VOLUME–VOLATILITY RELATIONSHIPS FOR CRUDE OIL FUTURES MARKETS

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INTRODUCTION

When new information arrives on the market, agents react by trading until prices reach a revised, postinformation equilibrium. Trade occurs both in response to the arrival of new information on the asset's value itself and as risk averse agents engage in hedge rebalancing trades.[1] Hedgers are motivated to trade in futures contracts to stabilize their future income flows or costs, with their volume of trading determined by their expectations of future spot (and futures) price movements. Similarly, speculators take an interest in futures contracts based upon their expectations of futures' price variability. The above process of revision results in changes in prices and trading volume; and, since they are both driven by the same directing variable, namely, the flow of information, it is expected that they will exhibit positive correlation. The precise nature of the relationship between price variability and volume has not, however, found consensus.

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[1] It should be noted that as traders switch from nearby contract to next-nearby contract this creates volume that is not related to the arrival of new information. In terms of this investigation the construction of the data series is such that such volume is not considered.

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This article investigates the dynamic relationship between trading volume and price variability in oil futures markets on an empirical level with the aim of addressing three main areas of interest. The primary aim is to examine the general relationship between trading volume and price variability. This is achieved by testing whether the predicted contemporaneous volume–volatility relationship holds over an alternative where lagged volume explains current price variability. If the latter is found to be true, it implies that current volume may be used to predict future price variability. Such a case would violate the notion of informational efficiency in futures markets.

A second question is whether the level of trading volume associated with a price rise is different from that associated with a price fall, i.e., does market activity differ with the direction of price movements? Karpoff (1987) suggests that the response of trading volume to price change in futures markets should not be affected by the sign of price change, an assertion tested in this article. Moreover, this question offers a test of futures markets' efficiency in that a symmetric relationship is indicative of a market where agents have linear unbiased responses to information. The third area of interest is whether the size or maturity of a futures market affects its volume–volatility relationship.

Investigations of this type are of interest because they can provide information on the efficiency of futures markets, and can be of use to regulators in deciding upon the desirability of market restrictions. Increased volume in futures may lead to increased price variability in futures and so invite demands for their regulation. The question of regulation depends, however, upon the precise effects of the positive relationship between volume and volatility. Increased trading volume causing increased price variability may suggest a need for greater regulatory restrictions. Conversely, increased price variability and volume due to a liquid and efficient market could imply that further regulation may harm the price responsiveness of futures.

The role of trading volume in markets has been the subject of a considerable amount of research, which commonly points towards a strong positive relationship between volume and price variability. On a theoretical level, explanations for the relationship have revolved around two main theories; the sequential information model and the mixture of distributions hypothesis, descriptions of which are reserved for the next section. The reason why such a relationship exists has, however, only recently received attention on a theoretical basis in the form of a model furnished by Blume, Easley, and O'Hara (1994), which describes the informational role of volume. This model is distinct from others in that it studies volume in itself, demonstrating how volume can affect market behavior, rather than simply describing the correlation of volume with price.[2] On an applied level investigation has been largely based upon identifying empirical regularities between volume and price change.

This investigation is intended to extend current methodology in a number of ways, and provide evidence of the volume–volatility relationship for oil futures, which have not previously been tested for such relationships. First, it considers the symmetry of the volume–volatility relationship both as a test of market behavior and as an indication of efficiency. Second, consideration is given to the effects of market size and maturity on the volume–volatility relationship. In brief, the relationship is found to be symmetric, while market size/maturity is seen to have little effect other than that which could be attributed to increased liquidity. The main body of this investigation deals, however, with the temporal relationship between price variability and trading volume, which is found to be largely contemporaneous. In undertaking this analysis the study offers a further contribution by using empirical techniques which permit volume and volatility to be modeled simultaneously, a practice largely absent in the current literature. The article proceeds as follows: first it reviews selected literature and presents a discussion of the theoretical issues of the volume–volatility relationship. It then presents some empirical issues and explains the methodology of preliminary tests, deals with the main methodologies adopted by the investigation and describes their application to tests of the volume–volatility relationship. It describes the data used and presents preliminary empirical results in accordance with the tests detailed earlier. Empirical results for the main methodologies are presented and discussed and, finally, concluding remarks are offered.

LITERATURE REVIEW AND THEORETICAL ISSUES

The literature to date is large and diverse, and in the interest of brevity this review is restricted to some of the key articles in the field. Perhaps the most instructive general article on the subject is that provided by Karpoff (1987) which serves the dual purpose of reviewing the existing literature and suggesting a number of areas requiring further research;

[2]A similar point is raised by Gallant et al. (1992) who remark that much of the work in this field has centered around data-based empirical work, and has failed to properly analyze the information structure.

two of which are taken up in this study. Grammatikos and Saunders (1986) use correlation and causality tests to investigate the relationship between price variability and trading volume for currency futures. Consistent with the mixture of distributions hypothesis [see Harris (1987) and Section III below] they find a strong contemporaneous relationship between price-variability and volume in the majority of cases, but finds some evidence of sequential relationships.

Lamoureux and Lastrapes (1990) investigate actively traded stocks to examine whether the ARCH (Autoregressive Conditional Heteroskedasticity) effects commonly found in stock returns are due to time dependence in the process generating information flows. Empirical testing focuses on the variance of daily returns conditional upon the directing variable. Since the daily rate of information flow into the market cannot be observed, it is proxied by contemporaneous daily trading volume. The introduction of contemporaneous volume into the conditional variance equation is found to make the ARCH effects disappear for the majority of stocks considered, a phenomena the authors explain as being due to the fact that volume can explain price volatility. This observation infers that trading volume causes price volatility. A major concern with this type of investigation, and one recognized by the authors, is that the use of contemporaneous volume to explain volatility raises the issue of simultaneity bias, in that volume will not be an exogenous variable. An attempt is made to circumvent this problem by using lagged volume in the ARCH specification, but this variable is found to have little explanatory power. As a consequence, the authors qualify their results by noting that the results may be subject to an unquantified specification bias.

