_1} \sum_{t=1}^{L_1} R_{\tau n}, \qquad (2)$$

where L_1 is the number of days in the estimation period. The mean-adjusted return model has been performed based on $L_1 = 30$, which is a common choice in the literature (see McKenzie et al., 2004).[11]

In particular with respect to performing event studies on freight and freight derivative markets, the mean-adjusted return model is methodologically appealing. This is because selecting an appropriate reference market index, which is inevitable to perform analyses based on the market model, can be somewhat cumbersome for commodity markets. Given that the mean-adjusted return model relies solely on freight return series itself in order to establish expected returns, no reference return series is required for this model. Exemplary event studies on commodity markets that relied on mean-adjusted returns include Milonas (1987), Miclăuș et al. (2008), and Lin and Tamvakis (2010).

b) *Market Model:* Employing the market model, the return generating process is modeled by relating the return series under investigation to a benchmark return series, which is selected to represent the reference market portfolio. As the choice of the reference market is a central issue in the estimation of the market model – especially, when dealing with event studies on commodities (McKenzie et al., 2004) – two alternative specifications are formulated. On the one hand, the Clarksea index (CSI), which is a value-weighted index of freight rate earnings in the main shipping markets (i.e. bulk, container, and tanker shipping), is chosen to represent the broad shipping market. Freight earnings in the tanker market are thus related

[11] In fact, based on their simulations, McKenzie et al. (2004) argue that shorter estimation windows yield inappropriate rejection rates of the null hypothesis, while constant mean return event studies based on 30-day estimation windows perform well. However, due to its regular use in the literature, the 8-day estimation window was tested for sake of robustness. The results qualitatively correspond with the ones based on a 30-day estimation window presented in this paper.

to earnings across shipping segments.[12] An analogous approach is taken by Demirer and Kutan (2010), who relate returns in the crude oil market to returns in the broad Dow Jones AIG commodity index. On the other hand, a narrower definition of the reference market is used in the second specification. For this purpose, a market index is constructed by arithmetically averaging the spot freight rates for crude oil trading routes that are not perceived to be directly affected by OPEC prediction volumes. Specifically, the Baltic Exchange basket routes TD7 (North Sea to Continent) and TD9 (Caribbean to US Gulf) are used.[13]

To determine abnormal returns around OPEC announcements, the market model is estimated with two alternative procedures: First, the single-factor market model is estimated in its standard Ordinary Least Square (OLS) form based on the dummy variable approach (Karafiath, 1988):

$$R_{tn} = \alpha_n + \beta_n R_t^m + \sum_{\tau=1}^{L_2} \gamma_{\tau n} D_{\tau n} + \varepsilon_{tn}, \qquad (3)$$

where R_t^m is the reference market return and $\gamma_{\tau n}$ is a vector of the abnormal returns for each event day τ. Dummy variable $D_{\tau n}$ represents individual days of the event window (τ_1 to τ_2, totaling to L_2 dummy variables). $D_{\tau n}$ assumes the value of one for the corresponding event day τ and zero otherwise.

Second, analogous to, for example, Bina and Vo (2007), the market model is also estimated as a modified market model to allow for non-constant volatility in freight rate and freight rate derivatives returns, as described above. Specifically, we employ Bollerslev's (1986) Generalized Autoregressive Conditional Heteroskedasticity (GARCH)-process with a

[12] It shall be noted that we certainly do not assume a long-term stable linear relationship to exist between the broad shipping market and the specific tanker trading route investigated here. As the market model is estimated separately for each event, we only assume the linear relationship to hold for the limited time of the event window.

[13] The choice of these basket routes is dictated by the suspected independence from OPEC output decisions as well as data availability over the entire sample period. As an alternative, the Baltic Dirty Tanker Index (BDTI) was considered as a proxy for the market index. However, the BDTI turned out to suffer from endogeneity issues as a large share of it is impacted by OPEC production volumes.

GARCH (1,1) specification, as generically defined in Corhay and Tourani (1996), with mean equation:[14]

$$R_{tn} = \alpha_n + \beta_n R_t^m + \sum_{\tau=1}^{L_2} \gamma_{\tau n} D_{\tau n} + \varepsilon_{tn} \qquad \varepsilon_{tn}|\Omega_t \sim N(0, h_{tn}), \qquad (4)$$

and variance equation:

$$h_{tn} = k_n + \rho_{1n}\varepsilon_{t-1n}^2 + \rho_{2n}h_{t-1n}, \qquad (5)$$

where h_{tn} is the conditional variance term, k_n, ρ_{1n} and ρ_{2n} are regression coefficients, and Ω_t is the information set at time *t.* McKenzie et al. (2004) argue that GARCH-based modified market models are slightly more powerful than OLS-based market models. This is because of their capacity to take into account common distributional characteristics of commodity (derivative) returns, for example, excess kurtosis and volatility clustering, which are also identified in section 3. Furthermore, the use of the modified market model is considered appropriate to partially overcome the problem of event-induced volatility (see, for example, Pynnönen, 2005). Both the market model and the modified market model are estimated with a 60-day estimation period as done by Demirer and Kutan (2010), among others.[15]

4.2 Hypothesis Testing

Following MacKinlay (1997), a cross-sectional average abnormal returns on event day τ (AAR_τ) is required to analyze the collective freight rate behavior around OPEC announcements:

$$AAR_\tau = \frac{1}{N}\sum_{n=1}^{N} AR_{\tau n}, \qquad (6)$$

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[14] Evidently, a large variety of GARCH models is available in the literature. However, empirical evidence suggests that the standard GARCH (1,1) approach often performs at least as well as more complex GARCH-specifications (see Hansen & Lunde, 2005, who study daily exchange rate and stock returns). The GARCH (1,1) model has been applied to the tanker freight markets in other research settings, such as in Kavussanos (2003) or Kavussanos & Dimitrakopoulos (2011). This issue is also discussed by Lauenstein & Walther (2016).

[15] We employ comparatively short estimation (L_1: 30 days for the mean-adjusted return model and 60 days for the market model) and event windows (L_2: 17 days) to keep the event effects separate from another (see Lin & Tamvakis, 2010, on this issue as well).

