OVER-THE-COUNTER FORWARD CONTRACTS AND SPOT PRICE VOLATILITY

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ABSTRACT

The purpose of the paper is to investigate the impact of the introduction of Forward Freight Agreement (FFA) trading on spot market price volatility in panamax 1, 1A, 2, and 2A trading routes of the dry-bulk shipping industry. The main concern about the impact of derivatives trading emanates from the results of studies that have found that the activities of speculators may destabilise (or stabilise) prices in the spot market. The proposed methodology is considering the link between volatility and information, and of possible asymmetric effects in the conditional volatilities. A GJR-GARCH (Glosten, *et al.*, 1993) process is found to be the most appropriate specification. The results suggest that the onset of FFA trading has had (a) a stabilising impact on the spot price volatility in all investigated routes, (b) an impact on the asymmetry of volatility in routes 2 and 2A, and (c) substantially improved the quality and speed of information flow in routes 1, 1A and 2. However, after including in the conditional variance equation other explanatory variables that may affect spot volatility, the results indicate that only in voyage routes 1 and 2 the reduction in volatility may be a direct consequence of FFA trading. The results suggest that the introduction of FFA trading has not had a detrimental effect on the spot market. It appears that there has been an improvement in the way that information is transmitted into spot prices following the onset of FFA trading.

1. INTRODUCTION

This study investigates whether, and to what extent, the recent introduction of trading in Forward Freight Agreement (FFA) contracts of the panamax dry-bulk sector of the shipping industry has impacted on the price volatility of the underlying spot market[1]. If the sole interest of a large number of market agents is not hedging themselves, against adverse freight rate movements, but to speculate using the FFA market, their actions may induce excess volatility, and therefore, destabilise the spot market.

While many derivatives markets can be seen to be enhancing economic welfare by allowing for new positions and expanding the investment sets or enabling existing positions to be taken at lower costs, they have been criticised for increasing spot market price volatility (see Antoniou and Holmes, 1995, amongst others). Goss and Yamey (1978) argue that derivatives markets, by allowing individuals to undertake speculative activity without them having to become involved in the production, handling or processing of the commodity or asset, can increase speculation. Furthermore, the low cost of participating and the rapid implementation of a position in the derivatives markets make it easy for market agents to engage in speculation. In contrast, several other studies argue that speculators have a useful and stabilising role in spot markets (see Kaldor, 1960; Moriarty and Tosini, 1985; Edwards, 1988; and Choi and Subrahmanyam, 1994, amongst others). It can be argued that derivatives markets require speculators, to enable hedgers to transfer risks which they wish to avoid.

This controversial issue of the impact of speculators, which dates back almost to the inception of derivatives trading, has been the subject of considerable empirical analysis and has received the attention of policymakers. Despite that, the issue of whether derivatives trading destabilises or stabilises the spot market, is still viewed with suspicion by market agents and policymakers alike. In currency markets, McCarthy and Najand (1993) employ a state-space model to provide mixed evidence on the stabilising influence of futures trading on daily futures currency prices. While the lagged levels of trading volume on the British Pound, Swiss Franc, and Deutsche

[1] FFA contracts were introduced in London in October 1991 by the shipbroking company Clarkson Securities Ltd., originally marketing them through their joint-venture company, Clarkon Wolff.

Mark futures are found to have a negative (stabilising) impact on the volatility of the respective futures price, the lagged trading volume levels on the Canadian Dollar futures are found to have a positive (destabilising) impact (see also Grammatikos and Saunders, 1986). Chatrath *et al.* (1996) using a GARCH model, as a proxy of volatility of the exchange rates, suggest that currency futures trading has a significant positive impact on the volatility in the exchange rate changes, with a weaker feedback from exchange rate volatility to futures trading.

In stock markets, Baldauf and Santoni (1991) use an ARCH model to examine for increased volatility in the stock index following the introduction of futures trading. Testing for changes in the parameters of the model did not yield any significant evidence, suggesting that the inception of futures trading had no significant effect on volatility. Brorsen (1991) argues that the autocorrelation of stock prices should be reduced by the introduction of futures trading, since such trading reduces market friction leading to prices adjusting more rapidly to new information. Darrat and Rahaman (1995) conclude that S&P500 futures volume did not affect spot market volatility. Board *et al.* (1997) report that contemporaneous futures market trading had no effect on spot market volatility. Bologna (1999) and Bologna and Cavallo (2002) argue that the introduction of stock index futures trading in the Italian stock exchange has led to diminished volatility. McKenzie *et al.* (2001) report a general reduction in systematic risk on individual stocks after the listing of futures, a decline in unconditional volatility, and mixed evidence concerning the impact on conditional volatility.

FFA contracts are traded in an over-the-counter (OTC) derivative market where two parties must agree to do business with each other. That means that each party accepts credit risk from the other party[2]. The primary advantages of an OTC market is that the terms and conditions are tailored to the specific needs of the two parties. It is a private market in which the general public does not know that the transaction was done. It

[2] The credit risk associated with forward contracts can take the form of the risk that occurs when one party is not performing, on the expiration date, the obligations relative to a change in the value of the forward contract from zero. If during the life of the contract, the forward price continually mirrors the spot price, then there is negligible credit risk associated with the forward contract and the contract can be sold at the market price.

also can save money by not normally requiring initial, maintenance and variation margins, common in the futures organised exchanges[3].

The aim of the creation (in 1992) of the FFA market was to provide a mechanism for hedging freight rate risk in the dry-bulk and wet-bulk sectors of the shipping industry. FFAs are principal-to-principal contracts between a seller and a buyer to settle a freight or hire rate, for a specified quantity of cargo or type of vessel, for usually one, or a combination of the major trade routes. Currently, FFA contracts have as the underlying asset spot freight rates in routes of the Baltic Panamax Index (BPI), the Baltic Handymax Index (BHMI), the Baltic Capesize Index (BCI), and the Baltic International Tanker Routes Index (BITR). One counterparty takes the view that the price of an agreed freight route, at an agreed time, will be higher in the future, and buys FFA contracts (charterer), in order to sell them in the future at the higher price, and thus, controls for the possibility of paying higher spot rates in the future. The other party takes the opposite position, and sells FFA contracts (shipowner). Settlement is made on the difference between the contracted price (forward price) and the average price for the route selected in the index over the last seven working days.

This study extends the empirical literature on the relationship between derivatives (futures and forward) trading and spot market price volatility in the following ways. First, most of the studies view the question about the impact of derivatives trading on spot price volatility from a stabilising or destabilising view-point by comparing spot price volatility during the pre- and post-derivatives trading areas. While a number of methodologies have been adopted to examine this issue the investigation of the link between information and volatility in earlier studies is neglected, (with the exception of Chatrath *et al*., 1996; Antoniou *et al*., 1998; Kavussanos and Phylaktis, 2002; and McKenzie *et al*., 2001).

[3] In futures markets, the trader is required to place with the clearing-house an initial margin, which is an amount of money on a per contract basis and is set at a size to cover the clearing-house against any loses which the trader’s new position might incur during the day. Moreover, futures contracts are mark-to-market at the end of each trading day. That is, the resulting profit or loss is settled on that day. Traders are required to post a variation margin in order to cover the extent to which their trading positions show losses.