Najand and Yung (1991) examine T-bond futures with a GARCH (Generalized ARCH) model. Using contemporaneous values for volume in the GARCH equation suggests statistically significant correlation between volume and volatility in only a few cases, a finding the authors attribute to simultaneity problems. In response, lagged volume data is used in the GARCH equation to "exogenize" volume. With this adjustment, the correlation becomes significant in all cases. This study concludes that volume is endogenous to price volatility and that volume and volatility are positively correlated. Implicit in this conclusion, though not stated directly by the authors, is the observation that the volume–volatility relationship is not contemporaneous but sequential. Unlike the study by Lamoureux and Lastrapes (1990), however, the authors find that ARCH effects remain when current volume is included in the equation for the conditional variance.

The previous section noted two leading models which provide theoretical explanations for the observed correlation between price variability and trading volume, the mixture of distributions hypothesis by Clark (1973), Epps and Epps (1976), and Harris (1987), and the sequential information model of Copeland (1976) and Smirlock and Starks (1984). The essential practical difference between the sequential information model and mixture of distributions model for explaining this association rests on the speed with which the new equilibrium is attained following the arrival of information. The sequential model allows a number of incomplete equilibria to be reached before the final equilibrium is found, while the mixture of distributions model assumes that the final equilibrium is immediately attained. The remainder of this section is given to explaining the two models in greater detail.

The Sequential Information Model

The sequential information model (SIM) by Copeland (1976) is based upon the key assumption that traders in a market receive new information in a sequential, random fashion. From an initial position of equilibrium where all traders possess the same set of information, news arrives on the market and traders shift their demand or supply accordingly. The information signal is not received by all traders simultaneously, but is observed by each individual. Each individual's trade in response to the signal represents one of a series of incomplete equilibria. Once all traders have received the information signal, a final market equilibrium is established where traders observe the same information set. Traders who are as yet uninformed are assumed not to infer the new signal from informed traders' actions. This notion conflicts with recent work on "mimetic contagion" [see Topol (1991)], where it is suggested that agents accept that they face an incomplete information set and so infer signals from the trading activity of others. In fact, Karpoff (1987) cites as a main criticism of the SIM its prohibition of traders learning from the market price of informed traders.

The main point of interest here is the SIM's implication for the volume–price-variability relationship, and on this point the model has a number of important implications. The primary implication is that a sequential reaction to information suggests that asset price volatility is potentially forecastable with knowledge of trading volume.

The Mixture of Distributions Hypothesis

The mixture of distributions hypothesis (MDH) provides a model which implies a positive relationship between trading volume and price variability, with the relationship being a function of the directing (or mixing) variable, defined as the rate of information arrival. Daily price variance is considered to be a random variable representing the sum of individual price changes within the day, and trading volume is positively related to the number of within-day price changes. The outcome of such trading is, therefore, the contemporaneous change of both prices and volume.

As described by Harris (1987), the MDH for the joint distribution of price change and volume is based upon two initial assumptions. First, the joint distribution of price changes and trading volume is bivariate normal conditional upon the arrival of information variable, n_t. Second, the number of information events in any one day, which determines the overall daily price variability, is random.[3] This assumption implies that price increments are generated by the directing variable, or stochastic rate of information arrival, n_t. Since price change and trading volume are assumed to respond to each information event, their total daily quantities is the cumulation of responses to each event. From the bivariate normal distribution, the conditional variance–covariance matrix is proportional to the directing variable n_t, and since that variable is stochastic the variance–covariance matrix is heteroskedastic. The implication of the MDH is that prices and volume have a joint response to information due to their common distribution. Intuitively, this means that all traders simultaneously view excess supply and demand, and the price implications of a new piece of information. As such, the shift to a new equilibrium is immediate, and the partial equilibria of the sequential information model are never visited.

The Information Content of Volume

Blume, Easley, and O'Hara (1994) provide a new model that describes the informational role of trading volume in markets. The model is based upon the primary assumption that traders receive pricing signals of differing precision or quality. They purport that volume provides information on the precision and dispersion of information signals which price alone does not. The model relates volume, information, and price movements which implies the possibility that volume contains

[3]The notion that the flow of information determines the variability of prices has received theoretical attention from Ross (1989).

information about price movements. The point of interest here is that the information content of volume implied by the model suggests a degree of inefficient pricing and that volume statistics can improve forecasts of future price movements. To begin, markets are assumed to contain noise whose source is the (deficient) precision of information contained in prices. Since price alone does not permit traders to observe the information signal, or the true value of the asset, volume may yield sufficient additional information for that signal to be observed. Given price, volume is assumed to convey information about the price signal's precision, which is used in conjunction with price to make inferences about the mean information signal, i.e., the true asset value.[4] Traders, therefore, condition their price expectations on volume as well as price.

The Blume et al. model implies that low volume may be just as indicative of new information as high volume. In addition, it is not just information per se, but the quality of information which dictates trading volume. Thus, if low quality information signals are received by market agents, then traders place little confidence in them and are reluctant to trade. This is best illustrated by the limit position where the information signals are of such poor quality that trading volume is zero. In this way volume can indicate the precision of an information signal.

