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Ulibarri, Carlos A.

Pacific Northwest National Laboratories

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CARLOS A. ULIBARRI*

INTRODUCTION

Commodity futures markets are institutions that exist to facilitate exchange. The recent extension into after-hours trading attests to this remarkable role in allowing traders to establish or liquidate extant contract positions at virtually any time of the day or night (Burns, 1997). This widening of trading opportunities has testable implications for intraday price/volume movements based on the potential informational links between overnight and daytime trading sessions. This article presents an early study of these links.[1] The informational attributes of overnight trading can expand market efficiency by providing more continuous price evolution. During the times day trading sessions are closed, the arrival of new information is revealed in after-hours price changes and trading volumes. This line of argument makes clear the idea that after-hours transactions can be helpful in the "discovery" of price-volume structures in the ensuing daytime trading sessions. However, the essential question posed by this phenomenon concerns the means by which after-hour futures markets reveal news, and how the subsequent impacts of this news are disseminated through daytime prices and trading activity.

This article investigates the informativeness of after-hours trading under the prior assumption that daytime and after-hours trading sessions

*For correspondence, MS K8-11 Pacific Northwest National Laboratories, Box 999, Battelle Blvd., Richland, WA 99352.

[1]The analysis of price-volume relationships between day-and-night futures markets contributes to the broad array of price-volume studies in other market contexts, as seen in Grunbichler, Longstaff, and Schwartz (1994), Cambell, Grossman, and Wang (1993), Gallant, Rossi, and Tauchen (1992), Stephan and Whaley (1990), Jain and Joh (1988), Tauchen and Pitts (1983), and the survey in Karpoff (1987).

■ *Carlos A. Ulibarri is a Senior Economist at Pacific Northwest National Laboratories.*

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are completely segmented, signifying stochastic independence between day and overnight futures trading. Our research methodology uses a vector autoregressive (VAR) structural model to identify the lead/lag structure between the leading overnight session and the lagging daytime session. This framework permits us to impose testable restrictions in considering the view that after-hours price changes and trading volumes provide contemporaneous information in the daytime price discovery process. Furthermore, the reduced-form VAR allows testing whether innovations (surprises) in daytime prices and trading activity influence overnight price/volume behavior.

The study investigates price and trading volume relations for near-term crude oil contracts at the New York Mercantile Exchange (NYMEX). The after-hours trading session uses an electronic trading system known as the American Computerized Commodity Exchange System and Services (ACCESS). The NYMEX ACCESS market was approved by the Commodity Futures Trading Commission (CFTC) in December 1992 and was made available to traders on 24 June 1993 (CFTC, 1992). ACCESS hours are from 5:00 PM to 8:00 AM (EST) Monday through Thursday and from 7:00 PM Sunday to 8:00 AM Monday. Trading continues in the NYMEX Regular Trading Hour (RTH) session between 9:45 AM and 3:10 PM Monday through Friday. The NYMEX trading week begins with ACCESS at 7:00 PM Sunday evening and ends with the conclusion of daytime trading at 3:10 PM Friday afternoon. ACCESS contributes to the completion of NYMEX energy markets by allowing hedgers and speculators to trade on news outside of floor-trading hours.[2] Thus a general assumption throughout the study is that price-volume behavior in both trading sessions reflects new information disseminated into the marketplace.

The testable implications are twofold. First, as a pre-floor/post-floor market for NYMEX traders, it seems reasonable to expect that ACCESS price-volume information can, at times, be instrumental in establishing price-volume benchmarks in daytime trading sessions. Therefore, the study considers the informational role of ACCESS trading by examining the impacts of contemporaneous innovations in ACCESS price changes and trading volume on the daytime market. A second market-structural implication of round-the-clock trading concerns the concentration of floor-trading activity in the daytime market. Clearly, vigorous floor trading

[2]It deserves noting that Brent crude oil is traded in London's International Petroleum Exchange (IPE) between 4:45 AM and 10:10 AM (New York time). Thus, IPE could potentially act as an intermediate market relative to the NYMEX trading sessions. However, the overlap between IPE and ACCESS is scarcely two hours long, and so would not seem to seriously affect price-volume relations between NYMEX trading sessions.

has critical organizational influence, affecting the nature of competition and pricing throughout the entire NYMEX energy complex. Therefore, the study considers if daytime trading performs a market-leadership role by examining the impacts of lagged innovations in daytime price changes and trading volume on the ACCESS overnight market; since daytime transactions follow the closure of ACCESS trading, they cannot have a contemporaneous impact on ACCESS. More generally, however, the study suggests that the two trading sessions do feed on each other, depending on the volume and continuity of trading in the marketplace. Together these implications beg consideration of a two-way relationship between daytime and nighttime trading and, at the same time, compound the manner by which news is revealed through surprises in price-volume behavior.