Moreover, an accumulation of average abnormal returns over time (cumulative average abnormal returns, $CAAR_{(\tau_1,\tau_2)}$) is necessary in order to analyze event-induced returns in a multi-day event period:

$$CAAR_{(\tau_1,\tau_2)} = \sum_{t=\tau_1}^{\tau_2} AAR_{\tau}, \qquad (7)$$

In our analysis, the event study methodology is made use of in order to test the following hypotheses:

$$H_0: CAAR_{(\tau_1,\tau_2)} = 0$$

$$H_A: CAAR_{(\tau_1,\tau_2)} \neq 0$$

where cumulative average abnormal returns are expected to have positive (negative) signs in case of production increases (cuts).

a) *Parametric Approach:* We employ the standardized cross-sectional test statistic proposed by Boehmer et al. (BMP, 1991), which is robust to event-inducted volatility and heterogeneous variances of abnormal returns across events. The BMP test statistic (t_1) is formalized as

$$t_1 = \sqrt{N}\frac{CSAAR_{(\tau_1,\tau_2)}}{s_{CSAAR_{(\tau_1,\tau_2)}}}, \qquad (8)$$

where $CSAAR_{(\tau_1,\tau_2)}$ is the cumulative standardized average abnormal return across N events during the event window from days τ_1 to τ_2 calculated as

$$CSAAR_{(\tau_1,\tau_2)} = \frac{1}{N}\sum_{n=1}^{N} CSAR_{n(\tau_1,\tau_2)}, \qquad (9)$$

and with standard deviation of $CSAAR_{(\tau_1,\tau_2)}$ given as

$$s_{CSAAR_{(\tau_1,\tau_2)}} = \frac{1}{N-1}\sum_{n=1}^{N}(CSAR_{n(\tau_1,\tau_2)} - CSAAR_{(\tau_1,\tau_2)})^2. \qquad (10)$$

Abnormal returns are standardized as follows

$$SAR_{n\tau} = \frac{AR_{n\tau}}{s_{AR_{n(L_1)}}}, \qquad (11)$$

where $s_{AR_{n(L_1)}}$ is the specific time series standard deviation of abnormal returns of event n during its estimation period. Then, $SAR_{n\tau}$ can be accumulated as in equation (7).

Adapting the approach offered by Savickas (2003), the above BMP test statistic (t_1) can be improved for the GARCH-augmented modified market model by standardizing abnormal returns with the conditional variance. Consequently, equation (11) can be rewritten as

$$SAR_{n\tau}^{GARCH} = \frac{AR_{n\tau}}{\sqrt{h_{tn}}}, \qquad (12)$$

with h_{tn} being the conditional variance from the GARCH model, as outlined in equation (5). The GARCH-based test (t_2) statistic can be formulated accordingly:

$$t_2 = \sqrt{N}\frac{CSAAR_{(\tau_1,\tau_2)}^{GARCH}}{s_{CSAAR_{(\tau_1,\tau_2)}^{GARCH}}}. \qquad (13)$$

b) *Non-Parametric Approach:* In view of the comparatively small amount of sample events, a non-parametric test statistic is applied to complement the above parametric tests.[16] This approach may also be considered as a partial remedy to the non-normality of freight rate and FFA returns, as discussed in section 3.

We employ the Corrado (1989) rank test with its multiday extension suggested by Cowan (1992) to derive a non-parametric test statistic (t_3) for $CAAR_{(\tau_1,\tau_2)}$:

$$t_3 = \sqrt{L_2}\frac{\overline{K}_{N(\tau_1,\tau_2)} - K_n}{s_{\overline{K}}}. \qquad (14)$$

Here, abnormal returns from a combined estimation and event period ($L_1 + L_2$) are ranked, with 1 indicating the lowest rank. The average rank across N events and the event window days τ_1 to τ_2 is represented by $\overline{K}_{N(\tau_1,\tau_2)}$, K_n is the mid-rank per event n, L_2 is the length of the event window, and $s_{\overline{K}}$ is the standard deviation of ranks over the combined estimation and event period.

[16] For other applications of non-parametric test statistics to commodity derivative markets see Bina & Vo (2007) and for a recent general methodological review see Kolari & Pynnönen (2011).

4.3 Robustness: Random Sampling

To further examine the robustness of our methodological approach, in particular concerning the expected return measures, we performed a random sampling procedure by selecting a pseudo-sample of 50 random event dates from our dataset. We then perform the event study procedure outlined above on this random pseudo-sample. The results from this procedure indicate that no significant cumulative abnormal returns can be observed based on a sample of randomly drawn event dates (see Table A.1 in the appendix for the respective cumulative average abnormal returns and Figures 2 to 4 for graphical representations). This underlines the suitability of our methodological approach.

5 Empirical Results

$CAAR$ paths are presented in Figures 2 to 4 based on normal return estimations from the mean-adjusted model, market model, and modified market model, respectively. Return paths for reactions to each output announcement type are illustrated in separate panels for the three freight and freight forwards return series. Generally, as documented in other event studies on commodity markets (see section 2), detected abnormal returns are large in size, in particular compared to abnormal returns typically observed event studies on stock markets.

Figure 2
Cumulative average abnormal returns using the mean-adjusted return model ($CAAR_{MAR}$)

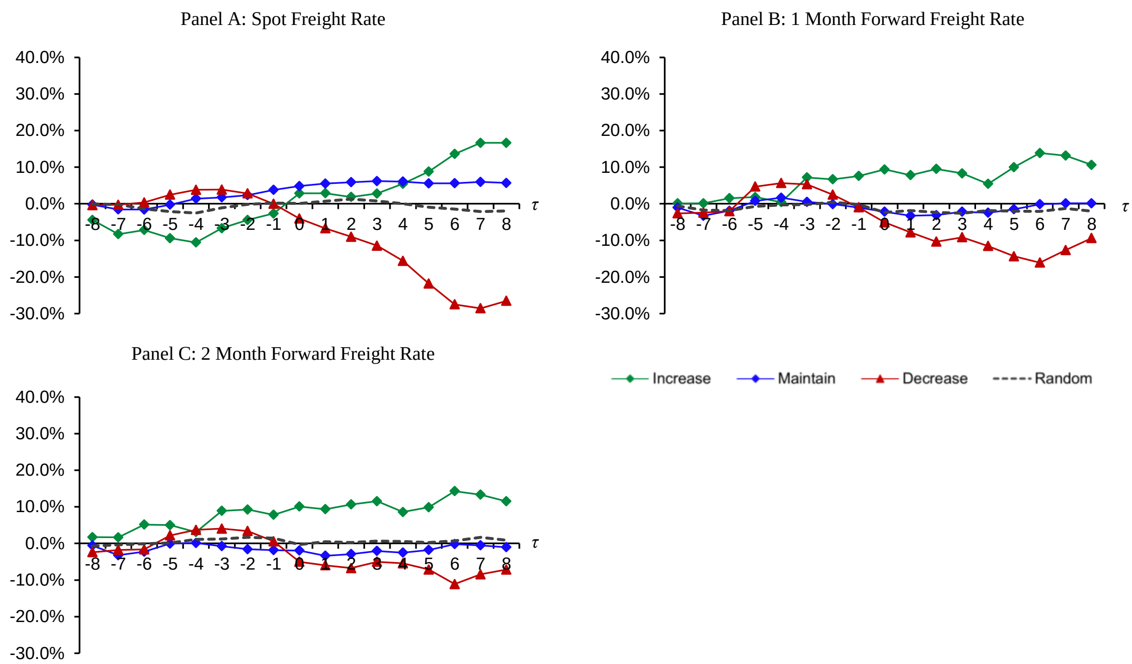


Figure 3
Cumulative average abnormal returns using the OLS market model and the CSI $(CAAR_{OLS}^{CSI})$