Another dimension to the model is that it allows the dispersion of information to play a role in the volume–volatility relationship. By stipulating a market consisting of informed and uninformed traders, the model proposes that the more widely an information signal (of a given precision) is spread amongst market agents, the lower will be the trading volume. This arises from the assumption that informed traders will only trade with uniformed traders. As with the question of information precision, the relationship between information and volume is shown to be complex with the need to take a broader set of factors into consideration. The implications of this model are examined in the section "Data and Preliminary Analysis."

EMPRICIAL ISSUES

Volume and Price Change Per Se

It is commonly held that large trading volumes are related to increasing prices, while falling prices correspond to low trading volume.[5] Such

[4]The mean information signal should converge to the asset's true value plus a common error term.
[5]This is supported on a casual basis by the obervation that trading tends to be higher in bull markets than in bear markets.

phenomena suggest that the direction of price change rather than its dispersion is related to the magnitude of trading volume. Findings in support of this relationship have been reported only for spot equity and bond markets, and results tend to be weak. Moreover, these findings conflict with the theoretical view derived from the MDH that price change and volume are positively correlated. Karpoff (1987) provides an explanation for this observation based upon asymmetric costs between long and short positions for spot assets. Due to their relative costliness there is a restricted demand for short sales in spot markets. Since short sales are made by traders whose information leads them to expect a price fall, relative trading volume will be lower for price falls than for price rises given such cost asymmetries.[6] Futures markets do not face short sale restrictions and the cost of taking long or short positions are symmetric. Previous empirical evidence finds no significant relationship between the direction of price change and trading volume for futures markets.

Previous empirical work notwithstanding, this study tests for such a relationship to establish whether the price–volume relationship is indeed symmetric for oil futures, and whether the dispersion of price changes is positively related to volume. The investigation is carried out on two levels. In the first case, casual observation of the volume–price-change relationship is undertaken by considering plots of price changes against volume. More rigorous testing follows by taking the series of daily (log) price changes and associated trading volume for each market and separating those series into sub-series of negative and positive price changes. The study then examines the volume statistics associated with each sub-series to assess whether volume responses are symmetric to the direction of price change by testing for significant differences between the mean and dispersion of the volume sub-series.

Market Size Effect

One area of interest identified by Karpoff (1987) as meriting further research is the effect of market size on the volume–volatility relationship. This effect can be studied on two levels; the first comparing the relationship for markets whose primary distinction is size, and the second investigating changes in the nature of the volume–volatility relationship as one market grows. The positive volume–volatility relationship relates

[6] In this regard any violation of the MDH is attributed to market frictions rather than inconsistencies in the relationship of information to volume and price change.

to markets where there is sufficient trading volume to yield levels of liquidity conducive to the rapid response of prices to information.[7] This results in prices becoming more informationally efficient, and therefore, more volatile, in the sense described by Ross (1989) as they grow. This study tests the hypothesis that, as a consequence of improved informational efficiency, markets with greater trading volume exhibit greater volatility.

To analyze the possible influence of market size on the volume–volatility relationship this study considers three market samples. The IPE futures contract is compared with the relatively larger NYMEX contract to give what might be termed a cross-sectional comparison. In addition, the NYMEX contract is compared at both early and more recent phases in its existence to provide a growth or maturity comparison.

MODELING METHODOLOGIES

GARCH Model for Volume and Volatility

Many previous studies use constructed measures of volatility, which are somewhat subjective and suffer from measurement problems. More recent studies address this issue by adopting GARCH models to assess volatility in a more objective fashion, notably, Lamoureux and Lastrapes (1990), and Najand and Yung (1991).

Since volume and volatility are assumed to be driven by information flows, the rate and size of which are stochastic, changes in volume and volatility will also change over time. This point is raised by Harris (1987) who suggests that since variations in the directing variable may be random rather than uniform, price variances too may randomly change through time. Heteroskedasticity in price returns is a consequence of their being generated from a mixture of distributions. This observation lends clear support for the use of GARCH models for investigating the volume–volatility issue.

The main motivation for the use of GARCH models for investigating the volume–volatility relationship is provided by Lamoureux and Lastrapes (1990), who describe a framework where the MDH can be expressed as a GARCH model whose specification derives from serial

[7]Tauchen and Pitts (1983) suggest another possible effect, where volatility declines as markets become larger or more liquid. Their suggestion does not conflict with the common observation of a positive volume–volatility relationship because it refers to increasing trading volume as having the effect of removing volatility induced by thin markets—infrequent trading with prices departing substantially from fundamentals.

correlation in the directing variable: the rate of information arrival. This practice finds intuitive support by noting that when information enters the market in clusters, this leads to the clustering commonly observed in asset returns which can be characterized with a GARCH process.[8] Since the rate of information flow is not directly observable, trading volume is proposed as a proxy for the directing variable. This practice is consistent with Copeland's SIM and the model provided by Epps and Epps (1976), but may, it is noted, be inappropriate if prices and volume are a joint function of information arrival. The assumption that volume can be used as the directing variable consigns it to be exogenous to the volatility equation, and it is entered into the GARCH representation as follows;

$$\Delta F_t = \alpha + \epsilon_t \qquad \epsilon_t = N(0, h_t) \tag{1}$$

$$h_t = a_0 + \sum_{i=1}^{q} a_i \epsilon_{t-i}^2 + \sum_{j=1}^{p} b_j h_{t-j} + \gamma V_t \tag{2}$$

where

ΔF_t is the futures price return in period t

V_t is trading volume with the MDH supported when $\gamma > 0$.