Second, the conditional variance from Glosten, Jagannathan, and Runkle (1993) GJR-GARCH model is found to be the appropriate process of volatility of the spot freight rates, enabling the investigation of the link between information and conditional volatility and of the market dynamics, as reflected by a change in the asymmetric volatility response. Antoniou *et al*. (1998) argue that derivatives markets may change the role of market dynamics in terms of the way in which volatility is transmitted and, therefore, how information is incorporated into prices. Merton (1995) argues that the introduction of derivatives markets can improve efficiency by reducing asymmetric responses to information. The prior literature has generally restricted itself to testing changes in spot price volatility and has not considered whether reduced asymmetry (linked to news arrival) has resulted from derivatives trading. Such a restricted testing framework may lead to inappropriate policy responses.

Third, if a stabilising/destabilising impact is found, we investigate whether the introduction of FFA trading is the only cause for a change in the spot market volatility. The hypothesis that other factors may have affected market volatility is tested. For this purpose several other economic indicators are included as proxies for market factors in the variance model.

Fourth, the FFA market is organised quite differently from a futures market. All trading is bilateral, there is no clearing-house, no open outcry, and no centralised exchange. Only at the end of the trading day, information on deals negotiated during the day, is widely disseminated[4]. During the day, traders must rely on their contacts for information on the transactions consummated.

Finally, much of the analysis in previous studies has been devoted to considering the impact of trading in stock indices. Such studies are useful in assessing the market-wide impact, but any effect in the underlying spot market can be dissipated across the many constituent assets in the index, making it difficult to detect. Because FFA are route-specific contracts (the underlying asset is freight rates of a trading route) this study can contribute in the general literature by examining changes in the volatility of

[4] Shipbrokers in London report to their clients daily the FFA quotes by email around 16:00 UK time.

individual routes (assets). In addition there are special features in these contracts, which do not appear in other markets. These include (i) the investigation of the issue on a forward rather than a futures market. We have not seen any studies before on OTC markets, primarily due to the lack of available data. Yet differences in the results between forward and futures markets may arise; (ii) the underlying "commodity" is a service and the usual cost-of-carry relationship between spot and forward does not exist here, and (iii) transactions costs are thought to be lower in FFA markets in comparison to spot and also in FFA compared to futures.

This study can provide regulators and practitioners with important insights into the FFA trading - spot market price volatility relationship. If FFA markets cause a change in the level of volatility in the spot market (as in the arguments that speculators increase volatility) and this, in turn, is associated with greater uncertainty and unduly higher required freight rates, then there may well be a case for the Forward Freight Agreements Brokers Association (FFABA) to increase the regulation of these markets. However, if these markets lead to new channels of information being provided, more information due to more traders, and a reduction in uniformed investors, then FFA markets provide a useful service and calls for their regulation are unwarranted.

The remainder of this study is structured as follows. Section two discusses the theoretical issues relating to the relationship between information and volatility and presents the research methodology. Section three describes the data and provides some preliminary statistics. The empirical results are presented in section four. Finally, the last section summarises the findings.

2. METHODOLOGY AND THEORETICAL CONSIDERATIONS

To test the impact of the introduction of FFA contracts, a GARCH model is modified along the lines of the GJR-GARCH model of Glosten *et al*. (1993)[5]. This allows for

[5] In order to determine the best GARCH specification several other specifications are used, such as the symmetric GARCH (Bollerslev, 1986), and the asymmetric E-GARCH (Nelson, 1991), but yield inferior results judged by the evaluation of the log-likelihood, in terms of residual specification tests,

asymmetric impact of news (positive or negative) on volatility. Thus, the mean equation of the GJR-GARCH process can be defined as follows:

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

where S_t is the natural logarithm of the daily spot price change, Δ is the first-difference operator and ε_t are the residuals that follow a normal conditional distribution with mean zero and time-varying covariance, h_t. The conditional variance of the process can be specified as follows:

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

where D_{t-1}^- is a dummy variable that takes on a value of unity if the error is negative ($\varepsilon_{t-1} < 0$) and zero otherwise. Comparisons can then be made on the estimated coefficients, in order to examine the impact of FFA trading on the nature of spot volatility and to assess if FFA trading has led to changes in the asymmetric response of volatility.

The impact of the onset of FFA trading is captured by the introduction of a dummy variable in the variance equation of the process, representing the time period before and after FFA trading[6]:

$$h_t = a_0 + a_1 h_{t-1} + a_2 D_1 h_{t-1} + \beta_1 \varepsilon_{t-1}^2 + \beta_2 D_1 \varepsilon_{t-1}^2 + \gamma_1 \varepsilon_{t-1}^2 D_{t-1}^- + \gamma_2 D_1 \tag{3}$$

where D_1 is a dummy variable that takes the value of unity after the introduction of FFA contracts. The specification of the conditional variance in Equation (3) allows the examination of the impact of FFA trading on the unconditional volatility of the

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and in terms of a LR test which is χ^2 distributed with degrees of freedom equal to the number of restrictions imposed (not reported).

[6] Besides FFA trading, other factors, such as, industrial production, grain exports and international trade are likely to impact spot price volatility. Rather than attempting to identify the whole spectrum of factors that may impact spot price volatility, the study focuses on the internal dynamics of daily spot price volatility and only considers some indicative proxy variables (see section 4.2) which represent major economic conditions. Furthermore, most macroeconomic series are available on monthly and quarterly basis, while the interest in this study is in day-to-day basis of the spot freight market.

spot market through the γ_2 coefficient. A significant positive γ_2 coefficient indicates increased spot price unconditional volatility in the post-FFA period, whereas a significant negative γ_2 coefficient indicates decreased spot price unconditional volatility in the post-FFA period.

Furthermore, the model allows a number of tests of the impact of FFA trading on conditional spot price volatility[7]. We may individually test the ARCH term or the GARCH term. However, in the context of the GARCH framework, it is more appropriate to test the joint null hypothesis of no impact on the conditional variance specification ($a_2 = \beta_2 = 0$) against the alternative of at least one coefficient being non-zero. Furthermore, we may test the joint hypothesis that the FFA introduction has had no impact on volatility per se ($a_2 = \beta_2 = \gamma_2 = 0$) against the alternative of at least one coefficient being non-zero. In this case, the test examines both unconditional and conditional volatility effects.

Finally, the specification of Equation (3) allows the investigation of whether FFA trading has changed the role of market dynamics in terms of the way in which volatility is transmitted, and therefore, inferences can be made on how information is incorporated into prices. When the coefficient on D_{t-1}^{-} is equal to zero, the model of Equation (5.2) is the symmetric GARCH model. A negative shock ($D_{t-1}^{-} = 1$) can generate an asymmetric response. Where $\gamma_1 > 0$ ($\gamma_1 < 0$), the model produces a larger (smaller) response for a negative shock compared to a positive shock of equal magnitude.

However, to address the issue of the relationship between information and volatility, and not simply investigate whether FFA trading has led to an increase or decrease in volatility in the spot market, the period under investigation is partitioned into two sub-periods relating to before and after FFA trading began. GJR-GARCH models of Equation (3) are estimated for both sub-periods, without the D_1 dummy variable for the existence of FFA trading. Accordingly, the impact of the FFA trading on this

[7] For a formal discussion of dummy variables see Gujarati (1970). He argues that the Chow test might reject the hypothesis of stability but not tell us which particular coefficients are unstable, whereas the dummy variable method gives this information.

asymmetry feature can be assessed through a comparison of the γ_1 coefficient in pre- and post-FFA periods.