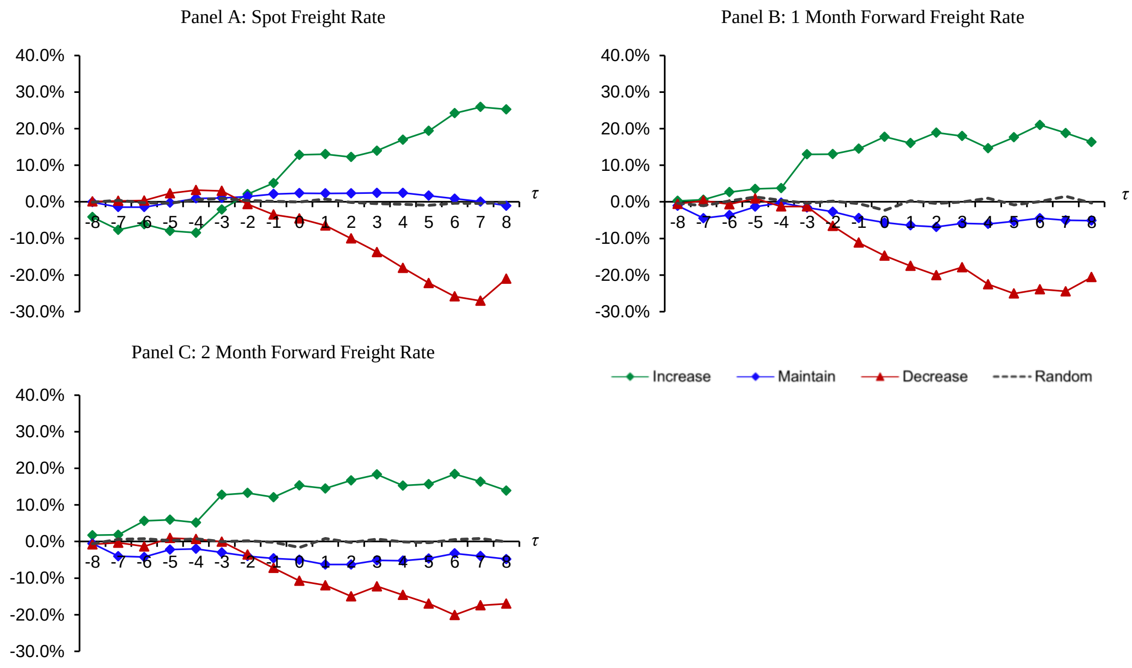


Figure 4
Cumulative average abnormal returns using the GARCH modified market model and the CSI $(CAAR_{GARCH}^{CSI})$

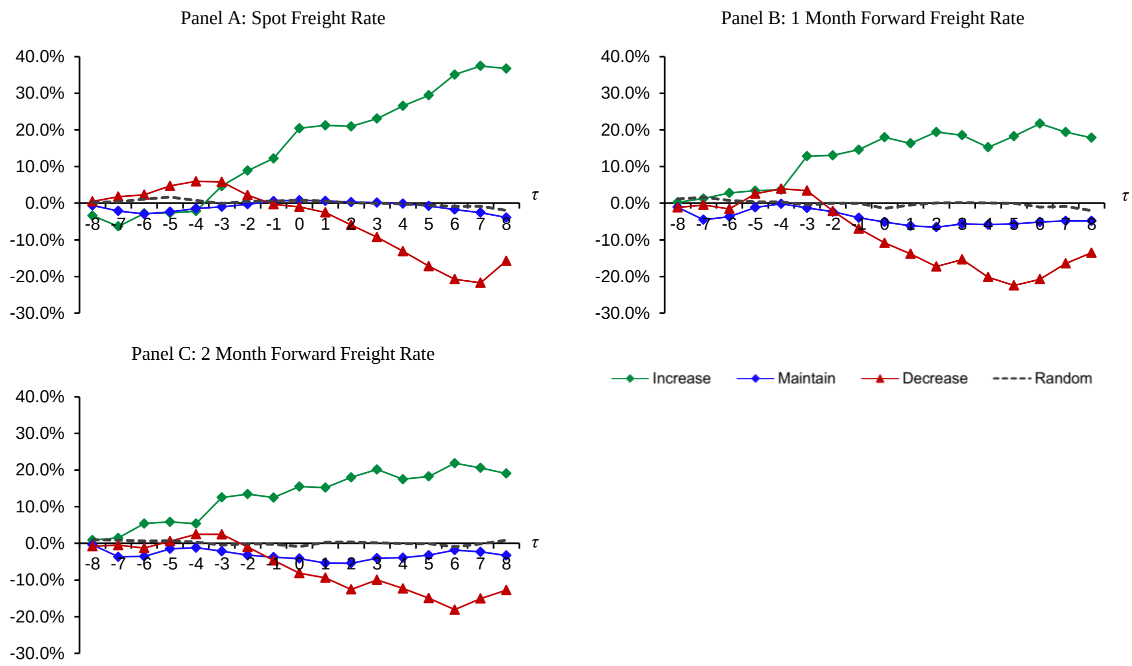


Figure 5
Cumulative average abnormal returns using the OLS market model and the Tanker Index ($CAAR_{OLS}^{TD}$)