If prices and volume are jointly determined, or if information is not exogenous, then eq. (2) may be subject to some simultaneity bias. Najand and Yung (1991), adopt the model in eq. (2) but find volume to be endogenous, and so avoid the problems of specification bias by treating it as predetermined with the following model variation:

$$h_t = a_0 + \sum_{i=1}^{q} a_i \epsilon_{t-i}^2 + \sum_{j=1}^{p} b_j h_{t-j} + \gamma V_{t-1} \tag{3}$$

While the use of GARCH analysis may be useful for the purpose of examining the relationship of volume on volatility, it does leave some shortcomings. The introduction of volume into the GARCH equation is more a test of whether volume represents a proxy for information than a test of the volume–volatility relationship. Also, the use of contemporaneous volume still leaves open the question of simultaneity bias. In light of these factors, this study progresses from GARCH analysis to model volume and volatility as a system of simultaneous equations. An

[8]For an exposition of the representation of the MDH as a GARCH representation, the interested reader is directed to Lamoureux and Lastrapes (1990).

appropriate technique for this type of analysis is the generalized method of moments (GMM) as proposed by Hansen (1982).

GMM Model for Volume and Volatility

This investigation uses an instrumental variable (IV) estimator as a GMM estimator. In modeling the volume–volatility relationship, a dual problem is faced: the presence of simultaneity bias leading to an inconsistent estimator; and heteroskedasticity in the estimator's covariance matrix as predicted by the MDH. The IV approach is particularly suited to this subject since it allows one to model contemporaneous volume and price-variability, thus avoiding problems of simultaneity bias. In addition, the use of a GMM framework produces heteroskedasticity-consistent estimates by correcting the covariance matrix of the (consistent) IV estimator. Thus, in light of the contemporaneous relationship between volume and volatility, the following structural system can be specified;

$$\begin{aligned} V_t &= \alpha_0 + \alpha_1 h_t + \alpha_2 V_{t-1} + \alpha_3 V_{t-2} + \epsilon_t \\ h_t &= \gamma_0 + \gamma_1 V_t + \gamma_2 V_{t-1} + \gamma_3 h_{t-1} + u_t \end{aligned} \tag{4}$$

where

h_t represents the volatility variable,

V_t is the volume variable.

It is evident from eq. (4) that the parameters α_1 and γ_1 are on endogenous variables, a fact which guarantees that OLS estimates of the system parameters will be inconsistent. Conversely, the parameters α_2, α_3, γ_2, and γ_3 are attached to predetermined variables. Restricting attention to the first equation, for convenience only, the predetermined variables V_{t-1} and V_{t-2} are independent of the error term ε; however, h_t is correlated with the error term and so $\text{cov}(h, \varepsilon) \neq 0$. For the system to be estimated, instrumental variables are required for h_t and V_t and lagged values of volume and volatility can be used for that purpose. When a unique set of estimates for the parameters in the structural equation system exist, the system is said to be exactly identified. When multiple estimates are obtained, the system of structural equations is overidentified, while the failure to obtain estimates of the parameters implies an unidentified model.

DATA AND PRELIMINARY ANALYSIS

The data includes daily closing prices for a roll-over of nearby futures contracts written on Brent crude and WTI crude from the IPE and NYMEX, respectively, together with their corresponding daily trading volumes. The nearby futures contract is selected since it attracts the greatest amount of trading activity. Futures returns series are calculated as the first difference of the log of closing prices. The sample used for both markets is from the January 1990 contract to the June 1994 contract. Due to a number of unavailable observations for volume data, the series yield 1120 observations for the Brent contract and 1062 observations for the WTI contract. A third sample covering WTI futures from the January 1984 contract to the June 1988 contract contains 1109 observations. It is included to permit comparisons of the volume–volatility relationship with respect to market maturity.[9]

The amount of trading volume for both oil futures markets has experienced rapid growth since their inception, and consequently, the volume data exhibits an upward trend. To properly assess the relationship between volume and price variability it is desirable to remove such trends prior to empirical analysis. The method of Gallant, Rossini, and Tauchen (1992) is used here. This method preserves the units of measure in detrended data that are used in the unadjusted data, thus avoiding the negative volume figures associated with other methods.

Volume and Price Change Per Se

To provide a preliminary analysis of the volume–price-variability relationship, Figures 1 to 3 are presented, which plot price returns against classes of trading volume.[10] Each class consists of a range of trading volumes, For example, volume class 4 represents all values of the logarithm of trading volumes between 4.00 and 5.00. Each figure illustrates a clear relationship between the magnitude of price movements and the amount of trading volume, with the dispersion of the distribution of price returns increasing with volume.[11] This finding

[9]The IPE Brent futures started trading in mid-1988. The sample start date of January 1990 is chosen to prevent potential problems from low trading volume in its early period. The first NYMEX–WTI period is chosen according to the same criteria.

[10]Due to automatic scaling applied to graphs by the computer software used in this article, the volume–volatility observation for the Invasion of Kuwait by Iraq (2nd August 1990) is removed from all figures covering the 1990–1994 period to improve readability.

[11]For the WTI 1984–88 sample, relatively high volumes appear to relate to lower price changes. The limited number of observations at such high volumes, however, advises caution in making strong inferences from this phenomena.