With a sample of four spot routes for which FFA contracts have been introduced, it is possible that factors, other than the introduction of forward contracts, may affect the variables considered in each of the hypotheses tests. For example, market-wide changes may have occurred around the time of the FFA introduction date that altered the dynamics of the market. Tests may erroneously attribute such a change, if it occurred, to the introduction of FFA. To this end, a control procedure is implemented under which we augment the conditional variances of the spot freight routes by incorporating the conditional variances of other economic indicators. Thus, the model is recursively estimated in two-steps. First, we estimate the conditional variance of every selected economic variable [S&P500 Composite Index (SPI), S&P500 Commodity Index[8] (SPCI), London Brent crude oil Index (BCOI) and West Texas Intermediate (WTI) crude oil] computed by the most parsimonious GARCH model (in terms of the log-likelihood and residual diagnostic tests). The selected economic variables are commonly used as control variables in the literature. In the next step, the model of Equation (3) is augmented by incorporating the conditional variance of the economic variables from the previous step. Thus, the augmented variance model is the following:

$$h_t = a_0 + a_1 h_{t-1} + a_2 D_1 h_{t-1} + \beta_1 \varepsilon_{t-1}^2 + \beta_2 D_1 \varepsilon_{t-1}^2 + \gamma_1 \varepsilon_{t-1}^2 D_{t-1}^- + \gamma_2 D_1 + \delta_1 G_t \qquad (4)$$

where G_t is the conditional variance, from a GARCH model, of an economic variable. A significant δ_1 coefficient indicates that the conditional variance of the economic variable affects the conditional variance of the spot freight rates. Thus, if its inclusion in the model does not alter the significance level and sign of the γ_2 coefficient, then the unconditional volatility of the spot freight market has not increased/decreased due to this variable and the conclusions drawn with respect to the impact of the introduction of the FFA contracts are strengthened.

[8] The SPCI covers a broad cross section of commodities traded in the US, providing a broad, accurate picture of the commodity market. It tracks 17 Commodities in 6 Sectors (Grains, Meat and Livestock, Metals, Softs, Fibres and Energy).

Bollerslev and Wooldridge (1992) argue that excess kurtosis in the estimated standardised residuals ($\varepsilon_t / \sqrt{H_t}$), even after accounting for second moment dependencies, can invalidate traditional inference procedures. Therefore, the GJR-GARCH processes are estimated with the Quasi Maximum-Likelihood Estimation (QMLE), which estimates robust standard errors, and thus, yields an asymptotically consistent normal covariance matrix (Bollerslev and Wooldridge, 1992)[9]. For symmetric departures from conditional normality, the QMLE is generally close to the exact Maximum-Likelihood Estimation (MLE). The Berndt-Hall-Hall-Hausman (1974) (henceforth, BHHH) optimisation algorithm is employed to obtain maximum-likelihood estimates of each of the coefficients in the mean and variance equations.

3. DESCRIPTION OF DATA AND PRELIMINARY STATISTICS

From the creation of the FFA market on February 1st 1992 until November 1st 1999, the eleven panamax and capesize voyage and time-charter routes of the Baltic Freight Index (BFI) served as the underlying assets of the FFA trades, in the dry-bulk sector of the shipping industry. After the latter date, with the exclusion of the capesize routes and with the renamed index as BPI, the underlying assets of the FFA contracts are panamax routes. The composition of the BPI, as it stands on January 2001, is presented in Table 1.

Freight rates on the individual underlying trading routes are reported on a daily basis (at 11:00 a.m. London time) by a panel of eleven independent London shipbrokers to the Baltic Exchange and the latter reports them in the market at 13:00 p.m. London time. Each member of the panel submits, to the Baltic Exchange, its daily view of the rate on each constituent route of the Baltic indices. Each freight rate assessment is derived from actual fixtures, or in the absence of an actual fixture from the panellist's expert view of what the rate would be on that day if a fixture had been agreed. Then the Baltic Exchange, for each trade route, after excluding the highest and lowest

[9] The GJR-GARCH models are also estimating by using the Student-*t* distribution of Bollerslev (1987). The results, of the coefficient of the degrees of freedom, v, indicate that the QMLE should be used, as in all routes v was lower than 4, which implies an undefined or infinite degree of kurtosis (Bollerslev and Wooldridge, 1992).

assessments of the day, takes an arithmetic average of the remaining. The average rate of each route is then multiplied by the *Weighting Factor*[10] (WF) to return the contribution of each route to the index. Finally, by adding all the route contributions, an overall average index is created, for example the daily BPI.

The impact of FFA trading, on the volatility of the underlying spot freight market in panamax atlantic (1 and 1A) and pacific (2 and 2A) routes, is investigated by estimating a model for a period which covers the time before and after the introduction of FFA contracts. Due to the specific nature of the FFA market it was not until late 1990s when this market started to attract a respectful number of market agents. From Table 2 it is clear that until 1996 the market was very thin (with only 27 deals on average per month in 1996), so it was unlikely that the existence of speculators (if any) could impact the spot market volatility. Thus, in the ensuing analysis January 1997 will be the threshold point that separates pre- and post-FFA trading in order for robust inferences to be made[11]. The data set comprises daily observations of the spot freight rates for each of the aforementioned panamax routes. It covers the periods 29 November 1989 to 31 July 2000 in route 1, 7 August 1990 to 31 July 2000 in route 1A, 29 November 1989 to 24 August 2001 in route 2, and 12 February 1991 to 24 August 2001 in route 2A. Spot prices in all routes are from the Baltic Exchange. SPI, SPCI, BCOI and WTI prices are from Datastream. All prices are transformed to natural logarithms.

The descriptive statistics of logarithmic first-differences of the daily spot prices in the four routes are reported in Table 3, which is divided into three periods. The first period (panel A) corresponds to the whole period of the analysis. The second (panel B) and third (panel C) periods correspond to the pre- and post-FFA periods, respectively. The results indicate excess skewness and kurtosis in all price series. In turn, Jarque-Bera (1980) tests indicate departures from normality for spot prices in all routes. Applying the Augmented Dickey-Fuller (ADF, 1981) and Phillips and Perron (PP, 1988) unit root tests on the log-levels and log-first differences of the daily spot

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[10] The WF is a constant, unique for each route, and reflects the importance of each route to the index. For example, the WF for each BPI route is: 11.185 (route 1), 0.027 (route 1A), 7.067 (route 2), 0.015 (route 2A), 9.307 (route 3), 0.031 (route 3A), 0.023 (route 4).
[11] Several other threshold point dates were also used, which yield qualitatively the same results.

price series, the results indicate that all variables are log-first difference stationary, all having a unit root on their log-levels representation[12].

Of greatest interest in Table 3 are the figures obtained for the standard deviation estimates, providing an initial view of volatility for each route in the sample. In the pre-FFA period spot prices in routes 2 and 2A provide the lowest standard deviations. In the post-FFA period, routes 1 and 2 provide the lowest standard deviations, where route 2 shows considerable reduction in the standard deviation from the pre-FFA period. By comparing the two periods, it seems that the volatility of the voyage routes (time-charter routes) has decreased (increased) over time.