The study examines the various price-volume relations by employing a four-equation structural VAR model. Using techniques introduced by Sims (1986) and Bernanke (1986), theoretical restrictions are imposed on the contemporaneous structural coefficients to segment ACCESS and daytime trading on the basis of their lead–lag relationship to one another. The first identification of the structural VAR presumes that daytime and overnight trading are stochastically independent; i.e., innovations in daytime volume depend on contemporaneous daytime price changes, while innovations in ACCESS volume depend on contemporaneous ACCESS price changes. This restricted identification serves as a straw man for examining alternative views, whereby innovations in the ACCESS market have a contemporaneous influence over the daytime price-volume behavior. Finally, Granger tests of the reduced-form VAR are used in examining the leadership role of daytime markets.

The article is organized as follows. The following section describes the NYMEX sample data for nearby contract maturities (one- and two-month contracts) traded during regular and after-hours over the inaugural year of the ACCESS futures market. Then a structural VAR model is presented which provides testable implications of the informational attributes of the futures exchange. The proceeding section presents the empirical findings of the article, which suggest that more can be learned about the price-volume behavior in the oil futures market by studying the intersession dynamics than by focusing simply on transactions during regular business hours. Finally, concluding remarks are provided on the usefulness of these results in further studies of the informational attributes of after-hours futures trading.

NYMEX SAMPLE DATA

The investigation focuses on NYMEX one- and two-month Light, Sweet Crude Oil contracts (1000 U.S. barrels). These contracts are the basis of the ACCESS market. Study data obtained from NYMEX cover a sampling period between 24 June 1993 and 24 June 1994—the inaugural year of NYMEX ACCESS (251 trading days). However, to examine adaptation to the ACCESS market, the one-year period is broken into two subsamples: 24 June 1993 to 20 November 1993 and 20 November 1993 to 24 June 1994.

Summary statistics for daytime (DVOL) and ACCESS trading volumes (AVOL), daytime open (DOP) and last prices (DLP), and ACCESS open prices (AOP) are shown in Table IA for one- and two-month NYMEX contracts. ACCESS and daytime volumes are hugely different, reflecting the novelty of ACCESS as well as the longstanding "tradition and culture" surrounding daytime floor trading. Meanwhile, volume variability is relatively larger in the ACCESS market, as measured by the coefficients of variation (CV), skewness, and kurtosis. Nonetheless, the large Jarque-Bera (J-B) statistics for both volume series easily reject the null hypothesis of normality. With the exception of the two-month contract, Engel's (1982) Lagrange multiplier (LM) test for ARCH is insignificant for all of the volume series. In contrast, all of the price data have significant ARCH effects, while all but the open price on the one-month contract have insignificant GARCH effects. The price series are all closely similar in terms of their lower moments, skewness, kurtosis, and J-B statistics. The endogenous variables used in structural VAR estimation are generated from the raw data by taking the natural logs of ACCESS and daytime volumes, $AV = \log(AVOL)$ and $DV = \log(DVOL)$, and by measuring absolute changes in the ACCESS and daytime open-to-last prices, $AP = |ALP - AOP|$ and $DP = |DLP - DOP|$.[3] Augmented Dickey-Fuller (ADF) tests for unit roots with a drift and a lagged value of first-difference terms suggest the transformed series is stationary (Dickey and Fuller, 1981).

Table IB reports the correlation coefficients for the transformed price-volume measures. The patterns vary between contracts. For example, the correlations between daytime volume and ACCESS price and volume measures are similar in sign and size for the one-month contract ($p = 0.28$ and $p = 0.27$), but quite a bit different for the two-month contract ($p = 0.21$ vs. $p = 0.53$), especially where volumes are con-

[3]Unfortunately, ACCESS last prices are not generally available to the public. However, NYMEX does use these prices in reporting daytime open prices (DOP two hours later). Thus, for lack of a better measure, daytime open prices are taken as a proxy for the ACCESS last price ($ALP = DOP$).

TABLE I

Descriptive Statistics: 24 June 1993–24 June 1994

A. Summary Statistics

	Contract Month	Mean	Standard Deviation	CV	Skew	Kurtosis	J-B	ARCH	ADF
Day volume (DVOL)	1	46,246	14,167	0.31	0.82	4.12	41.48	0.02	
	2	33,743	16,839	0.49	1.31	6.06	169.87	22.07	
Day open price (DOP)	1	16.72	1.62	0.10	−0.14	1.80	15.77	197.11	
	2	16.81	1.55	0.09	−0.19	1.59	22.31	203.36	
Day last price (DLP)	1	16.73	1.63	0.10	−0.14	1.83	15.11	201.41	
	2	16.81	1.56	0.09	−0.20	1.63	21.52	199.75	
ACCESS volume (AVOL)	1	977	726	0.74	2.42	13.39	1,374	0.14	
	2	612	559	0.91	2.32	12.32	1,133	0.44	
ACCESS open price (AOP)	1	16.72	1.62	0.10	−0.14	1.84	15.77	195.33	
	2	16.81	1.56	0.09	−0.20	1.60	22.30	199.57	
DV = log (DVOL)	1	10.69	0.30	0.03	−0.07	2.85	0.43	4.42	−5.04
	2	10.31	0.49	0.05	−0.12	2.69	1.59	41.17	−6.15
DP = |DLP − DOP|	1	0.19	0.18	0.95	1.49	5.62	164.07	0.62	−5.38
	2	0.17	0.16	0.94	1.69	6.82	272.08	0.43	−5.35
AV = log(AVOL)	1	6.62	0.81	0.12	−1.05	5.57	115.00	0.15	−4.71
	2	5.95	1.17	0.20	−1.45	6.69	230.57	0.08	−5.49
AP = |DOP − AOP|	1	0.09	0.08	0.88	1.57	6.41	225.39	0.21	−7.07
	2	0.08	0.06	0.75	1.20	4.28	77.60	1.47	−6.77

