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Spillover effects in energy futures markets

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Abstract

Price discovery in crude oil and refined oil products has been extensively undertaken in organised futures markets for over a decade now. There are two dominant such markets today: the first one in the New York Mercantile Exchange; and the second in London's International Petroleum Exchange. With the demise of OPEC as the leading price setter for crude and products, NYMEX light sweet crude and Brent crude have usurped the role of benchmark grades for price setting. To date considerable work has been done to scrutinise the degree to which these two markets price efficiently, but little with regard to the way the two markets interact. Participants in these markets move with relative ease from one market to the other and usually take positions in both of them. It is of interest, therefore, to investigate the information transmission mechanism by looking at spillover effects and, perhaps, identify which market is the true price leader. This paper is a first attempt to look at such a problem in the energy market, although similar studies have been done on stock market indices. It is found that substantial spillover effects do exist when both markets are trading simultaneously, although IPE morning prices seem to be considerably affected by the close of the previous day on NYMEX. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

Organised commodity futures markets have been around since the end of the last century, but despite their longevity they have often been criticised as relatively less transparent, more inefficient and more difficult to interpret than more recently established financial futures markets. Agricultural commodity futures have been

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the prime focus of most research, but energy futures came to the limelight after the oil price collapse in 1986. Since then, there are primarily two markets which act as benchmarks for the pricing of crude oil and its refined products, on an international basis: New York and London.

In the crude oil market, more specifically, it is two 'marker' crudes that set the pace in prices: West Texas Intermediate and Brent Blend. The former is the base grade traded, as 'light sweet crude', on the New York Mercantile Exchange (NYMEX), while the latter is traded on London's International Petroleum Exchange (IPE) and is also one of the grades acceptable for delivery of the NYMEX contract.

Much of the research to date has focused on the interaction between the cash and the futures tiers of the crude oil market. In contrast, our research question focuses on the information linkages between the two markets. Variations of this question could be: Does the law of one price hold for the two markets?; Is one market more efficient than the other in assimilating information?; and Does one market 'lead' the other in its pricing function?

This paper investigates the information transmission mechanism between NYMEX and IPE crude oil contracts in both non-overlapping and simultaneous trading hours. It also addresses the concomitant questions of: how fast information is transmitted (e.g. within the same day or overnight); in which direction the information flows; and through which mechanism(s) information is transmitted (e.g. through price returns themselves or the variance of these returns).

We start by reviewing the literature on energy futures markets and — more importantly — on the issue of market linkages. We continue with a review of the data at our disposal, their characteristics and shortfalls (where inevitable), and the consequences in the choice of methodology. Following that is the section discussing the methodology employed and the interpretation of empirical results. The paper concludes with a summary of the most important findings and suggestions for further research.

2. Literature review

We concentrate on the subject of linkages between geographically separated markets where research has been restricted to the financial markets only, with work largely concentrated on stock markets. The dominance of the US market is well documented. King and Wadhwani (1990) investigate the volatility spillover issue among stock markets and find evidence supporting contagion effects, and Eun and Shim (1989) find that innovations in the US are rapidly transmitted to other markets, whereas no single foreign market can significantly explain US market movements. Koutmos and Booth (1995) find: (a) price interdependencies, with significant price spillovers from New York to Tokyo, as well as from Tokyo and New York to London; and (b) extensive price volatility interdependencies and sign effects.

Hamao et al. (1990) examine the transmission mechanism in common stock prices across Tokyo, London and New York Stock Markets and suggest that there is some informational inefficiency in these markets. Susmel and Engle (1994) re-examine the evidence of spillovers in returns and return volatility between the US and UK but do not find strong evidence of international volatility spillovers, even for the period including the 1987 stock market crash. The high frequency data used in the later paper may have played an important role in the different results of the two studies.