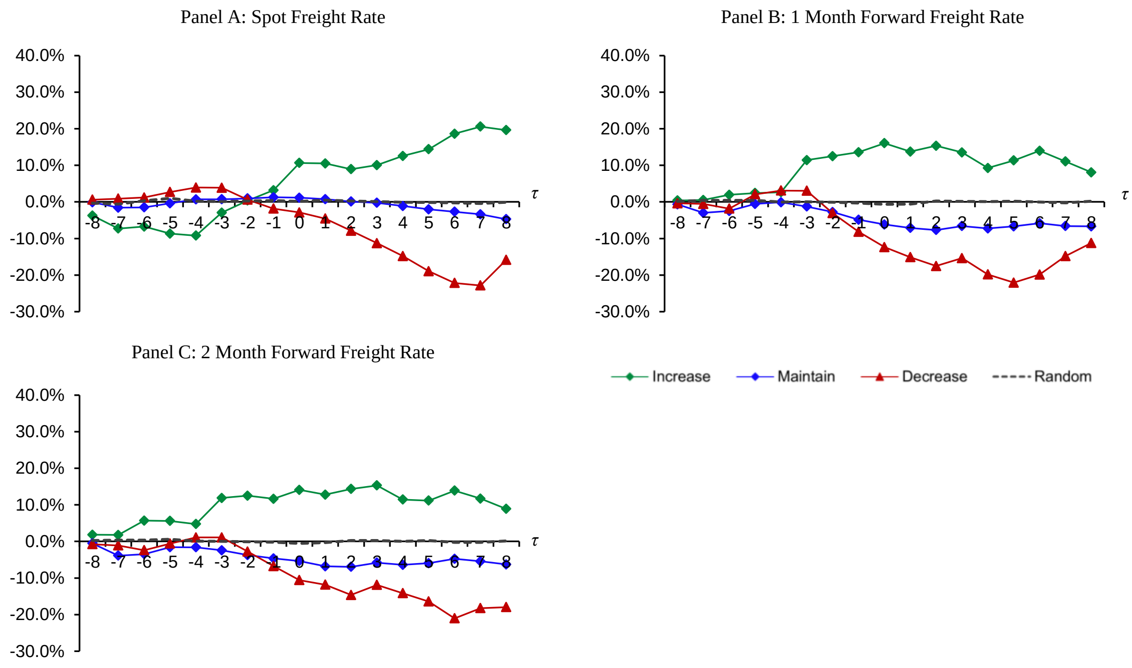
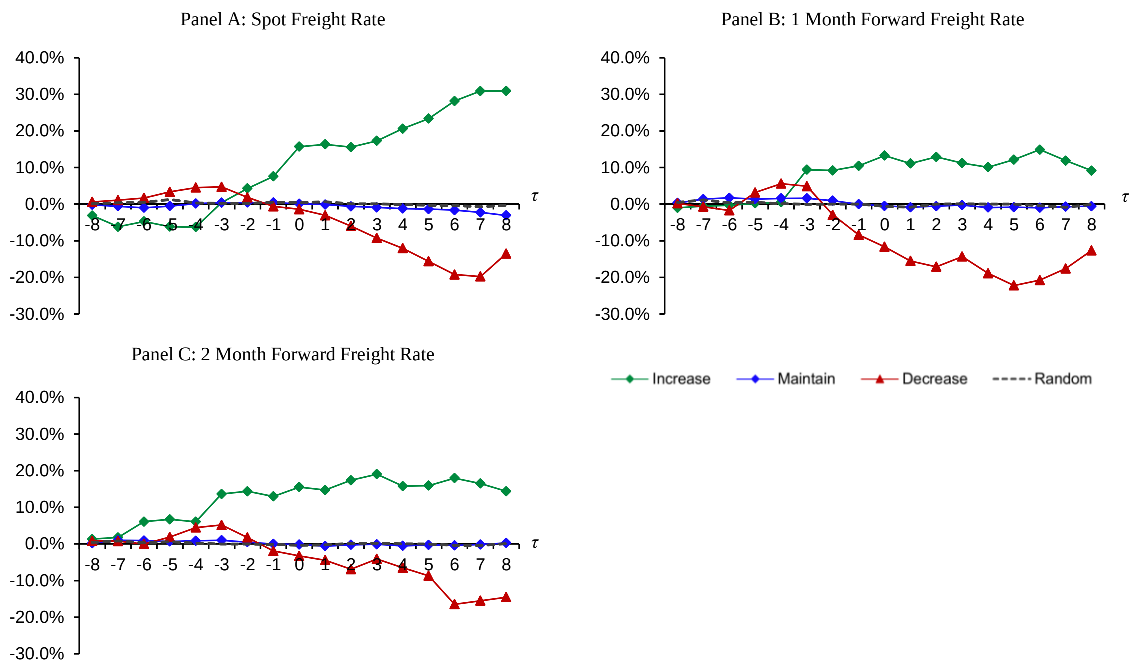


Figure 6
Cumulative average abnormal returns using the GARCH modified market model and the Tanker Index ($CAAR_{GARCH}^{TD}$)



An initial visual inspection of the $CAAR$ paths illustrated in Figures 2 to 6 shows that, consistently for all three normal return models and maturities, the tanker freight markets on the TD3 route react to OPEC output announcements. This is in accordance with the initially formulated conjecture about the relationship between crude oil production levels and freight rates: positive abnormal returns can be observed around production increase announcements, while the tanker freight market reacts negatively to announcements of deceased future crude oil production levels. Announcements of maintained production levels do not seem to cause market reactions. Abnormal returns reveal that the market has not fully anticipated and priced the information content of OPEC announcements prior to the event window selected here. Thus, it appears that OPEC decisions carry a surprise component for the tanker market. However, as also observed by Deaves and Krinsky (1992) as well as Demirer and Kutan (2010) for the crude oil market, it is visible that the information content of the announcements is anticipated by market participants three to five days in advance of the event day, both for output increases and cuts and across normal return estimation models. This short-term formation of *a priori* expectations about the actual outcome of the OPEC conferences prior to the official announcement may be attributed to the fact that rumors about the outcome of the conference may disseminate in the market due to information leakages. In general, reactions to output announcements are observed to be somewhat stronger for spot freight returns as compared to forward markets. Existing empirical evidence that information is processed faster in the FFA market as compared to the spot market, which is attributed to comparatively lower transaction costs in the paper market (Kavussanos and Visvikis 2004), cannot be supported by a visual inspection of Figures 2 to 4. Moreover, "good news" triggered by production quota increase announcement seems to induce larger abnormal returns as compared to "bad news". Here, Lin and Tamvakis (2010) suggest that the enforcement of quota cuts by the individual OPEC member states may be less credible as compared to quota increases. Contrasting the alternative specifications of the (modified) market model based on the CSI ($CAAR^{CSI}$) and the tanker index ($CAAR^{TD}$), it appears that abnormal returns from the CSI-based model are somewhat larger. However, both specifications yield similar $CAAR$ paths. Finally, persistence of $CAAR$ can be observed, particularly in the spot freight. Diminishing $CAAR$ towards the end of the event window may moreover indicate inefficiencies in the form of market overreactions (and corresponding readjustment) for both increases and more pronounced decreases of production levels.

The parametric significance of $CAAR$ paths against the null hypothesis is formally tested, as presented in Table 2. Contrasting the first visual impression, $CAAR$ in the spot market across normal return estimation procedures and announcement types are mostly insignificant. The only exception is the GARCH-type market model based on the CSI in case of increase announcements (Panel A, $CAAR_{GARCH}^{CSI}$). The insignificance of abnormal returns may partially be ascribed to the higher volatility inherent in the spot return series (see Table 1). Otherwise, the above findings from the visual inspections of the $CAAR$ paths can largely be confirmed in Table 2. Interestingly, some significance of negative abnormal returns can be detected around announcements of maintained OPEC production levels. From a methodological point-of-view, the market model and modified market model, the related test statistics t_1 and t_2, as well as the specifications based on the CSI ($CAAR^{CSI}$) and the tanker index ($CAAR^{TD}$) perform similarly in detecting significance of abnormal returns. With respect to the mean-adjusted return model, although cumulative abnormal returns are large in size, the null hypothesis of no abnormal returns cannot be rejected, which supports the perception that abnormal returns from the mean-adjusted return model have a greater variance as compared to abnormal returns generated by the market model (MacKinlay, 1997).