One possible reason for this, in route 2, is the increase in inbound cargoes to the US (primarily coal following the US energy crisis), which has meant a substantial increase in tonnage coming open in the US Gulf region. This ensures that there is a constant supply of tonnage for the US Gulf market, which in turn, has guaranteed that demand is regularly met. In contrast, historically the US Gulf market was a ballasters market, i.e. shippers needed to pay owners to come to the Gulf for cargoes, adding substantially to the volatility of the freight rates. The result of the recent change in the import status of the US is that freight rates now seem to move in a narrower bound for voyage trips and volatility has been reduced. On the other hand, time-charters in this region (route 2A) are not generic in terms of specifications and every shipper introduces his preferences. This in turn can generate increased volatility in time-charter freight rates.

Similarly to the authors of earlier studies in this area, we initially conduct equality of variance tests (see Chatrath, *et al.*, 1996). The results in Table 4 panel A reveal significant differences between the pre- and post-FFA variances in all trading routes. In panel B, of the same table, we compare the pre- and post-FFA variances of various economic indicators. The results indicate that, with the exception of the F-test and the Levene test statistics for the WTI crude oil, the level of the variances has changed between the two periods. This may indicate that besides the introduction of FFA contracts, there might be several other economic events (i.e. Asian crisis) that

[12] The ADF and PP test statistics were undertaken allowing for the presence of an intercept only. Allowing for the presence of a time trend did not affected the results qualitatively.

contributed to this change of variances. However, we must note that all investigated market indicators have a derivatives market (either exchange-based or OTC) which may contribute as well to the above result. The results suggest that some change has taken place over the relevant period, and thus, motivates further investigation.

4. EMPIRICAL RESULTS

4.1. Impact of FFA Trading on Spot Market Volatility

We examine whether the introduction of FFA trading had an effect on the way news impacts on volatility; that is, if FFA trading altered the market dynamics. To address this issue the GJR-GARCH models of conditional volatility are estimated for the return series for the pre- and post-FFA periods. The QMLE estimates of the GJR-GARCH models of spot freight rates for the pre-FFA period for each route are presented in Table 5. The standard diagnostic tests of the residuals from the model confirm the absence of any further ARCH effects, suggesting an appropriate model specification. That is, the squared standardised residuals of the modified GJR-GARCH(1,1) models reveal a general absence of significant autocorrelation, which indicates that the model has captured the ARCH effects.

The results of the coefficients of the lagged variance (a_1) and lagged error-terms (β_1) indicate that the conditional volatility in all routes is time-varying, and specifically in route 2A there are ARCH effects only. The results of the asymmetry coefficient (γ_1) suggest that in routes 1A, 2, and 2A there is a statistically significant and negative asymmetric effect, which implies that negative shocks elicit a smaller response than positive shocks of an equal magnitude. In contrast, in route 1 the asymmetry coefficient is significant and positive, which implies that negative shocks elicit a larger response than positive shocks of an equal magnitude. Finally, the persistence of volatilities of the spot markets following a shock, show that unconditional variances are stationary (persistence factors less than one) in all routes.

The issue of the impact of FFA trading on spot market volatility is further investigated by estimating the GJR-GARCH model for spot returns for the post-FFA period. The

QMLE estimates of the GJR-GARCH model of spot freight rates for the post-FFA period for each route are presented in Table 6. The results of the diagnostics tests report absence of any linear or non-linear dependencies. The impact of FFA introduction on asymmetric market responses may be assessed via consideration of the asymmetry coefficient (γ_1) that captures the nature of any bias in the post-FFA period. The results indicate that the post-FFA asymmetry coefficient, in routes 2 and 2A, is statistically insignificant. Thus, the introduction of FFA contracts appears to have had an impact on the asymmetry of volatility in those routes, as a significant asymmetry coefficient in the pre-FFA period results in an insignificant asymmetry coefficient in the post-FFA period. If noise/feedback traders are present in routes 2 and 2A and they overreact to news, especially good news, then the introduction of FFA trading seems to have reduced this overreaction. This could come about either because FFA markets provide more reliable information, and thus, traders become better informed, or because noise traders have less of an impact as a result of more reliable information in the public domain.

By comparing the coefficients of the lagged variances (a_1) and lagged error-terms (β_1) of the GJR-GARCH models in the pre- and post-FFA periods, it is possible to examine not just the impact of FFA trading in terms of increasing or decreasing spot price volatility, but also the impact of FFA trading on the nature of volatility. For the periods before and after the onset of FFA trading a GJR-GARCH(1,1) representation is the most appropriate in routes 1, 1A, and 2, where statistically significant coefficients of the lagged variance and lagged error-terms imply that the volatility is time-varying. The only exception is in route 2A where the insignificant coefficient of the lagged variance in the pre-FFA period result in a significant coefficient in the post-FFA period. Thus, the onset of FFA trading led to a change in the nature of volatility in route 2A only. The results of the unconditional volatility estimate (UV) indicate that in routes 1, 1A, and 2A there has been a decrease in the unconditional volatility. This finding is consistent with the earlier results of a stabilising impact in the volatilities and with the view that more information is being transmitted to the spot markets. In route 2 the unconditional volatility has increased which is not in accordance with the results of a stabilising impact from the introduction of FFA contracts.

In the context of this analysis the lagged error-term, β_1, relates to changes in the spot price on the previous day which are attributable to market specific factors. Assuming that markets are efficient, then these price changes are due to the arrival in the market of items of information, which are specific to the pricing of the FFA contracts. Thus, the coefficient of the lagged error-term can be viewed as a *new news* coefficient, which relates to the impact of yesterday's market specific price changes on price changes today. Hence, a higher value in the post-FFA period implies that recent news have a greater impact on price changes. The results, from Tables 5 and 6, indicate that this holds in routes 1, 1A and 2 suggesting that information is being impounded in prices more quickly due to the introduction of FFA trading.

The coefficient of the lagged variance term, a_1, can be thought of as reflecting the impact of *old news*. It is picking up the impact of price changes relating to days prior to the previous day, and thus, to news which arrived before yesterday. A reduction in uncertainty regarding previous news can be regarded as an increase in the rate of information flow with the onset of FFA trading (old news will have less impact on today's price changes). This argument seems to confirm the expectation of increased market efficiency as a consequence of the activity in the FFA market. The results, from Tables 5 and 6, indicate that this holds in routes 1, 1A, and 2, where the value of the a_1 coefficient has been reduced in the post-FFA period.

To assess whether there has been a change in volatility after the inception of FFA trading, GJR-GARCH(1,1) models of conditional volatility are estimated. A dummy variable that takes the value of 0 pre-FFA and 1 post-FFA is included. The most parsimonious specification for each model is estimated by excluding insignificant variables. The QMLE estimates of the GJR-GARCH models of spot freight rates for the whole period of the analysis for each route are presented in Table 7[13]. The diagnostic tests, on the standardised residuals and squared standardised residuals, indicate absence of linear and non-linear dependencies, respectively. Thus, the estimated models fit the data very well. The estimated implied kurtosis indicates the

[13] The financial literature has demonstrated that the GARCH(1,1) specification is the most appropriate for a wide variety of markets (see Bollerslev *et al*., 1992, amongst others).

presence of excess kurtosis in the standardised residuals in all investigated routes. As a result the Jarque-Bera (1980) test rejects normality in all routes.