We focus on the informational linkage of the two well-established energy futures markets in New York and London. A range of energy contracts are traded on both exchanges, including crude oil, heating oil, gas oil, unleaded gasoline and natural gas. We choose to examine crude oil contracts because of less complications due to quality specifications. We look at the two most liquid contracts: NYMEX light sweet crude oil and IPE Brent Blend. Both contracts have the same trading unit of 1000 net barrels (42 000 US gallons), are quoted in US dollars and have very close quality specifications.[1] They are also traded on exchanges with clearing houses providing 'exchange for physical' (EFP) facilities. The Brent contract was launched, in its current form, in June 1988. Its underlying physical base is pipeline-exported Brent blend, which is supplied at the Sullom Voe terminal in the North Sea, in parcels of 500 000 barrels. NYMEX's light sweet crude was introduced in 1982. Its underlying physical base is domestic West Texas Intermediate crude delivered at the end of the domestic US pipeline at Cushing, Oklahoma, in parcels of 50 000 or 100 000 barrels. In addition to WTI, there are six more domestic and four foreign grades deliverable against the contract, one of which is Brent.[2]

3. Data

As shown in Fig. 1, NYMEX trading hours are from 09.45 EST (14:45 GMT) to 15.10 EST (20.10 GMT) while IPE trading hours are from 10.02 GMT to 20.13 GMT. Two different time phases are examined: (1) London is open and New York is closed, i.e. 10.02–14.45 GMT; and (2) both markets are open, i.e. 14.45–20.13 GMT. By separating the overlapping trading hours and non-overlapping trading hours, market dependencies due to non-trading hours are filtered out. Daily return series are calculated using the log returns. London data are obtained from IPE while New York open and close prices are available on Datastream. Data series are from 4 January 1994 to 30 June 1997.

[1] Brent Blend has a specific gravity of 38° API (light), and a sulfur content of 0.2–1% (sweet). Similarly, West Texas Intermediate (the benchmark crude delivered against the NYMEX contracts) is also a light (40° API), sweet (0.5% sulphur) crude. Indeed, Brent blend is (among other crudes) also deliverable against NYMEX contracts on a discount basis (to cover the additional freight charge incurred to import it from the North Sea).

[2] The US domestic grades are: low sweet mix; mid-continent sweet; New Mexico sweet; North Texas sweet; Oklahoma sweet; and South Texas sweet. The foreign grades are: Bonny light (Nigeria); Oseberg (Norway); and Brent blend.

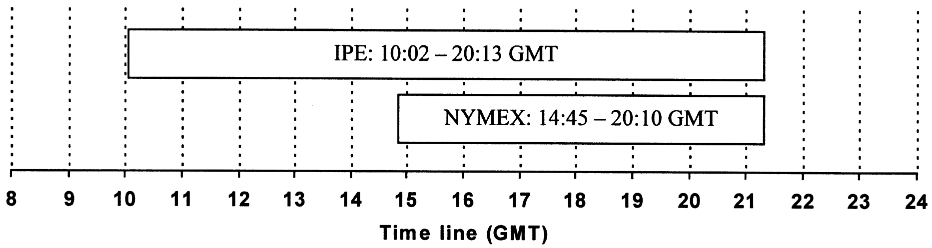

Fig. 1. IPE and NYMEX Trading Sessions.

To counter the non-synchronising problem due to different trading hours, the London open-to-close return data series is divided into two: 'open-to-noon' return (IPEOT); and 'noon-to-close' return (IPETC). The noon data are extracted from the newly released IPE tick data 5 min before the opening trading of NYMEX energy futures contracts. NYMEX opens at 09.45 EST (14.45 London time) Monday–Friday; its return series is denoted as NYOC. The average of the last 5 min high and low prices between 14.40 and 14.45 GMT is used as the London noon price. Trading data, when one market is open while the other is closed for holidays, are discarded to maintain consistency. A dummy variable for Mondays and public holidays is constructed to capture any such effects.

The continuous futures series are constructed by using the nearest contract and switching to the second-nearest contract when the former contract has 5 remaining working days before expiration. The reason for choosing the nearest contract is that it has the desirable characteristics of large volume and liquidity. The 5-working days' cutoff point could be considered arbitrary; however, there is eye-ball evidence that the last 5-day trading volume of the nearest expiry contract declines significantly. A second dummy is constructed at the cutoff point of changing contracts to capture this possible contract-switch effect.