B. Correlation Coefficients

Contract Month		AP	AV	DP	DV
1	AP	1.000	0.366	0.110	0.279
2		1.000	0.324	0.099	0.205
1	AV		1.000	0.032	0.267
2			1.000	0.057	0.527
1	DP			1.000	0.332
2				1.000	0.192
1	DV				1.000
2					1.000

Notes: Volume data are measured in thousands of contracts. Price data are measured in $/barrel of oil. The Jarque-Bera (J-B) statistic is a test for normality. Under the null hypothesis of normality, B-J is distributed as χ^2 with 2 d.f. The null hypothesis of normality is rejected at the 95% level if the test statistic is >5.99. The autoregressive conditional heteroskedasticity (ARCH) statistic is Engle's (1982) Lagrange multiplier (LM) test for first-order ARCH effects and is distributed as χ^2 with 1 d.f. The null hypothesis of first-order ARCH is rejected at the 95% level if the test statistic is >3.84. The augmented Dickey-Fuller (ADF) statistic (1981) is the *t*-statistic for existence of a unit root in the series. The null hypothesis of a unit root is rejected at the 95% level if the test statistic is < -3.43. No test for ADF is made on the nontransformed series because it is not used in the structural VAR estimation. CV = coefficients of variation.

cerned. Other distinctive correlation patterns are shown by daytime price changes and the ACCESS variables. These correlations are more alike for the two-month contract than the one-month contract, and generally smaller than the correlations between daytime volume and ACCESS. Although correlation measures do not imply causality, the asymmetric patterns suggest there is uniqueness in the informational content of the ACCESS variables relative to daytime market activity. The study pursues a more formal analysis of this conjecture by estimating a structural VAR of the NYMEX energy complex using contemporaneous and lagged measures of the ACCESS and daytime variables.

STRUCTURAL VAR MODELING

The critique of pursuing "measurement without theory" encouraged the development of "structural approaches" to VAR modeling based on the work of Sims (1986), Bernanke (1986), and Blanchard and Watson (1986).[4] Structural VAR modeling applies economic theory in transforming a reduced-form time series model of an economy into what essentially becomes a system of simultaneous structural equations. This methodology allows testing the informational content of ACCESS variables on daytime price-volume behavior by letting ACCESS innovations become endogenous information in the daytime market. Structural VAR modeling also allows testing the microstructural implication that ACCESS price-volume behavior is Granger-caused by the lagged innovations in the daytime market. It seems best to describe the framework using the linear, simultaneous-equations model:

$$\begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} \\ a_{21} & 1 & a_{23} & a_{24} \\ a_{31} & a_{32} & 1 & a_{34} \\ a_{41} & a_{42} & a_{43} & 1 \end{bmatrix} \begin{bmatrix} AP_t \\ AV_t \\ DP_t \\ DV_t \end{bmatrix} = \begin{bmatrix} C_{11}\ (L) & C_{12}\ (L) & C_{13}\ (L) & C_{14}\ (L) \\ C_{21}\ (L) & C_{22}\ (L) & C_{23}\ (L) & C_{24}\ (L) \\ C_{31}\ (L) & C_{32}\ (L) & C_{33}\ (L) & C_{34}\ (L) \\ C_{41}\ (L) & C_{42}\ (L) & C_{43}\ (L) & C_{44}\ (L) \end{bmatrix} \begin{bmatrix} AP_{t-1} \\ AV_{t-1} \\ DP_{t-1} \\ DV_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \varepsilon_{3,t} \\ \varepsilon_{4,t} \end{bmatrix}$$

or in compact form:

$$AX_t = C(L)X_{t-1} + \varepsilon_t \tag{1}$$

The A matrix contains the contemporaneous structural parameters on the endogenous variables (AP_t, AV_t, DP_t, and DV_t), while the matrix polyno-

[4]Conventional VAR modeling techniques, pioneered by Sims (1980), have the property of treating all variables symmetrically, whereby each variable is explained by its lagged values and the lagged values of the remaining variables in the model. A symmetrical treatment of the endogenous variables yields impulse response functions based on a unique economic structure which, generally, is difficult to reconcile with economic theory, i.e., a Choleski decomposition of the covariance matrix of VAR residuals as opposed to the Bernanke-Sims type decomposition used in the present study.