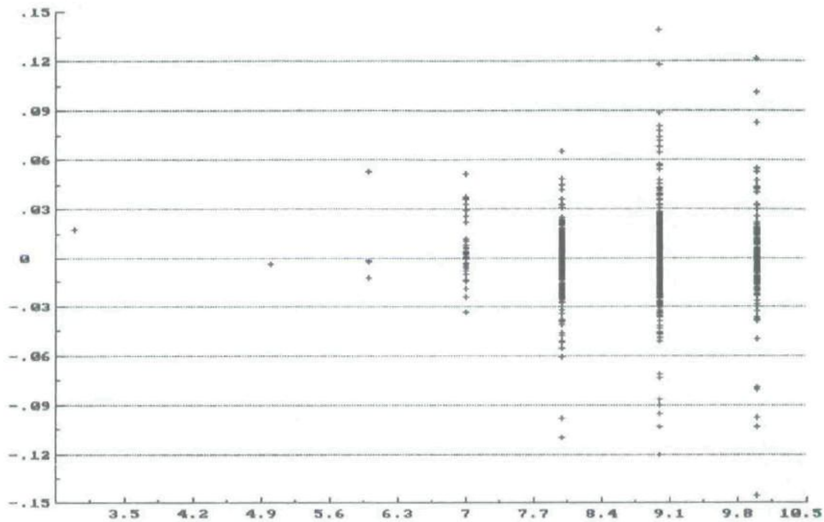

FIGURE 1
Plot of price returns against log volume class (Brent 1990–94).

is consistent with the theoretical propositions of Karpoff (1987) and Harris (1987) detailed in "Empirical Issues," and the empirical findings of Gallant et al. (1992), who adopt a broadly similar exposition of the volume–price-variability relationship.

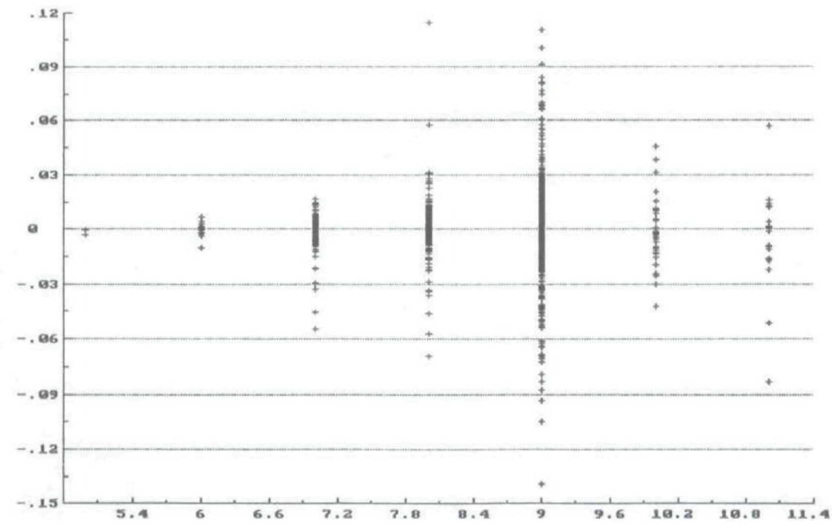

FIGURE 2
Plot of price returns against log volume class (WTI 1984–88).

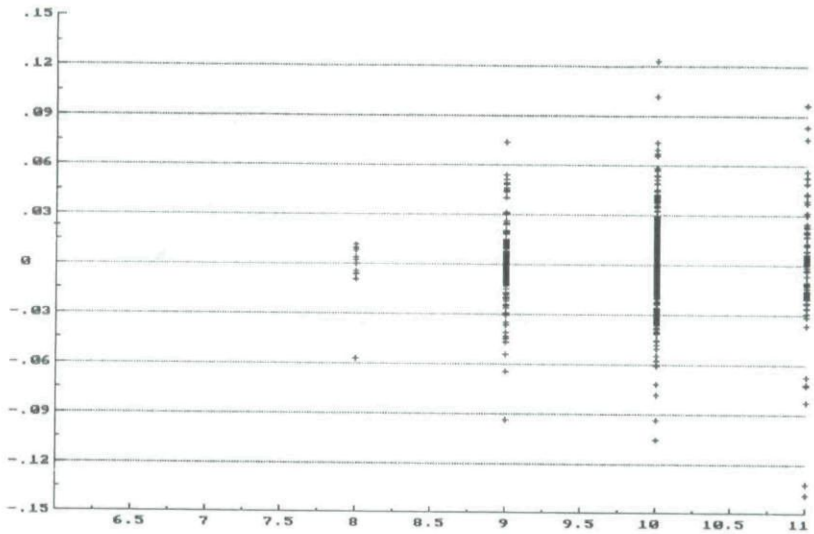

FIGURE 3
Plot of price returns against log volume class (WTI 1990–94).

Figures 4 to 6 essentially reproduce the results illustrated in Figures 1 to 3, but provide actual volume figures rather than volume classes, thus offering a more detailed view of the relationship between trading volume and price variability. The figures generally comply with

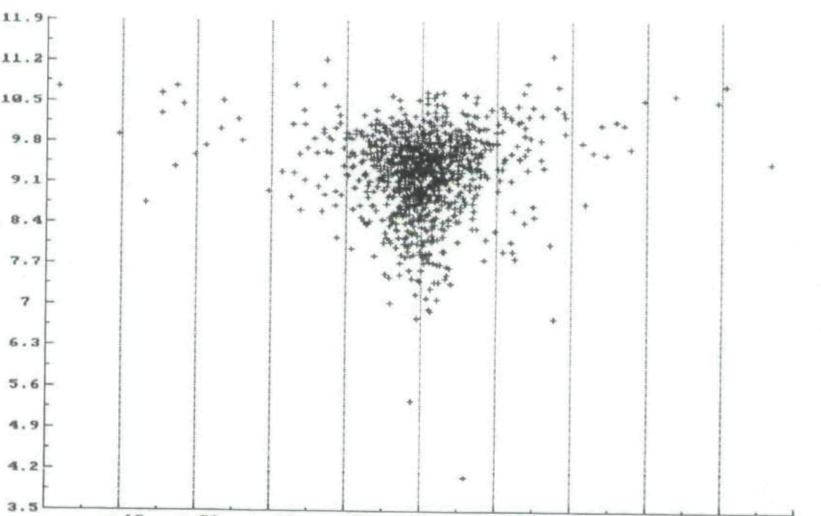

FIGURE 4
Plot of detrended log volume against price returns (Brent 1990–94).