Although NYMEX ACCESS, the screen-based global trading network launched in 1993 gives a constant window on market activity when the open out-cry trading is closed, its volume in average is less than 5% of the exchange trading volume. Its role in information assimilating, price setting and hedging is limited. Ulibarri (1998) investigates price and trading volume relations of the near term futures contracts and finds ACCESS variables are not informative in predicting NYMEX prices. In this paper investigation is concentrated on the open out-cry trading of the exchanges where markets are the largest and most liquid.

4. Methodology and empirical results

The aim of this work is to gather empirical evidence on the timing of information being transmitted from one energy market to the other. More precisely, whether two markets are linked intertemporally or, more likely, simultaneously due to the innovations of information technology. Time series models are most suited for this purpose.[3] We start with univariate GARCH models. After examining the superexogeneity of spillover effects from the foreign market, we advance to bivariate GARCH models. Empirical results from these two models are consistent with each other.

4.1. Univariate models

4.1.1. ARCH / GARCH model

In this paper we follow the standard ARCH (Autoregressive Conditional Heteroscedasticity) model developed by Engle (1982), later generalised by Bollerslev (1986) and known as the GARCH model.

$$R_t = \alpha + \varepsilon_t + b_1\varepsilon_{t-1} \quad \text{where} \quad \varepsilon_t \sim N(0,h_t) \tag{1}$$

$$h_t = \gamma_0 + \beta_1\varepsilon_{t-1}^2 + \beta_2\varepsilon_{t-2}^2$$

where h_t is the conditional variance of the residual.

Table 1 lists summary statistics for the three return series. All series are stationary. The sample means for the three series are not significantly different from zero. The measures for skewness and kurtosis are highly significant at the 5% level, which will be used consistently throughout this paper. Lagrange Multiplier (LM) tests for ARCH effects with lags are significant, suggesting the use of ARCH/GARCH methodology. Box-Jenkins ARMA (Autoregressive moving average) model methodology is applied to construct individual time series. Spillover effects from the foreign market are incorporated in the mean and variance equations of the return of crude oil futures contracts to test the significance.

Box-Jenkins methodology is used first to identify the order of ARMA models in the mean return equation. ARCH/ GARCH order is selected on the criterion of which model has the best fit. The results are shown in Table 2. Two series, i.e. the IPE morning session return (IPEOT) series and the NYMEX trading return (NYOC) series, follow a MA(1)–GARCH(1,1) process while the IPE afternoon session return (IPETC) series follows an AR(2)–GARCH(1,1) process. All three models are reasonably presented. There is no serious misspecification. Higher-order serial correlation on standardised residuals and squared standardised residuals is tested by Ljung-Box Q test with 15 lags and both are not significant.

4.1.2. Monday / holiday effects and contract-switching effects on the conditional mean and variances of futures returns

Two dummy variables are incorporated in the mean and variance equations of each series. The Monday and holiday dummy variable take the value of ‘1’ on days

[3]Crude oil futures contracts are effectively financial assets since 96.7% of NYMEX futures contracts and 95.4% (Horsnell and Mabro, 1993) of the contracts are cash settled.

Table 1
Descriptive statistics

	IPETC	IPEOT	NYOC
Mean	−0.0001	0.0002	0.0006
Variance	0.0002	0.0000	0.0002
Skewness	0.2116	−0.1749	0.2394
Kurtosis	2.81	4.06	2.38
ARCH(12)	**121.19**	**135.31**	**137.59**
LM	1 lag[a]	0 lag[a]	0 lag[a]
Augmented Dickey–Fuller	−19	−29	−28
Phillips–Perron	−841	−841	−822

[a] Lag length is decided by AIC and BIC.
Note: Bold numbers are statistically significant.

after weekends and holidays, and '0' otherwise. The contract-switching dummy variable takes on '1' on every first day that the second-nearest futures contract is adopted and '0' otherwise.