mial $C(L)$ contains structural parameters on their lagged values.[5] The vector ε_t contains disturbance terms on the structural equations. The study assumes that all shocks have temporary effects such that the ε_t disturbances are serially uncorrelated vector white noise.[6] The reduced-form VAR is obtained by premultiplying by A^{-1}, yielding:

$$X_t = \beta(L)X_{t-1} + e_t \tag{2}$$

where $\beta(L) = A^{-1}\, C(L)$ and $e_t = A^{-1}\varepsilon_t$. The covariance matrix for the VAR residuals is represented by

$$\Sigma_e = E[e_t\acute{e}_t] = A^{-1}E[\varepsilon_t\varepsilon_t']\, \acute{A}^{-1} = A^{-1}\Sigma_\varepsilon\acute{A}^{-1} \tag{3}$$

where E is the unconditional expectations operator and Σ_e is the covariance matrix for the structural innovations. Generally, Σ_e is taken to be a diagonal matrix on the assumption that structural innovations originate from independent sources.

Testable implications on the contemporaneous price-volume relations between ACCESS and the daytime market are specified by restricting elements in the A matrix. Under these restrictions, the estimated residuals from the reduced-form VAR equations (e_t) recover the structural innovations (ε_t) on the basis of $\varepsilon_t = Ae_t$:

$$\begin{bmatrix} \varepsilon_{AP} \\ \varepsilon_{AV} \\ \varepsilon_{DP} \\ \varepsilon_{DV} \end{bmatrix} = \begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} \\ a_{21} & 1 & a_{23} & a_{24} \\ a_{31} & a_{32} & 1 & a_{34} \\ a_{41} & a_{42} & a_{43} & 1 \end{bmatrix} \begin{bmatrix} e_{AP} \\ e_{AV} \\ e_{DP} \\ e_{DV} \end{bmatrix} \tag{4}$$

A necessary but not sufficient condition for identification is that the number of unknown structural parameters in A be less than or equal to the number of estimated parameters of the covariance matrix of the VAR residuals Σ_e. A four-equation VAR requires at least ten restrictions on the elements in the A matrix.[7] Four restrictions on A arise because each struc-

[5]More specifically, $C(L)$ is a kth degree matrix polynomial in the lag operator L; i.e., $C(L) = C_0 + C_1L + C_2L^2 + \ldots C_kL^k$, where all of the C matrices are square. This representation follows the one described in Keating (1992), where C_0 signifies a matrix of constant terms.

[6]The assumption is supported by the absence of autoregressive conditional heteroskedasticity (ARCH) generalized ARCH (GARCH) effects in the transformed data series, implying that the system in eq. (2) appropriately represents the reduced-form VAR of the structural model; i.e., the error terms are vector white noise and each endogenous variable is a function of lagged values of all the other variables in the system.

[7]Exact identification of an n-equation structural VAR system requires $n(n - 1)/2$ model restrictions (see Enders, 1995, p. 323). Because the zero restrictions on A outnumber unique elements in Σ_e, the identification results in the structural VAR having fewer parameters in A than there are unique elements in Σ_e; i.e., the contemporaneous structural parameters are overidentified. Identification procedures developed by Sims (1986) and Bernanke (1986) allow imposing $n(n - 1)/2$ or more restrictions on the structural model. Imposing more than $n(n - 1)/2$ restrictions results in an overidentified system, allowing individual and/or joint testing of the overidentifying restrictions.

tural equation is normalized on a particular endogenous variable, so that all diagonal elements in A equal unity. Four more restrictions arise from the lead–lag market structure between ACCESS and the daytime market. Specifically, the market timing between trading sessions implies that daytime price-volume information cannot contemporaneously impact the leading ACCESS market. This allows imposing zero restrictions on four of the upper off-diagonal elements: $a_{13} = a_{14} = a_{23} = a_{24} = 0$, resulting in the following simultaneous system:

$$\begin{bmatrix} \varepsilon_{AP} \\ \varepsilon_{AV} \\ \varepsilon_{DP} \\ \varepsilon_{DV} \end{bmatrix} = \begin{bmatrix} 1 & a_{12} & 0 & 0 \\ a_{21} & 1 & 0 & 0 \\ a_{31} & a_{32} & 1 & a_{34} \\ a_{41} & a_{42} & a_{43} & 1 \end{bmatrix} \begin{bmatrix} e_{AP} \\ e_{AV} \\ e_{DP} \\ e_{DV} \end{bmatrix} \tag{5}$$

This model structure takes account of the fact that ACCESS leads daytime trading by treating ACCESS variables as contemporaneously independent of the lagging daytime variables. However, the structure certainly does allow ACCESS variables to have contemporaneous influence on the daytime market. Thus, informational hypotheses between ACCESS and the daytime market may be put to test by selectively imposing theoretical restrictions on the lower off-diagonal elements: a_{31}, a_{32}, a_{41}, and a_{42}.