Table 2
Cumulative average abnormal returns and parametric significance testing

	Spot Returns					1 Month Forward Returns					2 Months Forward Returns				
τ	$CAAR_{MAR}$	$CAAR_{OLS}^{CSI}$	$CAAR_{GARCH}^{CSI}$	$CAAR_{OLS}^{TD}$	$CAAR_{GARCH}^{TD}$	$CAAR_{MAR}$	$CAAR_{OLS}^{CSI}$	$CAAR_{GARCH}^{CSI}$	$CAAR_{OLS}^{TD}$	$CAAR_{GARCH}^{TD}$	$CAAR_{MAR}$	$CAAR_{OLS}^{CSI}$	$CAAR_{GARCH}^{CSI}$	$CAAR_{OLS}^{TD}$	$CAAR_{GARCH}^{TD}$
Panel A: Increase															
-8	-0.04	-0.04	-0.03	0.00	-0.03	0.00	0.00	0.00	0.00	-0.01	0.02	0.02	0.01 *	0.02	0.01
-7	-0.08	-0.08	-0.06	0.01	-0.06	0.00	0.01	0.01	0.01	-0.01	0.02 ***	0.02 *	0.01	0.02 ***	0.02**
-6	-0.07	-0.06	-0.03	0.02	-0.05	0.02 ***	0.03	0.03	0.02	0.00	0.05 **	0.06	0.05	0.06 **	0.06*
-5	-0.09	-0.08	-0.03	0.02	-0.06	0.02 **	0.04	0.03	0.02	0.00	0.05 *	0.06	0.06	0.06 *	0.07**
-4	-0.11	-0.08	-0.02	0.03	-0.06	0.00	0.04	0.04	0.03	0.00	0.03	0.05	0.05	0.05 *	0.06**
-3	-0.07	-0.02	0.05 **	0.11	0.00	0.07	0.13 **	0.13 *	0.11 **	0.09	0.09 *	0.13 **	0.13	0.12 **	0.14**
-2	-0.04	0.02	0.09 **	0.12	0.04	0.07	0.13 **	0.13 *	0.12 **	0.09	0.09	0.13 **	0.13	0.12 **	0.14
-1	-0.03	0.05	0.12 **	0.14	0.08	0.08	0.15 ***	0.15 **	0.14 **	0.10	0.08	0.12 **	0.12	0.12 **	0.13
0	0.03	0.13	0.20 **	0.16	0.16	0.09	0.18 ***	0.18 **	0.16 *	0.13	0.10	0.15 **	0.16 **	0.14 **	0.16*
1	0.03	0.13	0.21 *	0.14	0.16	0.08	0.16 ***	0.16 *	0.14 *	0.11	0.09	0.14 **	0.15 **	0.13 **	0.15**
2	0.02	0.12	0.21	0.15	0.16	0.10	0.19 ***	0.19 **	0.15 *	0.13	0.11	0.17 **	0.18 *	0.14 **	0.17**
3	0.03	0.14	0.23 *	0.14	0.17	0.08	0.18 **	0.19 **	0.14	0.11	0.12	0.18 **	0.20 *	0.15 *	0.19
4	0.05	0.17	0.27	0.09	0.21	0.05	0.15 **	0.15 **	0.09	0.10	0.09	0.15 ***	0.17 *	0.11 *	0.16
5	0.09	0.19	0.29	0.11	0.23	0.10	0.18 **	0.18 **	0.11 **	0.12	0.10 *	0.16 ***	0.18 *	0.11 **	0.16
6	0.14	0.24	0.35	0.14	0.28	0.14 *	0.21 **	0.22 **	0.14 **	0.15 *	0.14 **	0.18 ***	0.22 *	0.14 **	0.18
7	0.17	0.26	0.37	0.11	0.31	0.13 *	0.19 **	0.19 *	0.11 **	0.12	0.13 *	0.16 ***	0.21 *	0.12 **	0.17
8	0.17	0.25 *	0.37 *	0.08	0.31	0.11 *	0.16 *	0.18	0.08 ***	0.09	0.12 *	0.14 **	0.19 *	0.09 *	0.14
Panel B: Maintain															
-8	0.00	0.00	-0.01 **	0.00	0.00	-0.01	-0.01	-0.01	-0.01	0.00	-0.01	-0.01	0.00	-0.01	0.00*
-7	-0.02	-0.01	-0.02 ***	-0.02	-0.01	-0.03 *	-0.04 **	-0.05 *	-0.03	0.01	-0.03 *	-0.04 **	-0.04	-0.04 *	0.01
-6	-0.02	-0.01	-0.03	-0.02	-0.01	-0.02	-0.04 *	-0.04	-0.02	0.02	-0.02	-0.04 *	-0.04	-0.03	0.01
-5	0.00	0.00	-0.02	0.00	-0.01	0.01	-0.01	-0.01	-0.01	0.01	0.00	-0.02	-0.01	-0.02	0.01
-4	0.01	0.01	-0.01	0.01	0.00	0.02	0.00	0.00	0.00	0.02	0.00	-0.02	-0.01	-0.02	0.01
-3	0.02	0.01	-0.01	0.01	0.00	0.01	-0.02	-0.01	-0.01	0.02	-0.01	-0.03	-0.02	-0.02	0.01
-2	0.02	0.01	0.00	0.01	0.00	0.00	-0.03	-0.02	-0.03	0.01	-0.02	-0.04	-0.03	-0.04	0.00
-1	0.04	0.02	0.01	0.01	0.00	-0.01	-0.04 *	-0.04	-0.05	0.00	-0.02	-0.05	-0.04	-0.05	0.00
0	0.05	0.02	0.01	0.01	0.00	-0.02	-0.06 *	-0.05	-0.06 *	0.00	-0.02	-0.05	-0.04	-0.05 *	0.00
1	0.06	0.02	0.01	0.01	0.00	-0.03	-0.06 **	-0.06	-0.07 **	-0.01	-0.03	-0.06 **	-0.05	-0.07 **	-0.01
2	0.06	0.02	0.00	0.00	-0.01	-0.03	-0.07 **	-0.07 **	-0.08 **	-0.01	-0.03	-0.06 *	-0.05	-0.07 **	0.00
3	0.06	0.02	0.00	0.00	-0.01	-0.02	-0.06 *	-0.06 *	-0.07	0.00	-0.02	-0.05	-0.04	-0.06 *	0.00
4	0.06	0.02	0.00	-0.01	-0.01	-0.02	-0.06 *	-0.06 *	-0.07 *	-0.01 *	-0.03	-0.05	-0.04	-0.06 *	-0.01
5	0.06	0.02	-0.01	-0.02	-0.01	-0.01	-0.05	-0.06 *	-0.07	-0.01	-0.02	-0.05	-0.03	-0.06 *	0.00
6	0.06	0.01	-0.02	-0.03	-0.02	0.00	-0.04	-0.05	-0.06	-0.01	0.00	-0.03	-0.02	-0.05	0.00
7	0.06	0.00	-0.03	-0.03	-0.02	0.00	-0.05	-0.05	-0.07	-0.01	-0.01	-0.04	-0.02	-0.05	0.00
8	0.06	-0.01	-0.04	-0.05	-0.03	0.00	-0.05	-0.05	-0.07	-0.01	-0.01	-0.05	-0.03	-0.06	0.00
Panel C: Decrease															
-8	0.00	0.00	0.00	0.01	0.01	-0.03	-0.01	-0.01	0.00	0.00	-0.02	-0.01	-0.01	-0.01	0.01
-7	0.00	0.00	0.02	0.01	0.01	-0.02	0.00	0.00	-0.01	-0.01	-0.02	0.00	-0.01	-0.01	0.01
-6	0.00	0.00	0.02	0.01	0.02	-0.02	-0.01	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	-0.02	0.00
-5	0.02	0.02	0.05	0.03	0.03	0.05	0.01	0.03	0.02	0.03	0.02	0.01	0.01	-0.01	0.02
-4	0.04	0.03	0.06	0.04	0.05	0.06	-0.01	0.04 *	0.03	0.06	0.04 *	0.01	0.02 *	0.01	0.04*
-3	0.04	0.03	0.06	0.04	0.05	0.05	-0.01	0.03	0.03	0.05	0.04 *	0.00	0.02	0.01	0.05
-2	0.03	-0.01	0.02	0.01	0.02	0.02	-0.07	-0.02	-0.03	-0.03	0.03	-0.04	-0.01	-0.03	0.02
-1	0.00	-0.03	0.00	-0.02	-0.01	-0.01	-0.11 *	-0.07	-0.08 *	-0.08 ***	0.01	-0.07	-0.05	-0.07	-0.02
0	-0.04	-0.05	-0.01	-0.03	-0.01	-0.05	-0.15 *	-0.11 *	-0.12 *	-0.12 ***	-0.05	-0.11	-0.08	-0.11	-0.03
1	-0.07	-0.06	-0.03	-0.05	-0.03	-0.08	-0.17 *	-0.14 **	-0.15 **	-0.15 ***	-0.06	-0.12	-0.09	-0.12	-0.04
2	-0.09	-0.10	-0.06	-0.08	-0.06	-0.10	-0.20 *	-0.17 ***	-0.18 **	-0.17 ***	-0.07	-0.15	-0.13	-0.15 *	-0.07
3	-0.11	-0.14	-0.09	-0.11	-0.09	-0.09	-0.18 *	-0.15 *	-0.15 *	-0.14 ***	-0.05	-0.12	-0.10	-0.12	-0.04
4	-0.16	-0.18	-0.13	-0.15	-0.12	-0.12	-0.23 **	-0.20 ***	-0.20 **	-0.19 ***	-0.05	-0.15 *	-0.12	-0.14 *	-0.07
5	-0.22	-0.22	-0.17	-0.19	-0.16	-0.14	-0.25 **	-0.22 ***	-0.22 ***	-0.22 ***	-0.07	-0.17 *	-0.15	-0.16 **	-0.09
6	-0.27	-0.26	-0.21	-0.22	-0.19	-0.16	-0.24 **	-0.21 ***	-0.20 ***	-0.21 ***	-0.11	-0.20 *	-0.18	-0.21 **	-0.16
7	-0.29	-0.27	-0.22	-0.23	-0.20	-0.13	-0.24 *	-0.16 **	-0.15 **	-0.18 ***	-0.08	-0.17 *	-0.15	-0.18 **	-0.16
8	-0.27	-0.21	-0.16	-0.16	-0.14	-0.09	-0.21 *	-0.13	-0.11 **	-0.13 ***	-0.07	-0.17 *	-0.13	-0.18 **	-0.15