The results in Table 7 indicate that in all routes FFA trading has had a negative impact (stabilising effect) on the level of price volatility of the underlying spot freight market (γ_2 coefficient). However, the magnitude of this negative impact is marginally larger in the voyage routes 1 and 2 and it is in accordance with earlier results that the volatility of the voyage routes has decreased. Thus, the introduction of FFA appears to have a stabilising impact on the level of volatility in the underlying spot routes. The results of the Wald test statistics for the null hypothesis of joint equality to zero of the change in ARCH and GARCH terms indicate that the null hypothesis is rejected in every route. This evidence suggests that the conditional variance of all spot routes underwent some form of change around the date of the FFA introduction. The analysis can be extended to consider the impact of the FFA trading on both the conditional and unconditional variance by testing that the FFA introduction has had no (joint) effect on any variance equation parameters, that is $a_2 = \beta_2 = \gamma_2 = 0$. The results of the Wald tests for the null hypothesis indicate that the relevant coefficients in the variance equation have significantly changed in all trading spot routes.

The results of the γ_1 coefficient of the asymmetric effects suggest statistically significant asymmetric effects in all routes, with the exception in route 2A. In routes 1A and 2 the statistically significant asymmetry coefficients (γ_1) are negative, suggesting that negative shocks elicit a smaller response than positive shocks of an equal magnitude. In routes 1 the asymmetry coefficient is significant and positive suggesting that negative shocks elicit a larger response than positive shocks of an equal magnitude. Finally, the persistence estimates of the conditional volatility reveal the presence of a near-Integrated GARCH (IGARCH) process in routes 1 and 2A, with persistence estimates close to but slightly less than unity (see Bollerslev, 1987).

4.2. Impact of FFA on Spot Market Volatility Considering Market Factors

The next step consists in examining whether the introduction of FFA trading is not the only factor responsible for the reduction in the spot market volatility. To address this issue, the behaviour of the spot variances is adjusted for exposition to additional factors which may affect spot market volatility. The adjustment is obtained by including the conditional volatility (computed by a GARCH process) of economic indicators as explanatory variables in the specification of the spot variance equation[14]. More specifically, the SPI, the SPCI, the BCOI and the WTI are used as economic indicators that can capture major world economic conditions, which may impact the spot market volatility of the investigated freight routes. Thus, we test the hypothesis that FFA trading is the only cause for the diminished volatility, testing the null hypothesis that the "FFA dummy" coefficient (γ_2) is zero.

In the interest of space, we report only those results that we feel are the most relevant to the issue at hand. Thus, the QMLE estimates of the most parsimonious and well-specified (in terms of diagnostic tests) GJR-GARCH model for every spot freight route are presented in Table 10. The estimates of the coefficients of the variance equation including: (i) the SPI variable are presented in panel A; (ii) the SPCI variable are presented in panel B; (iii) the BCOI variable are presented in panel C; and (iv) the WTI variable are presented in panel D.

The results in Table 8 indicate that the "FFA dummy" variable (γ_2 coefficient) has not been affected by the used economic variables that significantly contribute in the spot market's conditional volatility for voyage routes 1 and 2. This result supports not only the hypothesis of reduced spot volatility but also that the reduction in volatility may be a direct consequence of FFA trading. In contrast, in the time-charter routes 1A and 2A we notice that the "FFA dummy" variable has been affected by most of the economic variables. More specifically, in route 1A the γ_2 coefficient becomes positive and significant with the use of the SPI variable and insignificant with the use of the WTI variable. In route 2A despite the negative sign and significance of the γ_2 coefficient three out of the four economic variables (SPI, SPCI, and BCOI) fail to

[14] Including the first-differenced log price series of the economic indicators as explanatory variables in the spot mean equation, yielded insignificant coefficients, and therefore, are excluded from the final specification.

contribute to the spot market's conditional volatility. Thus, the results do not present a clear answer as to whether reduction in spot volatility, in routes 1A and 2A, is a direct consequence of FFA trading. Although these results are not as consistent as those from the GJR-GARCH models of Equation (2), we still observe a propensity for volatility to decrease after the FFA introduction in voyage routes 1 and 2.

We do not deny that these results may be influenced by other factors, and, as always, advocate caution in interpreting empirical results. In particular, several points should be considered that may confound the interpretation of the results, and those of all the previous papers in the literature. First, the introduction of FFA contracts is not an entirely exogenous event. The introduction process involved many decisions made by FFABA panelists, members of the Baltic Exchange and representatives from shipbroking companies, who may have been influenced by recent or anticipated market conditions. For example, in financial markets the reluctance of regulators to approve the introduction of derivatives contracts during periods of political uncertainty may introduce a selection bias.

Second, given that most financial and commodity markets in developed economies impound information into prices rapidly, the impact of the onset of derivatives trading in terms of the speed of the price change, while significant, is likely to be at the margin. If this change is to be identified, it is necessary to utilise high-frequency intraday data. In this study the most frequent data available are used, namely daily data. This data set proves to be sufficiently frequent to identify the changes resulting from the onset of FFA trading. If information is continually flowing into the spot market then the fact that FFA speeds up this flow may not be identified if the data set used is weekly or monthly, as the increase in the speed of information might by a matter of hours or even days. Third, different trading routes have different regulatory and economic conditions. There might have been important political and economic developments that are not captured by our model.

5. CONCLUSION

This study examines the impact of FFA trading and the activities of speculators on spot market price volatility in panamax voyage routes 1 and 2, and in time-charter routes 1A and 2A. The methodology extends the traditional analysis of examining whether FFA trading has increased spot market volatility by considering the link between volatility and information, and of possible asymmetric effects in the conditional volatilities (market dynamics). The study contributes to the general literature by examining the effects of the introduction of an OTC forward market, extending the concepts associated with spot and forward prices to non-storable commodities (e.g. services), with no explicit storage relationship linking spot and forward prices. In addition, a feature of this market is higher transactions costs in spot compared to the FFA market.

The results, which are in accordance with the results in most futures markets, suggest that the onset of FFA trading has had (i) a stabilising impact on the spot price volatility in all routes; (ii) an impact on the asymmetry of volatility in routes 2 and 2A; and (iii) substantially improved the quality and speed of information flowing in routes 1, 1A and 2. However, after including in the conditional variance equation other explanatory variables that may affect spot volatility, the results indicate that only in voyage routes 1 and 2 the reduction of volatility may be a direct consequence of FFA trading. The results do not present a clear answer as to whether reduction in spot volatility, in routes 1A and 2A, is a direct consequence of FFA trading.

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

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Table 1. Baltic Panamax Index (BPI) – Route Definitions

ROUTES	ROUTE DESCRIPTIONS	SIZE OF VESSELS (dwt)	WEIGHTING IN BPI
1	1-2 safe berths/anchorages Mississippi River not above Baton Rouge/Antwerp, Rotterdam, Amsterdam.	55,000	10%
1A	Transatlantic (including ESCA) round of 45/60 days on the basis of delivery and redelivery Skaw-Gibraltar range.	70,000	20%
2	1-2 safe berths/anchorages Mississippi River not above Baton Rouge/1 no combo port South Japan.	54,000	12.5%
2A	Basis delivery Skaw-Gibraltar range, for a trip via Gulf to the Far East, redelivery Taiwan-Japan range, duration 50/60 days.	70,000	12.5%
3	1 port US North Pacific/1 no combo port South Japan.	54,000	10%
3A	Transpacific round of 35/50 days either via Australia or Pacific (but not including short rounds such as Vostochy/ Japan), delivery and redelivery Japan/ South Korea range.	70,000	20%
4	Delivery Japan/ South Korea range for a trip via US West Coast – British Columbia range, redelivery Skaw-Gibraltar range, duration 50/60 days.	70,000	15%

Source: Baltic Exchange, 2001.