The structural VAR estimation proceeds by first estimating the reduced-form VAR containing four lags ($k = 4$) on each of the four endogenous variables.[8] An ordinary least squares (OLS) estimation of the reduced form yields 17 parameter estimates per equation, along with estimates of the reduced-form residuals (e_t) and estimates of the elements in the reduced-form covariance matrix Σ_e. The estimation continues by applying identification procedures to derive maximum likelihood estimates of the contemporaneous structural parameters between the estimated OLS residuals (e_t) and the structural innovations (ε_t).

EMPIRICAL ANALYSIS

The lead–lag microstructure between ACCESS and the daytime market provides a unique setting for examining the informativeness of after-hours trading and disentangling other causal relationships between prices and volumes in the NYMEX energy complex. A strong version of a segmented

[8]A VAR lag length of four trading days is selected for the study after considering likelihood ratio statistics for a ten-lag VAR relative to lag lengths of eight, six and two trading days. Chi-square (χ^2) tests suggest the four-day lag structure is sufficiently robust to capture the system's dynamics. Reducing the lag length to four days yields the value $\chi^2 = 80.92$ (with 86 d.f.), which is significant at only the 0.45 level.

TABLE II

Segmented-Market:
Contemporaneous Structural Parameter Estimates

24 June 1993–24 June 1994	*24 June 1993–20 November 1993*	*20 November 1993–24 June 1994*
	A. One-Month Contract	
$\varepsilon_{AP} = e_{AP}$	$\varepsilon_{AP} = e_{AP}$	$\varepsilon_{AP} = e_{AP}$
$\varepsilon_{AV} = -2.91\ e_{AP} + e_{AV}$	$\varepsilon_{AV} = -1.97\ e_{AP} + e_{AV}$	$\varepsilon_{AV} = -3.17\ e_{AP} + e_{AV}$
(0.61)	(1.08)	(0.66)
$\varepsilon_{DP} = e_{DP}$	$\varepsilon_{DP} = \varepsilon_{DP}$	$\varepsilon_{DP} = e_{DP}$
$\varepsilon_{DV} = -0.69\ e_{DP} + e_{DV}$	$\varepsilon_{DV} = -0.75\ e_{DP} + e_{DV}$	$\varepsilon_{DV} = -0.62\ e_{DP} + e_{DV}$
(0.09)	(0.15)	(0.11)
$\chi^2 = 34.79$ with 4 d.f.	$\chi^2 = 19.77$ with 4 d.f.	$\chi^2 = 15.39$ with 4 d.f.
	B. Two-Month Contract	
$\varepsilon_{AP} = e_{AP}$	$\varepsilon_{AP} = e_{AP}$	$\varepsilon_{AP} = e_{AP}$
$\varepsilon_{AV} = -4.94\ e_{AP} + e_{AV}$	$\varepsilon_{AV} = -4.91\ e_{AP} + e_{AV}$	$\varepsilon_{AV} = -4.22\ e_{AP} + e_{AV}$
(1.07)	(1.87)	(1.06)
$\varepsilon_{DP} = e_{DP}$	$\varepsilon_{DP} = e_{DP}$	$\varepsilon_{DP} = e_{DP}$
$\varepsilon_{DV} = -0.87\ \varepsilon_{DP} + e_{DV}$	$\varepsilon_{DV} = -0.77\ e_{DP} + e_{DV}$	$\varepsilon_{DV} = -0.98\ e_{DP} + e_{DV}$
(0.16)	(0.29)	(0.18)
$\chi^2 = 51.56$ with 4 d.f.	$\chi^2 = 31.59$ with 4 d.f.	$\chi^2 = 22.64$ with 4 d.f.

Notes: Standard errors are reported in parentheses. χ^2 statistics with 4 d.f. are for likelihood ratio tests of relaxing overidentifying restrictions on contemporaneous structural parameters in the *A* matrix.

markets hypothesis would suggest that surprises in ACCESS volume are explained only by contemporaneous changes in ACCESS prices, just as innovations in daytime volume are explained only by contemporaneous changes in daytime prices. This view is tested by isolating a_{21} and a_{43}, and imposing zero restrictions on all of the remaining off-diagonal elements. For future reference, the model estimation under the maintained hypothesis imposes $R_4 =$ four overidentifying restrictions.

Table IIA,B reports parameter estimates and their standard errors for the one- and two-month contracts under the segmented-market structure. These results are reported using the full sample period, running from 24 June 1993 through 24 June 1994, and the two subsamples, 24 June 1993 to 20 November 1993 and 20 November 1993 to 24 June 1994.