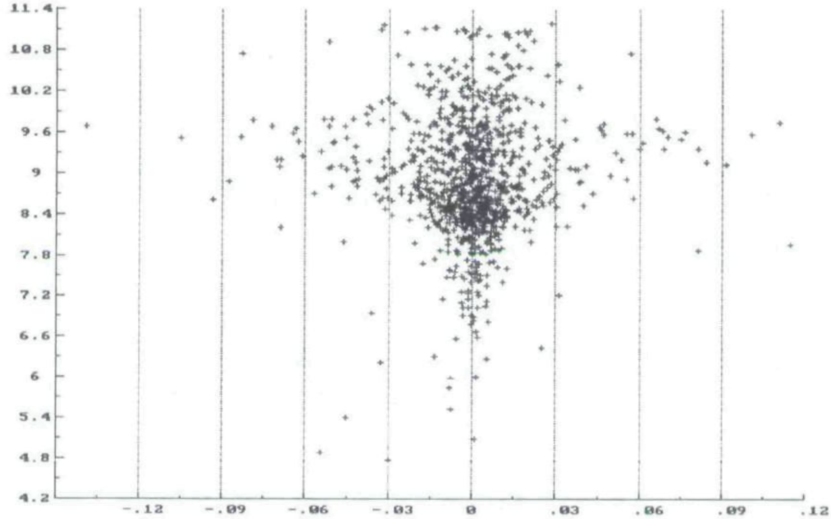

FIGURE 5
Plot of detrended log volume against price returns (WTI 1984–88).

the proposition of Blume et al. (1994), that volume is strictly convex in price. Moreover, the patterns in these figures conform to the shape predicted by the theoretical model furnished by Blume et al. and quite closely resemble the plots provided by the authors using a constructed and "well-behaved" set of data. In their theoretical model of volume and information, Blume et al. further suggest that the precision

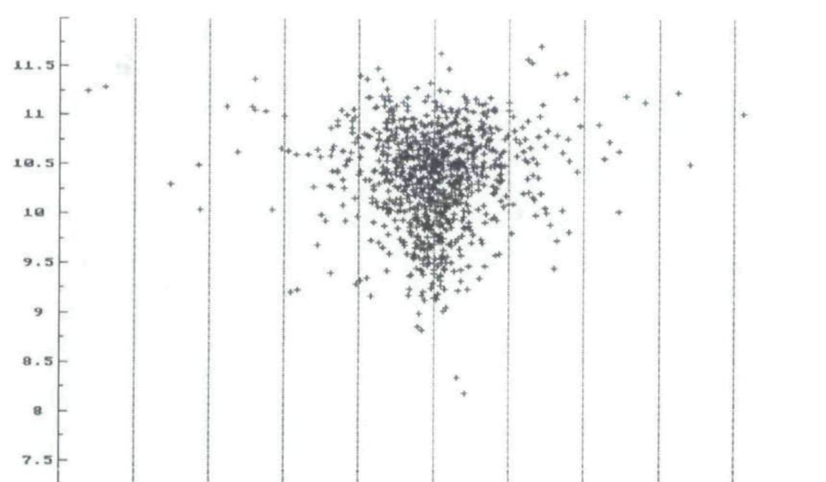

FIGURE 6
Plot of detrended log volume against price returns (WTI 1990–94).

and dispersion of information determine the shape of the relationship between price variability and volume. In their model, a high precision of information yields a V-shape relationship, with the V-shape becoming more sharply defined as the precision of information increases. Alternatively, a large dispersion of information (of a particular category of precision) among market agents gives a plot where increasing volume is associated with an increasing dispersion of the price change distribution, thus yielding a ∇-shape plot.

If for convenience it is assumed that the precision of information in oil futures markets is fixed, then with reference to the proposition of the Blume et al. (1994) model of volume, information and volatility, the nature of the relationship between volume and price change (illustrated in Figs. 4 to 6) are suggestive of futures markets which experience a wide dispersion of information. Since the *V*-shape relationship predicted by the Blume et al. model is not detectable in these plots, it is not possible to make inferences on the precision of information in oil futures markets. The plots generated by Blume et al. to illustrate the effects of different information precision on the volume–volatility relationship cannot be easily provided using real data since information precision is difficult to model in this way. That is why this study assumes a fixed precision of information. A further important observation is that there is no apparent difference between the volume associated with negative or positive price changes, as the plots of volume are evenly distributed about the volatility mean zero line in every case. This observation is consistent with Karpoff's assertion that the direction of price change and the level of trading volume should not be correlated in futures markets. It is also consistent with agents reacting in an unbiased fashion to both price rises and price falls, and, as such, offers evidence in favor of efficiency in futures markets. Preliminary evidence presented from Figures 4 to 6 suggest then that volume is symmetric to the sign of the price change. Statistical evidence provides further support to this finding. For all three data series, the negative and positive price changes are separated into groups together with their corresponding trading volumes. This generates two series of trading volume, one associated with price rises and the other with price falls. Summary statistics for each of the volume groups are presented in Table I. It is evident from the results that oil futures markets do exhibit symmetric trading volume responses to price changes of opposite signs. As such support is given to Karpoff's hypothesis that the direction of price change does not dictate the direction or size of trading volume for futures markets.