Table 2. Indications of Activity Growth In the FFA Market

Year	Number of Deals per Month	Number of Counterparties	Freight Covered by Trading FFA ($m.)
1992	Average 2	10	0.5
1993	Average 4	18	48
1994	Average 10	25	70
1995	Average 20	35	203
1996	Average 27	52	331

Notes: **Source:** Clarkson Securities, 1999.

- All Indications are from Clarkson Securities Ltd. They posses a market share of around 30%.

Table 3. Descriptive Statistics of Logarithmic First-Differences of Spot Freight Prices

Panel A: Spot Freight Prices; Whole Period

	N	Mean	SD	Skew	Kurt	J-B	ADF (lags) Lev	PP(8) Lev	ADF (lags) 1st Diffs	PP(8) 1st Diffs
Route 1	2,773	0.0000049	0.01255	1.196 [0.00]	26.327 [0.00]	80,742.22 [0.00]	-2.418 (1)	-2.799	-17.432 (3)	-36.669
Route 1A	2,594	0.000101	0.01263	1.065 [0.00]	5.899 [0.00]	4,251.92 [0.00]	-2.704 (3)	-2.043	-15.569 (2)	-27.744
Route 2	3,038	-0.000136	0.01067	0.592 [0.00]	14.549 [0.00]	26,974.64 [0.00]	-2.825 (2)	-2.527	-24.111 (1)	-32.093
Route 2A	2,721	-0.000296	0.01323	2.682 [0.00]	32.745 [0.00]	124,824 [0.00]	-2.113 (2)	-1.758	-20.501 (1)	-28.700

Panel B: Spot Freight Prices; Pre-FFA Period

	N	Mean	SD	Skew	Kurt	J-B	ADF (lags) Lev	PP(12) Lev	ADF (lags) 1st Diffs	PP(12) 1st Diffs
Route 1	1,849	0.0000069	0.01394	1.397 [0.00]	24.881 [0.00]	48,294.07 [0.00]	-2.748 (2)	-2.610	-14.557 (3)	-30.864
Route 1A	2,594	0.000101	0.01263	1.065 [0.00]	5.899 [0.00]	4,251.92 [0.00]	-2.704 (3)	-2.043	-15.569 (2)	-27.741
Route 2	1,849	-0.000021	0.01123	0.553 [0.00]	15.375 [0.00]	18,306.75 [0.00]	-2.763 (2)	-2.521	-19.708 (1)	-27.006
Route 2A	1,532	-0.000065	0.01185	3.664 [0.00]	53.984 [0.00]	189,458.37[0.00]	-2.413 (3)	-1.908	-13.508 (2)	-24.372

Panel C: Spot Freight Prices; Post-FFA Period

	N	Mean	SD	Skew	Kurt	J-B	ADF (lags) Lev	PP(12) Lev	ADF (lags) 1st Diffs	PP(12) 1st Diffs
Route 1	923	0.0000011	0.00912	-0.650 [0.00]	7.475 [0.00]	2,213.88 [0.00]	-1.835 (3)	-1.427	-9.650 (2)	-16.012
Route 1A	923	-0.000065	0.01387	1.193 [0.00]	5.192 [0.00]	1,255.50 [0.00]	-2.017 (2)	-1.659	-10.726 (1)	-14.282
Route 2	1,188	-0.000315	0.00973	0.655 [0.00]	11.154 [0.00]	6,242.87 [0.00]	-2.085 (1)	-1.916	-16.285 (0)	-16.426
Route 2A	1,188	-0.000594	0.01483	1.980 [0.00]	19.073 [0.00]	18,782.77 [0.00]	-2.302 (2)	-1.974	-12.948 (1)	-16.694

Notes:

- All series are measured in logarithmic first differences.
- Figures in parentheses (.) and in squared brackets [.] indicate *t*-statistics and exact significance levels, respectively.
- N is the number of observations; SD is the standard deviation.
- Skew and Kurt are the estimated centralised third and fourth moments of the data; their asymptotic distributions under the null are $\sqrt{T}\,\hat{\alpha}_3 \sim N(0,6)$ and $\sqrt{T}\,(\hat{\alpha}_4 - 3) \sim N(0,24)$, respectively.
- Q(12) and $Q^2(12)$ are the Ljung-Box (1978) Q statistics on the first 12 lags of the sample autocorrelation function of the series and of the squared series; these tests are distributed as $\chi^2(12)$.
- J-B is the Jarque-Bera (1980) test for normality, distributed as $\chi^2(2)$.
- ADF is the Augmented Dickey Fuller (1981) test. The ADF regressions include an intercept term; the lag-length of the ADF test (in parentheses) is determined by minimising the SBIC.
- PP is the Phillips and Perron (1988) test; the truncation lag for the test is in parentheses.
- Lev and 1st Diffs correspond to price series in log-levels and log-first differences, respectively.
- The 5% critical value for the ADF and PP tests is –2.89.

Table 4. Equality of Variance Tests for Pre- and Post-FFA Trading

Panel A: Spot Freight Routes

	F-test	Bartlett	Levene	Brown-Forsythe
Route 1	3.443 [0.000]	331.74 [0.000]	20.282 [0.000]	20.132 [0.000]
Route 1A	1.289 [0.000]	14.894 [0.000]	15.704 [0.000]	15.868 [0.000]
Route 2	1.489 [0.000]	46.647 [0.000]	3.346 [0.006]	3.269 [0.007]
Route 2A	1.578[0.000]	61.136 [0.000]	54.945 [0.000]	56.458 [0.000]

Panel B: Economic Indicators

	F-test	Bartlett	Levene	Brown-Forsythe
SPI	3.105 [0.000]	477.99 [0.000]	288.85 [0.000]	287.52 [0.000]
SPCI	1.831 [0.000]	135.98 [0.000]	88.74 [0.000]	88.154 [0.000]
BCOI	1.200 [0.000]	11.849 [0.000]	7.895 [0.000]	7.922 [0.000]
WTI	1.003 [0.956]	0.004 [0.953]	20.714 [0.000]	20.797 [0.000]

Notes:

- The F-test is given by $F = s_L^2/s_S^2$, where s_L^2 and s_S^2 are the larger and smaller variances, respectively. The F-test has a F-distribution with n_L–1 numerator degrees of freedom and n_S - 1 denominator degrees of freedom.
- The Bartlett test compares the logarithm of the weighted average variance with the weighted sum of the logarithms of the variances. It is distributed as $\chi^2(1)$ degrees of freedom and is reported adjusted for departures from normality.
- The Levene test is based on an analysis of variance (ANOVA) of the absolute difference from the mean. The Levene test has a F-distribution with 1 numerator degrees of freedom and n_L + n_S - 2 denominator degrees of freedom.
- The Brown-Forsythe test is a modification of the Levene test in which the absolute mean difference is replaced with the absolute median difference.
- SPI is the S&P500 Composite Index; SPCI is the S&P500 Commodity Index; BCOI is the London Brent Crude Oil Index; and WTI is the West Texas Intermediate crude oil.