There are well-documented Monday and holiday effects in stock markets (see French, 1980). However, this effect is not significant in this investigation. The mean and variance of the returns of energy futures markets are immune to such 'irregular' days with one exception, i.e. Monday/holiday effects on the variance equation of NYMEX open-to-close trading section.[4] It can be interpreted that the first day returns of NYMEX after trading halts due to holidays seem to be more volatile than otherwise. The contract-switching dummies are not significant in all cases.

4.1.3. Spillover effects on the conditional mean and variance of futures returns in non-overlapping trading hours

Foreign market volatility is incorporated to test whether it has any significant effects on domestic markets. IPE morning trading information is utilised to test the spillover from IPE to NYMEX of the same day. NYMEX trading information is used as a spillover variable for the IPE trading of the following day.

$$R_t = \alpha + \varepsilon_t + b_1\varepsilon_{t-1} + \text{spillovers} \quad \text{where} \quad \varepsilon_t \sim N(0,h_t) \tag{2}$$

$$h_t^2 = \gamma_0 + \beta_1 h_{t-1}^2 + \beta_2 \varepsilon_{t-1}^2 + \text{spillovers}$$

It is demonstrated from Table 3 that the above spillover effects in the variance equations of non-overlapping trading sections are all significant. In addition there

[4] Results of tests for Monday/holiday effects are available from the authors on request.

Table 2
Estimation of GARCH models[a]

	IPETC	IPEOT	NYOC
Model Specification	AR | 2 | GARCH(1,1)	MA(1) GARCH(1,1)	MA(1) GARCH(1,1)
Constant	−0.0001	0.0002	0.0005
	(−0.2688)	(1.2871)	(0.9337)
MA(1)		−0.0019	0.0543
		(−0.0543)	(1.4305)
AR(2)	**0.0874**		
	(2.7706)		
GARCH constant	0.000001	**0.000001**	**0.000002**
	(1.7313)	(2.4052)	(2.2020)
H(1)	**0.9648**	**0.9274**	**0.9640**
	(104.2544)	(53.2370)	(93.0638)
$E(1)^2$	**0.0298**	**0.0516**	**0.0288**
	(3.7495)	(4.3615)	(3.2997)
LL	3203	3949	3133
SK	0.0238	0.1495	−0.0083
KU	1.9592	2.3130	1.7133
AIC	−1499	−2980	−1358
SBC	−1489	−2970	−1349
Ljung-Box Q(15)	15.71	13.13	15.29
Ljung-Box $Q^2(15)$	7.46	20.02	5.20

[a]*Abbreviations*: Ljung-Box Q(15) and $Q^2(15)$, serial correlation tests on standardized mean and standardized mean squared respectively, with 15 lags; SK, Skewness of the standardized residual; KU, Kurtosis of the standardized residual; LL, Log likelihood function value; AIC, Akaike information criterion value; and SBIC, Schwarz Bayesian information criterion value. Numbers in brackets are *t*-statistics.

Note: Bold numbers are statistically significant

are mixed results of spillover effects in the mean equations. For the London IPE morning section, there is a significant coefficient of 0.0376 from the previous New York market while for NYMEX there is no significant spillover effects from the IPE morning section. This is a very interesting result. It implies that NYMEX is an efficient market in terms of incorporating London's information. However, this does not seem to be the case for the London market. Previous day's NYMEX trading information has significant effects on IPE open-to-noon section, implying IPE is not so much an efficient market with regard to information incorporation. This result is in line with recent research on stock market behaviour. Eun and Shim (1989) found that 'innovations in the US are rapidly transmitted to other

Table 3
Spillover effects[a]