Notes: $CAAR_{MAR}$ characterize cumulative abnormal return estimation based on the mean-adjusted model. $CAAR_{OLS}^{CSI}$ and $CAAR_{OLS}^{TD}$ are cumulative abnormal returns from the OLS market model estimated based on the CSI and the tanker index, respectively. $CAAR_{GARCH}^{CSI}$ and $CAAR_{GARCH}^{TD}$ are cumulative abnormal returns from the GARCH-augmented modified market model estimated based on the CSI and the tanker index, respectively. The market model was estimated with Newey-West correction for heteroskedasticity and autocorrelation. Significance of $CAAR_{MAR}$ and $CAAR_{OLS}$ against the null hypothesis has been tested based on test statistic t_1 and $CAAR_{GARCH}$ based on t_2, both being assumed to follow a t-distribution. Asterisks *, ** and *** indicate significance at levels of 10%, 5% and 1%, respectively.

The results of the non-parametric test of the significance of $CAAR$ over the event window are reported in Table 3. Significant cumulative abnormal returns confirm the informational importance of OPEC announcements to increase or decrease production levels for the tanker freight and FFA market. However, there are some instances where the parametric test statistic identifies significant $CAAR$ over the event window but the non-parametric test does not, and vice versa.

Table 3
Non-parametric significance testing over the event window

	Spot Returns			1 Month Forward Returns			2 Months Forward Returns		
τ1 to τ2	Increase	Maintain	Decrease	Increase	Maintain	Decrease	Increase	Maintain	Decrease
$CAAR_{MAR}$	0,17	0,06	-0,27 *	0,11	0,00	-0,09 *	0,12	-0,01	-0,07 *
$CAAR_{OLS}^{CSI}$	0,25 *	-0,01	-0,21	0,16 **	-0,05	-0,21 *	0,14 *	-0,05	-0,17 *
$CAAR_{GARCH}^{CSI}$	0,37 **	-0,04	-0,16	0,18 **	-0,05	-0,13	0,19	-0,03	-0,13
$CAAR_{OLS}^{TD}$	0,20	-0,05	-0,16	0,08 *	-0,07	-0,11	0,09	-0,06	-0,18
$CAAR_{GARCH}^{TD}$	0,31 **	-0,03	-0,14	0,09	-0,01	-0,13	0,14 *	0,00	-0,15 **

Notes: $CAAR_{MAR}$ characterize cumulative abnormal return estimation based on the mean-adjusted model. $CAAR_{OLS}^{CS}$ and $CAAR_{OLS}^{TD}$ are cumulative abnormal returns from the OLS market model estimated based on the CSI and the tanker index, respectively. $CAAR_{GARCH}^{CS}$ and $CAAR_{GARCH}^{TD}$ are cumulative abnormal returns from the GARCH-augmented modified market model estimated based on the CSI and the tanker index, respectively. Significances of cumulative average abnormal returns have been tested based on test statistic t_3, which is assumed to follow a t-distribution. Asterisks *, ** and *** indicate significance at levels of 10%, 5% and 1%, respectively.