Table 5. GJR-GARCH Model Estimates for the Pre-FFA Period

Panel A: Coefficient Estimates

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

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

	Route 1-AR(3) (29/11/89 – 01/01/97)	Route 1A-AR(3) (07/08/90 – 01/01/97)	Route 2-AR(2) (29/11/89 – 01/01/97)	Route 2A-AR(3) (15/02/91 – 01/01/97)
Mean Equation				
φ_0	2.34E-05 (0.639)	2.33E-05 (0.651)	-4.80E-06 (-0.261)	-3.76E-05 (-0.054)
φ_1	0.413* (22.218)	0.568* (23.005)	0.483* (19.221)	0.524* (14.722)
φ_2	0.169* (5.737)	0.164* (5.797)	0.135* (4.963)	0.112* (3.151)
φ_3	0.116* (3.963)	0.062* (2.674)	-	0.073* (2.301)
Variance Equation				
a_0	6.04E-07* (13.164)	1.60E-05* (20.351)	4.21E-06* (11.139)	8.03E-5* (10.218)
a_1	0.951* (613.89)	0.619* (38.985)	0.884* (118.721)	0.061 (0.668)
β_1	0.018* (14.495)	0.329* (12.869)	0.112* (12.709)	0.223* (5.486)
γ_1	0.024* (7.137)	-0.191* (-7.018)	-0.071* (-7.671)	-0.124* (-2.452)

Panel B: Residual Diagnostic

	Route 1	Route 1A	Route 2	Route 2A
LL	7,468.70	10,940.23	7,700.19	6,297.11
Skewness	0.596 [0.000]	1.522 [0.000]	0.682 [0.000]	6.654 [0.000]
Kurtosis	16.101 [0.000]	18.395 [0.000]	12.331 [0.000]	138.839 [0.000]
J-B	20,049.5 [0.000]	37,531.30 [0.000]	11,844.1 [0.000]	1,239,341.3 [0.000]
Q(24)	22.082 [0.515]	20.158 [0.632]	23.938 [0.407]	26.518 [0.277]
$Q^2(24)$	22.946 [0.464]	12.088 [0.969]	29.951 [0.151]	0.367 [0.999]
ARCH(12)	1.534 [0.105]	0.403 [0.963]	1.454 [0.213]	0.011 [0.999]
Persistence	0.996	0.757	0.925	0.160
UV	0.000001	0.000021	0.000005	0.000502

Notes:

- All variables are transformed in natural logarithms.
- Figures in parentheses (.) and in squared brackets [.] indicate *t*-statistics and exact significance levels, respectively.
- * and ** indicate significance at the 5% and 10% levels, respectively.
- The GJR-GARCH process is estimated with the QMLE. The BHHH algorithm maximised the QMLE.
- LL is the System's Log-Likelihood.
- J-B is the Jarque-Bera (1980) normality test.
- Q(24) and $Q^2(24)$ are the Ljung-Box (1978) tests for 24^{th} order serial correlation and heteroskedasticity in the standardised residuals and in the standardised squared residuals, respectively.
- ARCH(5) is the Engle's (1982) F-test for Autoregressive Conditional Heteroskedasticity.
- The joint hypothesis tests ($a_2 = \beta_2 = 0$ and $a_2 = \beta_2 = \gamma_2 = 0$) are Wald tests.
- Persistence is defined as the degree of convergence of the conditional volatility to the unconditional volatility after a shock and is calculated as $a_1 + a_2 + \beta_1 + \beta_2 + \gamma_1$.
- UV is the unconditional volatility estimate of the GJR-GARCH models, measured as a_0 / (1-a_1-b_1-γ_1)].

Table 6. GJR-GARCH Model Estimates for the Post-FFA Period

Panel A: Coefficient Estimates

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

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

	Route 1-AR(2) (01/01/97 - 31/07/00)	Route 1A-AR(3) (01/01/97 - 31/07/00)	Route 2-AR(2) (01/01/97 - 24/08/01)	Route 2A-AR(2) (01/01/97 - 24/08/01)
Mean Equation				
φ_0	4.82E-06 (1.702)	-1.85E-05 (-0.967)	-1.05E-04 (-0.417)	-1.88E-04 (-0.133)
φ_1	0.539* (16.339)	0.650* (14.576)	0.675* (15.222)	0.619* (18.963)
φ_2	0.152* (4.289)	0.217* (4.415)	0.072* (1.996)	0.169* (5.548)
φ_3	-	-0.085* (-2.390)	-	-
Variance Equation				
a_0	8.33E-08 (1.094)	1.23E-05* (11.378)	2.11E-05 (13.260)	1.11E-06* (5.028)
a_1	0.902* (115.26)	0.547* (18.021)	0.329* (7.429)	0.726* (88.684)
β_1	0.042* (5.649)	0.502* (6.531)	0.313* (9.652)	0.227* (14.269)
γ_1	0.052* (4.672)	-0.290* (-3.767)	-	-

Panel B: Residual Diagnostic

	Route 1	Route 1A	Route 2	Route 2A
LL	4,182.11	3,832.72	5,298.14	4,942.74
Skewness	-0.210 [0.009]	0.826 [0.000]	-0.783 [0.000]	0.032 [0.649]
Kurtosis	6.289 [0.000]	16.468 [0.000]	13.965 [0.000]	10.332 [0.000]
J-B	1,524.38 [0.000]	10,500.6 [0.000]	9,080.8 [0.000]	5,159.33 [0.000]
Q(24)	31.185 [0.118]	34.518 [0.058]	19.579 [0.667]	25.032 [0.349]
$Q^2(24)$	24.605 [0.371]	14.735 [0.904]	14.731 [0.904]	11.351 [0.979]
ARCH(12)	0.650 [0.799]	0.458 [0.939]	0.268 [0.994]	0.533 [0.894]
Persistence	0.996	0.759	0.642	0.953
UV	0.0000001	0.000016	0.000059	0.000023

Notes:

- See notes in Tables 5.

Table 7. GJR-GARCH Model Estimates of the Effect of FFA Trading on Spot Market Volatility (Whole Period)

Panel A: Coefficient Estimates

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

$$h_t = a_0 + a_1 h_{t-1} + a_2 D_1 h_{t-1} + \beta_1 \varepsilon_{t-1}^2 + \beta_2 D_1 \varepsilon_{t-1}^2 + \gamma_1 \varepsilon_{t-1}^2 D_{t-1}^- + \gamma_2 D_1 \qquad (3)$$

	Route 1-AR(3) (29/11/89 – 31/07/00)	Route 1A-AR(3) (07/08/90 – 31/07/00)	Route 2-AR(2) (29/11/89 – 24/08/01)	Route 2A-AR(2) (15/02/91 – 24/08/01)
Mean Equation				
φ_0	1.72E-05 (0.865)	2.11E-05 (0.633)	-4.87E-05 (-0.094)	-1.17E-04 (0.163)
φ_1	0.454* (28.439)	0.566* (23.240)	0.545* (25.221)	0.585* (26.193)
φ_2	0.159* (6.658)	0.166* (5.835)	0.126* (5.997)	0.158* (7.409)
φ_3	0.083* (3.485)	0.06* (2.606)	-	-
Variance Equation				
A_0	6.65E-07* (13.336)	1.69E-05* (15.958)	4.31E-06* (11.241)	8.15E-05* (11.763)
A_1	0.914* (562.23)	0.609* (28.762)	0.881* (114.35)	0.074 (0.947)
A_2	-0.023* (-4.153)	0.056* (2.128)	-0.536* (-11.913)	0.704* (9.586)
β_1	0.030* (15.275)	0.312* (11.820)	0.112* (12.522)	0.153* (5.663)
β_2	0.027* (3.543)	0.047* (1.796)	0.233* (7.584)	0.064* (2.268)
γ_1	0.033* (-8.151)	-0.198* (-6.796)	-0.061* (-6.362)	-
γ_2	-6.01E-07* (-7.191)	-4.97E-06* (-3.569)	-1.62E-06* (-9.830)	-8.05E-05* (-11.591)