	IPEOT	IPETC	NYOC	NYOC
Model Specification	MA(1) GARCH(1,1)	AR | 2 | GARCH(1,1)	MA(1) GARCH(1,1)	MA(1) GARCH(1,1)
Constant	0.0002	−0.0004	0.0005	0.0005
	(1.0677)	(−2.8562)	(1.00683)	(2.9206)
MA(1)	0.0117		0.0519	0.0652
	(0.3549)		(1.3882)	(1.8192)
AR(2)		0.0406		
		(3.1884)		
Spilllover from NYOC{1}	**0.0376**			
	(2.7759)			
Spilllover from NYOC		**0.8658**		
		(83.6659)		
Spilllover from IPEOT			0.0115	
			(0.1234)	
Spilllover from IPETC				**1.0073**
				(77.9025)
GARCH Constant	−0.0000004	−0.000001	−0.000004	−0.0000002
	(−2.1810)	(−3.0199)	(−4.6102)	−0.5725
H(1)	0.9586	0.9338	0.9845	0.8834
	(115.1768)	(80.6145)	(149.7071)	(65.5048)
$E(1)^2$	0.0233	0.0458	−0.0012	0.0895
	(3.7055)	(4.1671)	(−0.2049)	(6.5100)
Spillover	**0.000001**	**0.000001**	**0.00001**	**0.000001**
	(4.5405)	(4.9989)	(6.5846)	(4.0636)
LL	3959	4081	3146	4007
SK	0.0892	−0.0669	−0.0695	−0.0114
KU	1.5915	1.2704	0.9687	2.3784
AIC	−2995	−3202	−1363	−3064
SBC	−2981	−3188	−1349	−3050
Ljung-Box Q(15)	16.41	13.37	16.74	16.61
Ljung-Box $Q^2(15)$	22.97	13.57	7.49	8.71

[a]*Abbreviations*: Ljung-Box Q(15) and $Q^2(15)$, serial correlation tests on standardized mean and standardized mean squared respectively, with 15 lags; SK, Skewness of the standardized residual; KU, Kurtosis of the standardized residual; LL, Log likelihood function value; AIC, Akaike information criterion value; and SBIC, Schwarz Bayesian information criterion value. Numbers in brackets are *t*-statistics.

Note: Bold numbers are statistically significant markets, whereas no single foreign market can significantly explain the US market movement.'

4.1.4. Spillover effects on the conditional mean and variance of futures returns in contemporaneous trading hours

In addition, spillover effects in overlapping trading hours, i.e. the spillovers between IPE afternoon section and NYMEX trading section are also examined. Results of IPETC and NYOC series in Table 3 demonstrate that there are substantial spillover effects being transmitted between the two markets. In the mean equation the coefficient of spillovers from NYMEX to IPE is 0.8658 and 1.0073 from IPE to NYMEX. Spillover from IPE to NYMEX is larger than from NYMEX to IPE. In the variance equation spillover effects remain significant with similar magnitude to the non-overlapping sections. The results imply that the spillover effects in over-lapping trading hours are dominant and in both directions. A word of caution, however, is in order when using this result. By including simultaneous trading variables in the system we inevitably introduce bias. One way of tackling this problem is to examine the exogeneity of spillovers from the foreign market. These tests will be carried out later in the paper.

4.1.5. Joint effects of Monday / holiday and spillover effects on the conditional mean and variances

Both dummies and volatility spillovers are incorporated in the mean and variance of the return series.[5]

Spillover effects across all series remain robust. Dummy effects appear to have more impact on both the mean and variance of return series compared to the previous version that dummy effects are analysed in isolation. The Monday/Holiday dummy is significant in the mean equation of NYOC series of simultaneous trading session while in the non-simultaneous trading, its significance appears in the variance of NYOC series. This result is consistent with the Monday/Holiday effects discussed previously.

As for the contract-switch effects, the previously insignificant coefficients in variance equations are now significant. On the contract switching day, the nearer contract is replaced by the further contract and a different basis is introduced. As a result volatility of the return on the day is reduced. However, the magnitude of this contract-switching effect is negligible.