TABLE I
Summary Statistics for Trading Volume Respective of Sign of Price Change

		Trading Volume		*Tests*	
Market	*Observations*	*Mean*	*Variance*	t-*tests*	F-*tests*
Brent +ve	559	9.3155	.5382	1.34	1.00
Brent −ve	562	9.2530	.4352		
WTI (1) +ve	574	8.8816	.7012	1.16	.99
WIT (1) −ve	535	8.8822	.7981		
WTI (2) +ve	549	10.384	.2581	1.85	1.00
WIT (2) −ve	513	10.354	.2290		

Trading volume is the detrended logarithm of daily trading volume. The column labeled *Market* is for the sub-samples of positive (+ve) and negative (−ve) price changes for each market group. The WTI(1) group represents the sample period from 1984 to 1988, while WTI(2) represents the 1990 to 1994 sample for the U.S. futures market. The column labeled *t-test* tests for statistically significant difference between the means of the positive and negative sub-samples, i.e., H_0: $\mu_{+ve} = \mu_{-ve}$ with a critical value of 1.96 at 5%, The column labeled *F-test* tests for a statistically significant difference between the variances for the sub-samples within each market group. Here the 5% critical value is 1.00 for the null hypothesis that the two variances are the same.

The Market Size Effect

This study examines two types of market size effects for volume–volatility relationships. The absolute effect is considered by comparing the IPE Brent market with the larger NYMEX–WTI relationship over the same period. The WTI market is compared at different stages in its development to investigate market maturity effects.[12] In smaller or immature markets, trading volume is low by definition; but, if illiquidity forces prices to extremities, a large trading volume may eventually appear in response to prices which have departed substantially from fundamentals. Such volume rushes can lead to considerable volatility in trading volume. A starting point, then, is to consider the volatility of volume. Results presented in Table II indicate the consistent phenomena that the larger a market is, the less variable its trading volume becomes. This observation is explained by mature or very large markets being less susceptible to periods of illiquidity. Examination of the mean trading volume and price variability (measured by standard deviation of price returns) in Table II, show a consistent pattern where greater volume is associated

[12]When using different samples in this way, it is necessary to be mindful of factors which could affect the relationship other than market growth. The 1984–88 sample contains the price collapse of 1988, while the 1990–94 sample contains the Gulf Conflict of 1990/1. Such factors, however, do not appear to have had a long-term effect upon volatility levels; and so, changes in the volume–volatility relationship can be attributed largely to differences in market size.

TABLE II
Summary Statistics and Correlations for Volatility and Volume

	IPE Brent 1990–94		*NYMEX WTI 1984–88*		*NYMEX WTI 1990–94*	
	Volume	$\lvert\Delta F_t\rvert$	*Volume*	$\lvert\Delta F_t\rvert$	*Volume*	$\lvert\Delta F_t\rvert$
Mean	9.284	.0138	8.883	.0127	10.3704	.0144
St. dev	.6979	.0169	.8646	.0164	.4935	.0216
Corr V	—	.2691	—	.1845	—	.2236

The columns labeled $|\Delta F_t|$ are for absolute price returns. Volume (V) is detrended log volume and the Corr V row shows the correlation coefficient for volume and the price returns series.

with more price volatility. This finding adds support to the notion that as markets become larger and more liquid, their informational efficiency and volatility rises. A full examination of this notion could form the basis of future research.

EMPIRICAL RESULTS

GARCH Analysis Results

As stated earlier, the view held here is that the practice of introducing volume figures into a GARCH model may be considered to be more a test of whether volume provides an adequate proxy for the information variable than a test of the volume–volatility relationship. In terms of this investigation, the effect of introducing volume into the GARCH equation is broadly similar for all markets under consideration. In all cases, the volume variables are significant in the GARCH models but are numerically very small and their impact on the GARCH coefficients is negligible. For each model, $\gamma > 0$, but a_1 and b_1 remain significant (see Table III). In no case does volume remove the GARCH effect, thus conflicting with the findings of Lamoureux and Lastrapes (1990), but supporting those of Najand and Yung (1991). In addition, the results suggest that volatility is better explained by previous volatility rather than volume. This finding holds for both contemporaneous and lagged volume. These results lead to the interpretation that volume does not proxy for information, as such.[13] The failure of volume to

[13]An alternative explanation could be that volume does proxy information, but that information does not explain price volatility. This alternative would be suggestive of markets containing a great deal of noise trading.

TABLE IIIa

GARCH Models of Price Volatility with Contemporaneous Volume

$$\Delta F_t = \alpha + \epsilon_t$$
$$h_t = a_0 + a_1\epsilon_{t-1}^2 + b_1 h_{t-1} + \gamma V_t$$

GARCH Coefficient	Series		
	Brent	*WTI(1)*	*WTI(2)*
a_0	.303E-5	.235E-4	.205E-5
	(.0054)	(.012)	(4.093)
a_1	.117	.121	.081
	(10.047)	(8.359)	(8.472)
b_1	.874	.879	.914
	(18.395)	(17.607)	(10.517)
γ	.624E-6	.296E-6	.207E-6
	(5.058)	(4.661)	(4.219)

TABLE IIIb

GARCH Models of Price Volatility with Lagged Volume

$$h_t = a_0 + a_1\epsilon_{t-1}^2 + b_1 h_{t-1} + \gamma V_{t-1}$$

GARCH Coefficient	Series		
	Brent	*WTI(1)*	*WTI(2)*
a_0	.537E-5	.311E-4	.366E-3
	(4.814)	(.108)	(.832)
a_1	.111	.117	.081
	(10.127)	(8.340)	(8.498)
b_1	.879	.884	.914
	(18.339)	(19.909)	(13.459)
γ	.261E-6	.273E-6	.202E-6
	(4.347)	(4.529)	(4.137)

WTI(1) denotes the period 1984 to 1988, while WTI(2) represents the 1990 to 1994 sample.

proxy for information receives indirect support from the proposition by Blume et al. (1994) that volume provides information about the dispersion and quality of information signals, rather than representing the information signal itself. This subtle difference in the role of volume would explain its statistical significance without requiring it to explain volatility directly. From these results it is proposed here that trading volume is an inappropriate surrogate for the rate of information arrival variable in the case of oil futures.