Panel B: Residual Diagnostic

	Route 1	Route 1A	Route 2	Route 2A
LL	11,665.03	10,942.16	13,033.41	11,274.72
Skewness	0.302 [0.000]	1.418 [0.000]	0.123 [0.006]	3.663 [0.000]
Kurtosis	13.307 [0.000]	17.856 [0.000]	12.821 [0.000]	79.864 [0.000]
J-B	20,481.6 [0.000]	35,289.4 [0.000]	20,801.8 [0.000]	72,868.8 [0.000]
Q(24)	23.845 [0.413]	21.387 [0.557]	32.215 [0.096]	21.995 [0.521]
$Q^2(24)$	31.566 [0.109]	11.073 [0.982]	27.723 [0.226]	0.788 [0.999]]
ARCH(12)	0.921 [0.573]	0.404 [0.963]	1.396 [0.160]	0.017 [0.999]
$a_2 = \beta_2 = 0$	17.864 [0.000]	28.262 [0.000]	142.531 [0.000]	163.753 [0.000]
$a_2 = \beta_2 = \gamma_2 = 0$	153.211 [0.000]	28.661 [0.000]	187.479 [0.000]	420.769 [0.000]
Persistence	0.981	0.826	0.629	0.995
UV	0.000003	0.000069	0.000007	0.000200

Notes:

- See notes in Tables 5.
- UV is the unconditional volatility estimate of the GJR-GARCH models, measured as $(a_0+\gamma_2)$ / $(1-a_1-a_2-\beta_1-\beta_2-\gamma_1)$.

Table 8. GJR-GARCH Model Estimates of the Effect of FFA Trading and Other Economic Indicators on Spot Market Volatility (Whole Period)

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

$$h_t = a_0 + a_1 h_{t-1} + a_2 D_1 h_{t-1} + \beta_1 \varepsilon^2_{t-1} + \beta_2 D_1 \varepsilon^2_{t-1} + \gamma_1 \varepsilon^2_{t-1} D^-_{t-1} + \gamma_2 D_1 + \delta_1 G_t \qquad (4)$$

	Route 1-AR(3) (29/11/89 – 31/07/00)	Route 1A-AR(3) (07/08/90 – 31/07/00)	Route 2-AR(2) (29/11/89 – 24/08/01)	Route 2A-AR(2) (15/02/91 – 24/08/01)
Panel A: Coefficient Estimates of Variance Equation with SPI variable				
a_0	7.12E-07* (12.988)	3.34E-06* (7.890)	3.29E-06* (9.160)	8.15E-05* (11.823)
a_1	0.934* (557.675)	0.659* (38.883)	0.887* (118.087)	0.073 (0.935)
a_2	-0.025* (-3.846)	-0.383* (-7.154)	-0.589* (-13.659)	0.719* (9.654)
β_1	0.031* (15.481)	0.297* (13.075)	0.105* (11.946)	0.143* (5.328)
β_2	0.024* (3.140)	0.108* (3.196)	0.258* (8.051)	0.065* (2.113)
γ_1	0.033* (7.999)	-0.188* (-6.949)	-0.059* (-6.050)	3.81E-03 (0.189)
γ_2	-4.41E-07* (-2.853)	1.65E-05* (3.504)	-1.69E-05* (-10.305)	-7.98E-05* (-11.547)
δ_1	-3.01E-03** (-1.880)	0.192* (14.613)	0.015* (5.932)	-4.93E-03 (-1.607)
Panel B: Coefficient Estimates of Variance Equation with SPCI variable				
a_0	4.46E-07* (3.899)	8.69E-06* (10.053)	4.69E06* (10.171)	8.15E-05* (11.846)
a_1	0.932* (577.92)	0.644* (33.786)	0.881* (111.49)	0.073 (0.927)
a_2	-0.027* (-4.451)	1.01E-03 (0.041)	-0.542* (-11.968)	0.721* (9.681)
β_1	0.026* (14.670)	0.312* (12.551)	0.111* (12.355)	0.123* (5.318)
β_2	0.030* (3.893)	0.045** (1.737)	0.233* (7.487)	0.066* (2.156)
γ_1	0.032* (8.564)	-0.191* (-6.936)	-0.061* (-6.426)	3.91E-03 (0.188)
γ_2	-6.898* (-7.107)	-3.06E-06* (-2.068)	-1.67E-05* (-10.106)	-8.04E-05* (-11.669)
δ_1	3.36E-03** (1.866)	0.117* (10.938)	-7.32E-03* (-2.199)	-2.60E-03 (-0.486)
Panel C: Coefficient Estimates of Variance Equation with BCOI variable				
a_0	2.82E-07* (5.273)	8.66E-06* (15.064)	2.51E-05* (16.559)	8.09E-05* (11.685)
a_1	0.931* (552.06)	0.689* (39.201)	0.469* (17.149)	0.075 (0.950)
a_2	-0.041* (-7.413)	0.191* (11.391)	-0.224* (-4.847)	0.724* (9.525)
β_1	0.022* (13.234)	0.217* (13.531)	0.196* (7.095)	0.124* (5.349)
β_2	0.040* (5.634)	-0.086* (-4.855)	0.089* (2.329)	0.071* (2.284)
γ_1	0.036* (9.065)	-0.041* (-2.713)	0.115* (3.644)	1.33E-03 (0.64)
γ_2	-6.91E-07* (-5.845)	-8.63E-06* (-12.317)	-5.76E-06* (-2.612)	-8.02E-05* (-11.541)
δ_1	1.93E-03* (10.169)	7.55E-03* (11.117)	0.016* (13.504)	6.54E-04 (0.566)
Panel D: Coefficient Estimates of Variance Equation with WTI variable				
a_0	2.04E-07* (4.033)	1.02E-05* (15.759)	2.68E-05* (17.574)	7.98E-05* (11.328)
a_1	0.932* (566.77)	0.634* (34.618)	0.432* (16.246)	0.083 (1.029)
a_2	-0.047* (-8.481)	3.59E-03 (0.169)	-0.229* (-5.189)	0.718* (9.158)
β_1	0.023* (13.469)	0.322* (13.183)	0.206* (7.149)	0.132* (5.441)
β_2	0.057* (6.234)	0.025 (0.959)	0.084* (2.065)	0.070* (2.587)
γ_1	0.031* (8.305)	-0.187* (-6.882)	0.128* (3.786)	-7.05E-03 (-0.286)
γ_2	-6.78E-07* (-5.790)	-3.99E-07 (-0.366)	-6.54E-06* (-3.077)	-7.94E-05* (-11.254)
δ_1	1.25E-03* (9.695)	7.58E-03* (11.102)	0.012* (17.158)	1.54E-03* (2.169)

Notes:

- See notes in Tables 5.