Overall, the parameter estimates for both contracts show strong evidence that ACCESS and daytime volumes are inversely related to contemporaneous price shocks. Over the full sample, the inverse relationship is significantly stronger during ACCESS trading than during daytime trading for both contracts: -2.91 and -4.94 (one- and two-month ACCESS) as opposed to -0.69 and -0.87 (one- and two-month daytime). Comparing subsampling periods is also revealing. Table IIA shows volume responsiveness increasing between periods during ACCESS sessions (-1.97 to -3.17) and decreasing between periods during daytime sessions (-0.75 to -0.62). Surprisingly, Table IIB shows just the opposite tendency: ACCESS volume decreases (-4.91 to -4.22), while daytime volume responsiveness increases (-0.77 to -0.98). These contemporaneous interactions spark interest in considering the informational characteristics between ACCESS variables and daytime market behavior.

Alternative hypotheses assume ACCESS variables influence daytime trading through contemporaneous impacts on daytime volumes and prices. The daytime volume relation is examined first by relaxing overidentifying restrictions on both a_{41} and a_{42}, so that only R_2 = two overidentifying restrictions are imposed in the estimation. The statistical significance is tested using the likelihood ratio (LR) test statistic, $\chi^2 = |\Sigma_{R4}| - |\Sigma_{R2}|$, with $R_4 - R_2 = 2$ d.f. Under nonbinding restrictions, Σ_{R4} and Σ_{R2} are equivalent. On the contrary, if the value of the χ^2 test statistic exceeds the critical χ^2 value, the joint restriction ($a_{41} = a_{42} = 0$) can be rejected at the corresponding level of significance. Table III summarizes the findings.

Overall, the results provide strong evidence that ACCESS price shocks and volume disturbances are informative variables in the ε_{DV} equations for both contracts. The LR test statistics in Table IIIA,B indicate that the contemporaneous structural parameter estimates, a_{41} and a_{42}, are jointly significant in explaining surprises in daytime volume at the 99% level. Over the full sample, ACCESS price shocks are seen having substantially larger impacts on daytime volume than ACCESS volume disturbances: -0.89 vs. -0.05 for the one-month contract and -0.69 vs. -0.15 for the two-month contract. Structural parameter estimates for e_{AP} in the ε_{AV} equations remain unaffected by the respecification of the model.

The remaining hypotheses on how ACCESS contemporaneously influences daytime trading focus on daytime price behavior and are tested by relaxing zero restrictions on the elements a_{31} and a_{32} in the ε_{DP} equations. The statistical significance of relaxing the joint restrictions is again tested using LR test procedures under the null hypothesis that $a_{31} = a_{32} = 0$. Table IV summarizes the findings.

Overall, the results give a strong indication that NYMEX daytime prices are contemporaneously independent of the ACCESS variables. The large standard errors on the parameter estimates a_{31} and a_{32} point

TABLE III

ACCESS Volume Informativeness:
Contemporaneous Structural Parameter Estimates

24 June 1993–24 June 1994	*24 June 1993–0 November 1993*	*20 November 1993–24 June 1994*
	A. One-Month Contract	
$\varepsilon_{AP} = e_{AP}$	$\varepsilon_{AP} = e_{AP}$	$\varepsilon_{AP} = e_{AP}$
$\varepsilon_{AV} = -2.91\ e_{AP} + e_{AV}$ (0.61)	$\varepsilon_{AV} = -1.97\ e_{AP} + e_{AV}$ (1.08)	$\varepsilon_{AV} = -3.17\ e_{AP} + e_{AV}$ (0.66)
$\varepsilon_{DP} = e_{DP}$	$\varepsilon_{DP} = e_{DP}$	$\varepsilon_{DP} = e_{DP}$
$\varepsilon_{DV} = -0.89\ e_{AP} - 0.05\ e_{AV} - 0.68\ e_{DP} + e_{DV}$	$\varepsilon_{DV} = -0.86\ e_{AP} - 0.06\ e_{AV} - 0.73\ e_{DP} + e_{DV}$	$\varepsilon_{DV} = -0.83\ e_{AP} - 0.03\ e_{AV} - 0.61\ e_{DP} + e_{DV}$
(0.21) (0.02) (0.08)	(0.30) (0.03) (0.14)	(0.27) (0.03) (0.10)
$\chi^2 = 1.72$ with 2 d.f.	$\chi^2 = 3.46$ with 2 d.f.	$\chi^2 = 0.96$ with 2 d.f.
LR test of overidentification $\chi^2 = 33.07$ with 2 d.f. Significance level = 0.01	LR test of overidentification $\chi^2 = 16.31$ with 2 d.f. Significance level = 0.01	LR test of overidentification $\chi^2 = 15.03$ with 2 d.f. Significance level = 0.01
	B. Two-Month Contract	
$\varepsilon_{AP} = e_{AP}$	$\varepsilon_{AP} = e_{AP}$	$\varepsilon_{AP} = e_{AP}$
$\varepsilon_{AV} = -4.94\ e_{AP} + e_{AV}$ (1.07)	$\varepsilon_{AV} = -4.91\ e_{AP} + e_{AV}$ (1.86)	$\varepsilon_{AV} = -4.22\ e_{AP} + e_{AV}$ (1.06)
$\varepsilon_{DP} = e_{DP}$	$\varepsilon_{DP} = e_{DP}$	$\varepsilon_{DP} = e_{DP}$
$\varepsilon_{DV} = -0.69\ e_{AP} - 0.15\ e_{AV} - 0.83\ e_{DP} + e_{DV}$	$\varepsilon_{DV} = -1.18\ e_{AP} - 0.16\ e_{AV} - 0.59\ e_{DP} + e_{DV}$	$\varepsilon_{DV} = -0.94\ e_{AP} - 0.14\ e_{AV} - 0.99\ e_{DP} + e_{DV}$
(0.39) (0.02) (0.14)	(0.68) (0.03) (0.26)	(0.47) (0.04) (0.16)
$\chi^2 = 1.53$ with 2 d.f.	$\chi^2 = 2.49$ with 2 d.f.	$\chi^2 = 0.07$ with 2 d.f.
LR test of overidentification $\chi^2 = 50.03$ with 2 d.f. Significance level = 0.01	LR test of overidentification $\chi^2 = 29.10$ with 2 d.f. Significance level = 0.01	LR test of overidentification $\chi^2 = 22.57$ with 2 d.f. Significance level = 0.01