To further test if the freight market reacts efficiently to OPEC announcements from an informational efficiency perspective, we test the significance of individual AAR in the post-event period. The results in Table 4 indicate that significant post-event abnormal returns can be observed across event types and normal return estimation procedures, suggesting either incomplete initial market reactions or readjustments following initial overreactions, which is in support of the initial visual observation of $CAAR$ paths. This could indicate excess profit opportunities for market players that take positions in the freight market based on public information. Short-term informational inefficiencies in the FFA markets, as indicated above, are in line with the findings by Goulas and Skiadopoulos (2012).

Table 4
Average abnormal returns and parametric significance testing

	Spot Returns					1 Month Forward Returns					2 Months Forward Returns				
τ	AAR_{MAR}	AAR_{OLS}^{CSI}	AAR_{GARCH}^{CSI}	AAR_{OLS}^{TD}	AAR_{GARCH}^{TD}	AAR_{MAR}	AAR_{OLS}^{CSI}	AAR_{GARCH}^{CSI}	AAR_{OLS}^{TD}	AAR_{GARCH}^{TD}	AAR_{MAR}	AAR_{OLS}^{CSI}	AAR_{GARCH}^{CSI}	AAR_{OLS}^{TD}	AAR_{GARCH}^{TD}
Panel A: Increase															
1	0.00	0.00	0.01	0.00	0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	0.00	-0.01	-0.01
2	-0.01	-0.01	0.00	-0.02	-0.01	0.02**	0.03**	0.03**	0.02	0.02	0.01	0.02	0.03	0.02	0.03
3	0.01	0.02*	0.02*	0.01	0.02	-0.01	-0.01	-0.01	-0.02	-0.02	0.01	0.02	0.02	0.01	0.02
4	0.03	0.03	0.03	0.02	0.03	-0.03	-0.03	-0.03	-0.04*	-0.01	-0.03	-0.03	-0.03	-0.04*	-0.03
5	0.03*	0.02*	0.03	0.02	0.03*	0.05**	0.03***	0.03	0.02	0.02	0.01	0.00	0.01	0.00	0.00
6	0.05*	0.05	0.06	0.04	0.05	0.04**	0.03	0.03*	0.03*	0.03	0.04*	0.03*	0.04**	0.03*	0.02
7	0.03**	0.02	0.02	0.02	0.03	-0.01***	-0.02	-0.02	-0.03	-0.03	-0.01	-0.02	-0.01	-0.02	-0.01
8	0.00	-0.01	-0.01	-0.01	0.00	-0.03	-0.02	-0.02	-0.03	-0.03	-0.02	-0.02	-0.02	-0.03	-0.02
Panel B: Maintain															
1	0.01	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	0.00	-0.01	-0.01*	-0.01	-0.01***	0.00
2	0.00	0.00	0.00	-0.01	-0.01	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01*	0.01	0.01	0.00
4	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	-0.01	-0.01	0.00	0.00	0.00	-0.01*	0.00
5	0.00	-0.01	-0.01	-0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.00
6	0.00	-0.01	-0.01	-0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.02**	0.01	0.01*	0.01	0.00
7	0.00	-0.01	-0.01	-0.01	-0.01	0.00	-0.01	0.00	-0.01	0.00	0.00	-0.01	0.00	-0.01	0.00
8	0.00	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	0.00*
Panel C: Decrease															
1	-0.03	-0.02	-0.02	-0.02	-0.02	-0.03***	-0.03	-0.03	-0.03	-0.04	-0.01	-0.01	-0.01	-0.01	-0.01
2	-0.02*	-0.04	-0.03	-0.03**	-0.03	-0.03	-0.03	-0.03***	-0.02	-0.02**	-0.01	-0.03	-0.03	-0.03*	-0.02
3	-0.02**	-0.04	-0.03	-0.03	-0.03	0.01	0.02	0.02	0.02	0.03	0.02	0.03	0.03	0.03	0.03
4	-0.04***	-0.04**	-0.04	-0.04*	-0.03	-0.02*	-0.05**	-0.05*	-0.04*	-0.05*	0.00	-0.02	-0.02	-0.02	-0.02
5	-0.06**	-0.04	-0.04	-0.04	-0.04	-0.03*	-0.03	-0.02	-0.02	-0.03*	-0.02***	-0.02**	-0.03*	-0.02**	-0.02
6	-0.06**	-0.04	-0.04	-0.03	-0.04	-0.02	0.01	0.02	0.02	0.01	-0.04	-0.03	-0.03	-0.05	-0.08
7	-0.01	-0.01	-0.01	-0.01	-0.01	0.03*	-0.01	0.04**	0.05**	0.03**	0.03*	0.03	0.03	0.03	0.01
8	0.02***	0.06	0.06	0.07*	0.06	0.03**	0.04**	0.03***	0.04***	0.05***	0.01	0.00	0.02	0.00	0.01

Notes: AAR_{MAR} characterize abnormal return estimation based on the mean-adjusted model. AAR_{OLS}^{CSI} and AAR_{OLS}^{TD} are abnormal returns from the OLS market model estimated based on the CSI and the tanker index, respectively. AAR_{GARCH}^{CSI} and AAR_{GARCH}^{TD} are abnormal returns from the GARCH-augmented modified market model estimated based on the CSI and the tanker index, respectively. The market model was estimated with Newey-West correction for heteroskedasticity and autocorrelation. Significance of AAR_{MAR} and AAR_{OLS} against the null hypothesis has been tested based on test statistic t_1 and AAR_{GARCH} based on t_2, both being assumed to follow a t-distribution. Asterisks *, ** and *** indicate significance at levels of 10%, 5% and 1%, respectively.

Slow incorporation of event-induced information into market prices may be attributed to certain characteristics of the freight and FFA markets: first, FFAs are mostly traded in the cleared OTC market. Compared to trading on formalized exchanges, (hybrid) OTC markets may show frictions due to less transparent information concerning, for instance, trading volumes or bids and asks, causing higher information costs (see, among others, Kavussanos et al., 2014). Similarly, spot freight rates are formed in decentralized private negotiations between ship owners and potential charterers. Second, following the argument by Chordia et al. (2008), comparatively low trading volumes and liquidity, as observed in the FFA market, negatively impact informational efficiency of capital markets. Third, excess reactions may be attributed to Zannetos's (1966) hypothesis of elastic price expectations in the tanker freight market (see Kavussanos and Nomikos, 2003, for empirical evidence): demand-side shocks may cause uncertainty for market participants concerning the future development of the market, triggering nervous overreactions. Fourth, OPEC announcements will not result in an immediate change of crude oil output, but it may take time for the new quota to materialize. With respect to the spot market, this implies that it may be reasonable for freight rates to gradually adjust to the new demand level. Fifth, more generally, informational inefficiencies around OPEC announcements may be caused by the fact that not all markets participants agree on implications of the information released during OPEC conferences. This may, in particular, be the case in view of potential cheating behavior of individual OPEC member states regarding the compliance with set production quotas, especially, for overproductions following quota cut announcements.