4.2. Exogeneity tests

Engle et al. (1983) introduced the concept of weak exogeneity, strong exogeneity and super exogeneity. Weak exogeneity provides a sufficient condition for conducting inference conditionally on variables (x_t) without loss of relevant sample information. If, in addition, x_t is not caused in the sense of Granger causality by

[5]Detailed results and tables are available from authors by request.

the endogenous variables in the system, then x_t is said to be strongly exogenous to the parameters of interest. If the conditional model is structurally invariant to structural changes in marginal distribution of x_t, then x_t is said to be superexogenous for the parameters of interest. In this paper we test whether inferences about the domestic market, conditional on the foreign market, are affected by the marginal distribution of the foreign market. If the two markets are mutually exogenous, risk diversification has a role to play.

4.2.1. Granger causality tests

Three pairs of series are tested for Granger causality. Results are shown in Table 4. The hypothesis that NYOC does not Granger-cause IPEOT is rejected. All other sessions accept the null hypothesis of no Granger causality. This result supports our univariate conclusion that there are spillover effects from the previous NYMEX market the IPE morning section.

4.2.2. Superexogeneity

Engle and Hendry (1993) introduced tests of superexogeneity and invariance. Following their structure and the applied work of Francis and Leachman (1998), we experiment with the superexogeneity tests on spillover from the foreign market.

Firstly, marginal distributions for each of the three return series are estimated with the introduction of Brent futures in the Singapore International Mercantile Exchange (SIMEX) as a dummy variable. During the period covered by this study, only the above event could have altered beliefs of agents operating in the markets. There exists now an international crude oil futures contract that can be traded outside European–American time zones. Agents may use the Singapore market to hedge and trade immediately after the relevant news hit the market rather than wait for the opening of the IPE in Europe.

Table 4
Pairwise Granger causality tests

Hypothesis:	F-statistic	Probability
IPEOT does not Granger cause NYOC	1.19284	0.31243
NYOC does not Granger cause IPEOT	***6.46509***	***0.00004***
IPETC does not Granger cause NYOC	0.20728	0.93443
NYOC does not Granger cause IPETC	0.48344	0.74793
IPEOC does not Granger cause NYOC	0.52967	0.71397
NYOC does not Granger cause IPEOC	1.09845	0.35609

Note: Bold numbers are statistically significant

The dummy variable of the launch of Brent futures in SIMEX is incorporated in the individual marginal distribution of IPEOT, IPETC, and NYOC. The specification of the marginal distribution is based on our previous analysis of univariate models. The reports on marginal distributions are as follows:

$$\mathrm{NYOC}_t = \underset{(0.62117)}{0.00053} + \varepsilon_t + \underset{(1.42)}{0.0544}\,\varepsilon_{t-1} - \underset{(-0.03073)}{0.000034}\,\mathrm{DSIM} \tag{3}$$

$$\mathrm{IPEOT}_t = \underset{(1.7951)}{0.00054} + \varepsilon_t - \underset{(-0.0301)}{0.00105}\,\varepsilon_{t-1} - \underset{(-1.33815)}{0.00051}\,\mathrm{DSIM}$$

$$\mathrm{IPETC}_t = \underset{(-0.5817)}{-0.00041} + \underset{(2.87865)}{0.0911}\,\mathrm{IPETC}_{t-2} - \underset{(0.40886)}{0.000369}\,\mathrm{DSIM}$$

Numbers in brackets are t-statistics. None of the dummy variables are significant in the above regressions.

Five variables are saved or constructed from each of the above distributions for superexogeneity tests. In the case of the superexogeneity test on the mean spillovers of IPE morning session to NYMEX open-to-close trading session, residuals (μ_{ipeot}) and variances ($\sigma^2_{\mathrm{ipeot}}$) are saved. The difference between each of the return series and its residuals (M_{ipeot}) is used as a proxy of conditional mean. The residual (μ_{ipeot}) is used to test for weak exogeneity. Variance ($\sigma^2_{\mathrm{ipeot}}$), conditional mean squared (M^2_{ipeot}) and a newly constructed variable ($\sigma^{2*}_{\mathrm{ipeot}} M_{\mathrm{ipeot}}$) are used to test parameter invariance. Another constructed variable ($\sigma^{2*}_{\mathrm{ipeot}} \mu_{\mathrm{ipeot}}$) is used for parameter constancy. Each of the above five variables is included in NYMEX trading session, as specified in Eq. (2), one by one. The Likelihood ratio test is applied for the significance. The same procedures are run for all other trading sessions.