Notes: Standard errors are reported in parentheses. LR is the likelihood ratio test of relaxing overidentifying restrictions on contemporaneous structural parameters in the *A* matrix, i.e., $a_{41} = a_{42} = 0$. Asymptotically, the test statistic is distributed as χ^2 with 2 d.f. because the test involves the two additional restrictions on *A*. The probability of obtaining χ^2 of 9.21 is 0.010, so we reject the null hypothesis that $a_{41} = a_{42} = 0$ at the 99% level.

to the statistical insignificance of ACCESS variables in all of the ε_{DP} equations. Further evidence of insignificance is seen in the small LR test statistics. Alas, the irrelevance of ACCESS variables on daytime prices was put to a final test by including them in both the daytime price and volume equations. Stepwise test procedures were then used to examine the significance of imposing zero restrictions on a_{31}, a_{32}, a_{41}, and a_{42} in the ε_{DP} and ε_{DV} equations (individually and collectively). Although not reported, the ACCESS variables again proved highly insignificant in the ε_{DP} equations while remaining significant in the ε_{DV} equations, thereby completing the postmortem.

TABLE IV

ACCESS Price Informativeness:
Contemporaneous Structural Parameter Estimates

24 June 1993– 24 June 1994	*24 June 1993– 20 November 1993*	*20 November 1993– 24 June 1994*
	A. One-Month Contract	
$\varepsilon_{AP} = e_{AP}$	$\varepsilon_{AP} = e_{AP}$	$\varepsilon_{AP} = e_{AP}$
$\varepsilon_{AV} = -2.91\, e_{AP} + e_{AV}$ (0.61)	$\varepsilon_{AV} = -1.97\, e_{AF} + e_{AV}$ (1.08)	$\varepsilon_{AV} = -3.17\, e_{AP} + e_{AV}$ (0.66)
$\varepsilon_{DP} = -0.19\, e_{AP} + 0.013\, e_{AV} + e_{DP}$ (0.16) (0.016)	$\varepsilon_{DP} = -0.30\, e_{AP} + 0.022\, e_{AV} + e_{DP}$ (0.20) (0.016)	$\varepsilon_{DP} = -0.17\, e_{AP} + 0.028\, e_{AV} + e_{DP}$ (0.24) (0.031)
$\varepsilon_{DV} = -0.69\, e_{DP} + e_{DV}$ (0.09)	$\varepsilon_{DV} = -0.75\, e_{DP} + e_{DV}$ (0.14)	$\varepsilon_{DV} = -0.61\, e_{DP} + e_{DV}$ (0.11)
$\chi^2 = 33.07$ with 4 d.f.	$\chi^2 = 16.30$ with 4 d.f.	$\chi^2 = 14.42$ with 4 d.f.
LR test of overidentification	LR test of overidentification	LR test of overidentification
$\chi^2 = 1.72$ with 2 d.f.	$\chi^2 = 3.47$ with 2 d.f.	$\chi^2 = 0.97$ with 2 d.f.
Significance level = 0.01	Significance level = 0.01	Significance level = 0.01
	B. Two-Month Contract	
$\varepsilon_{AP} = e_{AP}$	$\varepsilon_{AP} = e_{AP}$	$\varepsilon_{AP} = e_{AP}$
$\varepsilon_{AV} = -4.95\, e_{AP} + e_{AV}$ (1.07)	$\varepsilon_{AV} = -4.91\, e_{AP} + e_{AV}$ (1.87)	$\varepsilon_{AV} = -4.22\, e_{AP} + e_{AV}$ (1.06)
$\varepsilon_{DP} = -0.21\, e_{AP} + 0.0007\, e_{AV} + e_{DP}$ (0.18) (0.01)	$\varepsilon_{DP} = -0.30\, e_{AP} - 0.007\, e_{AV} + e_{DP}$ (0.24) (0.01)	$\varepsilon_{DP} = -0.04\, e_{AP} + 0.006\, e_{AV} + e_{DP}$ (0.26) (0.022)
$\varepsilon_{DV} = -0.87\, e_{DP} + e_{DV}$ (0.16)	$\varepsilon_{DV} = -0.75\, e_{DP} + e_{DV}$ (0.29)	$\varepsilon_{DV} = -0.98\, e_{DP} + e_{DV}$ (0.18)
$\chi^2 = 50.03$ with 4 d.f.	$\chi^2 = 29.09$ with 4 d.f.	$\chi^2 = 22.56$ with 4 d.f.
LR test of overidentification	LR test of overidentification	LR test of overidentification
$\chi^2 = 1.53$ with 2 d.f.	$\chi^2 = 2.50$ with 2 d.f.	$\chi^2 = 0.08$ with 2 d.f.
Significance level = 0.01	Significance level = 0.01	Significance level = 0.01