The empirical findings presented above suggest that freight traders should closely monitor the OPEC's behavior, as it appears to significantly affect the tanker freight markets. In addition, our findings may offer opportunities for market participants to adapt their chartering decision-making in the spot market to publicly available information (without assuming additional risk). In case of increase crude oil production levels, ship owners, for instance, may benefit from slow price adjustment to new demand levels by withholding transportation capacity from the charter market for a certain period of time following the OPEC output announcements by, for example, dry-docking of vessels. Charterers, on the other hand, may profit by rapidly chartering in required tonnage. The reverse reasoning may be put forward for reduced production levels. Essentially, the paper freight forward market offers similar opportunities to exploit short-term informational inefficiencies; however, these may be realized without taking physical positions in the charter market. Advantages in the forward market may additionally be realized at lower transaction costs compared to the physical spot market (Kavussanos and Visvikis 2004). Moreover, market participants in the spot or forward markets with private insider information or limited aversion towards speculation may make additional gains from the fact that the information content of the OPEC announcements appears not to be incorporated into market prices prior to the event window selected here. As mentioned above, abnormal returns prior to the official release of news regarding OPEC output decision may indicate such behavior.

6 Conclusion

In this paper, we investigate the processing of public information in spot and forward tanker freight markets to complement the existing literature on informational efficiency in these markets. For this purpose, we make use of the event study methodology to study the behavior of freight rate returns around OPEC output announcements. This is the first effort to adapt the classical event study method to shipping freight markets. We consistently find patterns of positive abnormal returns around production increases and negative abnormal returns around production cuts. Following the notion of semi-strong informational efficiency, significant abnormal returns around the events indicate that OPEC output decisions are not fully anticipated prior to the selected event window. However, our analysis suggests that market participants start to trade on their anticipation of the final informational content of the event three to five days before the actual output announcements, which is consistent with findings from related studies. Persistence of abnormal returns in the post-event period indicates incomplete initial reactions or, at least, slow adjustment to disseminated information. Here, a more transparent organization of freight and freight forward markets could be argued to foster informational efficiency due to lower information costs.

Our above findings are, of course, limited to the analysis of freight (forward) return behavior surrounding OPEC announcements. An apparent starting point for future research would be to study the processing of different types of event-induced information packages in order to accumulate more evidence concerning the semi-strong informational efficiency in freight rates and FFA markets.

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8 Appendix

Table A.1
Cumulative average abnormal returns from the random sample

	Spot Returns					1 Month Forward Returns					2 Months Forward Returns				
τ	$CAAR_{MAR}$	$CAAR_{OLS}^{CSI}$	$CAAR_{GARCH}^{CSI}$	$CAAR_{OLS}^{TD}$	$CAAR_{GARCH}^{TD}$	$CAAR_{MAR}$	$CAAR_{OLS}^{CSI}$	$CAAR_{GARCH}^{CSI}$	$CAAR_{OLS}^{TD}$	$CAAR_{GARCH}^{TD}$	$CAAR_{MAR}$	$CAAR_{OLS}^{CSI}$	$CAAR_{GARCH}^{CSI}$	$CAAR_{OLS}^{TD}$	$CAAR_{GARCH}^{TD}$
-8	0,00	0,00	0,00	0,00	0,00	-0,01	0,00	0,01	0,00	0,00	-0,01	-0,01	0,01	0,00	0,00
-7	0,00	0,00	0,00	-0,01	0,00	-0,02	-0,01	0,02	0,00	0,01	0,00	0,01	0,01	0,00	0,01
-6	-0,01	0,00	0,01	0,00	0,00	-0,02	0,00	0,01	0,00	0,00	0,00	0,01	0,01	0,00	0,00
-5	-0,02	0,00	0,02	0,01	0,01	-0,01	0,01	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,01
-4	-0,03	0,01	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,00	0,00	0,00
-3	-0,01	0,01	0,00	0,00	0,00	0,00	0,00	-0,01	0,00	0,00	0,01	0,00	0,00	0,00	0,00
-2	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,00	0,00	0,00	0,00
-1	0,00	0,00	0,01	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00
0	0,00	0,00	0,01	0,00	0,00	-0,02	-0,02	-0,01	-0,01	-0,01	0,00	-0,02	-0,01	-0,01	0,00
1	0,01	0,01	0,01	0,00	0,01	-0,02	0,00	-0,01	-0,01	-0,01	0,00	0,01	0,00	0,00	0,00
2	0,01	0,00	0,00	0,00	0,00	-0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3	0,01	-0,01	0,00	0,00	0,00	-0,03	0,00	0,00	0,00	0,00	0,01	0,01	0,00	0,00	0,00
4	0,00	-0,01	0,00	0,00	0,00	-0,02	0,01	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00
5	-0,01	-0,01	-0,01	0,00	0,00	-0,02	-0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6	-0,01	0,00	-0,01	0,00	0,00	-0,02	0,00	-0,01	0,00	0,00	0,01	0,01	-0,01	0,00	0,00
7	-0,02	0,00	-0,01	0,00	-0,01	-0,01	0,02	-0,01	0,00	-0,01	0,02	0,01	0,00	0,00	0,00
8	-0,02	0,00	-0,02	0,00	0,00	-0,02	0,00	-0,02	0,00	0,00	0,01	0,00	0,01	0,00	0,00

Notes: The results depicted in this table are from a random sampling procedure. $CAAR_{MAR}$ characterize cumulative abnormal return estimation based on the mean-adjusted model. $CAAR_{OLS}^{CSI}$ and $CAAR_{OLS}^{TD}$ are cumulative abnormal returns from the OLS market model estimated based on the CSI and the tanker index, respectively. $CAAR_{GARCH}^{CSI}$ and $CAAR_{GARCH}^{TD}$ are cumulative abnormal returns from the GARCH-augmented modified market model estimated based on the CSI and the tanker index, respectively. The market model was estimated with Newey-West correction for heteroskedasticity and autocorrelation. Significance of $CAAR_{MAR}$ and $CAAR_{OLS}$ against the null hypothesis has been tested based on test statistic t_1 and $CAAR_{GARCH}$ based on t_2, both being assumed to follow a t-distribution. Asterisks *, ** and *** indicate significance at levels of 10%, 5% and 1%, respectively.

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