Results are displayed in Table 5. Figures in bold indicate significant parameters of Superexogeneity, rejecting the null hypothesis of parameter. The rejection of the superexogeneity implies that in the market place, agents' perspectives have changed with the introduction of a new trading platform. It may also indicate the trading place is forward-looking. Therefore, there is a strong possibility that the two futures markets or indeed the three markets, including the SIMEX, are components of one large trading place.

That the IPE morning section is superexogenous to NYMEX trading returns is consistent with previous results of Granger causality tests. However, NYMEX previous day returns fail the weak exogeneity and superexogeneity tests in relation to the parameters of IPE morning session. It confirms our previous result that IPE morning return is influenced by returns of NYMEX of the previous days. Neither the IPE afternoon session nor the NYMEX trading session are exogenous to each other. The very different behaviour of IPE morning session and IPE afternoon

Table 5
Superexogeneity test results

Superexogeneity tests (LR test)	IPEOT to the parameters of nyoc	IPETC to the parameters of nyoc	NYOC{1} to the parameters of ipeot	NYOC to the parameters of ipetc
Residual	0.3969	***34.5852***	***24.0801***	2.7628
Variance	1.7758	0.2619	***11.6699***	0.1495
Residual* variance	2.0288	2.4509	0.4845	***4.9972***
Mean squared	0.3564	1.0375	***11.2961***	***4.1376***
Mean* variance	1.3478	***30.9950***	***23.2955***	***5.8664***

Note: Bold numbers are statistically significant.

session is surprising given all physical trading conditions remain the same except the simultaneous trading of NYMEX in IPE afternoon session. It may be an indication that IPE afternoon session is a lot more closely linked to tradings of NYMEX.

4.3. Bivariate VAR model

A bivariate vector autoregressive (VAR) system was set up in order to further investigate the spillover effects from the foreign market to the domestic market, in particular allowing recursive effects in the system. Three sets of models are estimated: (1) IPE afternoon return and NYMEX return; (2) IPE day return and NYMEX return; and (3) IPE morning return and NYMEX return. Following the Likelihood ratio test results, three lags are used in the system. Bivariate BEKK specification of GARCH proposed by Engle and Kroner (1995) is used. This method takes into account the simultaneous trading effects, in particular the cross-country-time-varying covariance and correlations covariance.

The estimation results of the bivariate GARCH(1,1), are consistent with results from univariate equations.[6] The IPE morning session is influenced by NYMEX returns in the 2 previous days with coefficients of 0.0354 and −0.0434, respectively. Any other trading session does not show significant influence from the other market in the mean. In the variance equations, however, there are significant spillovers in both directions in all trading sessions.

5. Conclusion

By investigating the NYMEX and IPE energy futures markets with univariate and bivariate time series models, evidence of spillovers in mean returns is found in the IPE morning section, where up to two previous days' NYMEX information has

[6] Detailed results are available from authors by request.

significant effects. NYMEX is efficient in incorporating past information. Variance spillovers are transmitted in both directions. When both markets are open, i.e. the IPE afternoon trading session and NYMEX day trading session, substantial spillover effects in the mean take place in both directions. These results are robust in relation to superexogeneity tests and Granger causality tests. They may indicate the existence of a common trading market place, which needs to be further investigated. In addition there is some evidence of Monday/holiday effects in NYMEX trading section and marginally significant negative contract-switching effects in the variance equations of all trading sections when two dummies and spillover effects are jointly examined. It may be caused by the arbitrary 5-day cutoff point before expiry when the next nearest contract is taken. It may, however, be due to the fact that when another contract is introduced, some inconsistency of basis is also introduced. Evidence provided by the data available for this paper seem to indicate that NYMEX has an edge on IPE, at least so far as the IPE morning section is concerned. The next step in this line of research should be to look at high frequency data (e.g. every 5 min) on both markets in order to establish who is the true market leader.

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