GMM Results

Models are constructed for the three samples considered, with each model being identified according to the test provided by Hansen (1982).

With reference to eq. (4), the variables of primary interest in the system are the coefficients on the contemporaneous value of volatility in the volume equation, i.e., α_1, and volume in the volatility equation, i.e., γ_1. The results are presented in Table IV and demonstrate that in all cases except the NYMEX–WTI market for the period 1984 to 1988, the contemporaneous variables are significant, thereby indicating a contemporaneous relationship between volume and volatility, and implying that both variables are endogenous to the system. For the early WTI period, contemporaneous volume does not explain volatility. This finding is discussed later. The common endogeneity of the volume and volatility variables for the two markets sampled over the early 1990s, however, suggests that they are both driven by an exogenous variable, assumed here to be the rate of information arrival. These findings in conjunction with the preliminary evidence cited in "Data and Preliminary Analysis" provide support of the MDH. Returning to the case of the NYMEX contract for the mid 1980s, the results suggest that

TABLE IV

Generalized Method of Moments Estimation of Volume–Volatility Relations

$$V_t = \alpha_0 + \alpha_1 h_t + \alpha_2 V_{t-1} + \alpha_3 V_{t-2} + \epsilon_t$$
$$h_t = \gamma_0 + \gamma_1 V_t + \gamma_2 V_{t-1} + \gamma_3 h_{t-1} + u_t$$

	Brent 1990–1994	*WTI 1984–1988*	*WTI 1990–1994*
α_0	3.942	3.204	4.014
	(11.698)	(9.947)	(12.097)
α_1	.033	.042	.0280
	(5.297)	(2.050)	(3.140)
α_2	.495	.473	.513
	(16.167)	(10.963)	(11.332)
α_3	.076	.161	.100
	(2.444)	(4.126)	(2.809)
γ_0	−2.069	.038	−1.736
	(−3.214)	(.556)	(−4.430)
γ_1	.413	–	.287
	(16.167)		(3.465)
γ_2	−.164	.021	−.096
	(−2.176)	(2.258)	(−2.017)
γ_3	.093	.974	.138
	(5.872)	(8.247)	(1.843)
Hansen	19.82	22.73	20.22

The row labeled *Hansen* is for the Hansen (1982) test which can be used as a test of identification. The test is $\chi^2(\pi - q)$ distributed where π is the number of instruments, and q is the number of variables in the structural equation system. All models pass the test of identification at the 5% level ($\chi^2(13)$ for Brent and WTI 1990–94, and $\chi^2(14)$ for WTI 1984–88). Figures in parentheses are *t*-statistics.

while contemporaneous volatility can explain trading volume, current volume does not explain volatility. This finding could be interpreted as suggesting that in its early stage of development, price volatility in the NYMEX contract was being driven by factors other than trading volume such as noise, or that trading volume was not proxying for information or offering a description of information. Such a phenomenon could be attributed to liquidity or efficiency problems in the early stages of the markets development.

Another interesting finding from the simultaneous model is that lagged volume (γ_2) is also significant in explaining price volatility in all cases. While this result does not directly contradict the MDH, it does suggest some degree of pricing inefficiency (in the sense of Blume et al.) in oil futures markets since it implies that knowledge of current volume could be used to explain future price variability. Thus, although price volatility for the NYMEX and IPE futures contracts on crude oil can be explained by contemporaneous trading volume, there does appear to be a continued effect from past volume. The implications of this finding are discussed in the next section.

SUMMARY AND CONCLUSIONS

The objective of this study is to address the question of volume–volatility relationships in oil futures markets, which have not been examined previously in this regard. In addition, GARCH techniques and recent work on the information content of volume are utilized to properly account for the role of volume in explaining volatility. The main contribution of the study is its use of the GMM technique to model the volume–volatility relationship contemporaneously. The primary finding is that volume is not an adequate proxy for the rate of information flow, but that volume and volatility are largely contemporaneously related and are both driven by the same factors, assumed here to be information. These results provide strong empirical support for the MDH of Clark (1973) and Harris (1987). The findings from both the GARCH and GMM models that lagged volume can also explain current price variability is not inconsistent with the MDH, but does suggest a degree of inefficiency in oil futures prices. Such inefficiency could be due to traders conditioning their prices on previous trading volume as a measure of market sentiment. Alternatively, it could be explained by a form of mimetic contagion where agents set their prices with reference to the trading patterns of other agents. Certainly the causes of this apparent inefficiency could form the basis of future research.

This study also finds that the magnitude of trading volume and the dispersion of price changes are symmetric, and as such, it is not expected that the level of trading volume is affected by the direction of price changes. Moreover, volume and volatility exhibit the positive correlation expected by theoretical models. The implication of this finding is that the oil futures markets do not react directly to the sign of a price change, i.e., any notion of an over-reaction to bad news is not supported. Indeed, the symmetry is indicative of markets which are efficient with respect to the sign of a price change in that agents have a linear unbiased reaction to price changes irrespective of their sign.

It is concluded that the magnitude of trading volume does not have implications for volatility or the volume–volatility relationship other than that which would be expected with increasing liquidity. In addition, evidence from the GMM model support the notion that illiquid or immature markets can suffer from some type of noise trading as price volatility is not explained directly by the flow of information or the nature of that information.

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