Notes: Standard errors are reported in parentheses. LR is the likelihood ratio test of relaxing overidentifying restrictions on contemporaneous structural parameters in the *A* matrix, i.e., $a_{31} = a_{32} = 0$. Asymptotically, the test statistic is distributed as χ^2 with 2 d.f. because the test involves the two additional restrictions on *A*. The probability of obtaining χ^2 of 9.21 is 0.010, so there is no evidence to reject the null hypothesis that $a_{31} = a_{32} = 0$ at the 99% level.

In the end, the result that NYMEX daytime prices are contemporaneously independent of ACCESS variables may come as no surprise. After all, daytime prices do evolve in a substantially larger, more liquid market, and, as the saying goes, "it takes volume to move prices." Accordingly, price leadership may be more a characteristic of the daytime market than ACCESS. This view is examined by considering whether lagged innovations in daytime price-volume behavior Granger-cause ACCESS price-volume structures. In this context, daytime price leadership is an exten-

TABLE V

Granger-Causality Tests of Daytime Price Leadership

	24 June 1993–24 June 1994		*24 June 1993–20 November 1993*		*20 November 1993–24 June 1994*	
	Lagged Daytime Prices	*Lagged Daytime Volmes*	*Lagged Daytime Prices*	*Lagged Daytime Volmes*	*Lagged Daytime Prices*	*Lagged Daytime Volumes*
			A. One-Month Contract			
ACCESS price	$F = 2.00$	$F = 0.65$	$F = 2.61$	$F = 0.71$	$F = 0.43$	$F = 0.59$
equation	$p < 0.10$	$p > 0.60$	$p < 0.05$	$p > 0.50$	$p > 0.70$	$p > 0.60$
ACCESS volume	$F = 3.92$	$F = 3.57$	$F = 3.99$	$F = 2.09$	$F = 0.37$	$F = 2.94$
equation	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.10$	$p > 0.80$	$p < 0.05$
			B. Two-Month Contract			
ACCESS price	$F = 4.23$	$F = 1.71$	$F = 6.26$	$F = 0.68$	$F = 0.88$	$F = 0.58$
equation	$p < 0.01$	$p > 0.10$	$p < 0.01$	$p > 0.60$	$p > 0.40$	$p > 0.60$
ACCESS volume	$F = 2.12$	$F = 5.38$	$F = 2.48$	$F = 4.78$	$F = 0.53$	$F = 2.54$
equation	$p < 0.10$	$p < 0.01$	$p < 0.05$	$p < 0.01$	$p > 0.70$	$p < 0.05$

Notes: F-statistics are for block exogeneity tests of daytime price and volume variables in the reduced-form ACCESS price and volume equations; p-values denote levels of significance for rejecting the null hypothesis that daytime prices and volume do not Granger-cause ACCESS price volume structures.

sion of the potential ways through which daytime and ACCESS trading sessions complement or substitute for one another. Granger's (1969) analysis of causality is applied in the sense of Zellner (1984), by testing the null hypothesis that shocks in daytime price changes are insignificant in explaining ACCESS price changes and trading volume. Zellner (1984) suggests causality should emphasize "confirmed predictability," according to a theory of the economy. Thus, the reduced-form VAR is used in examining the market-leadership role that is traditionally ascribed to daytime trading. Table V reports F-statistics reflecting the level of significance for the various lagged coefficients in each of the VAR equations.

Significant F-statistics ($p < 1$) are reported for the lagged daytime price parameter estimates in both the one- and two-month ACCESS price-volume equations, implying that daytime price behavior Granger-causes ACCESS price changes and trading volume. Test results concerning the impacts of daytime volume on ACCESS are also revealing. The F-statistics for the lagged daytime volume parameter estimates are statistically significant in the ACCESS volume equations for both contracts, but turn out to be insignificant in the ACCESS price-change equations. It is also interesting to note that results from the two subsamples show daytime price leadership becoming insignificant over the inaugural year of ACCESS trading, as indicated by the low p-values in the first subsam-

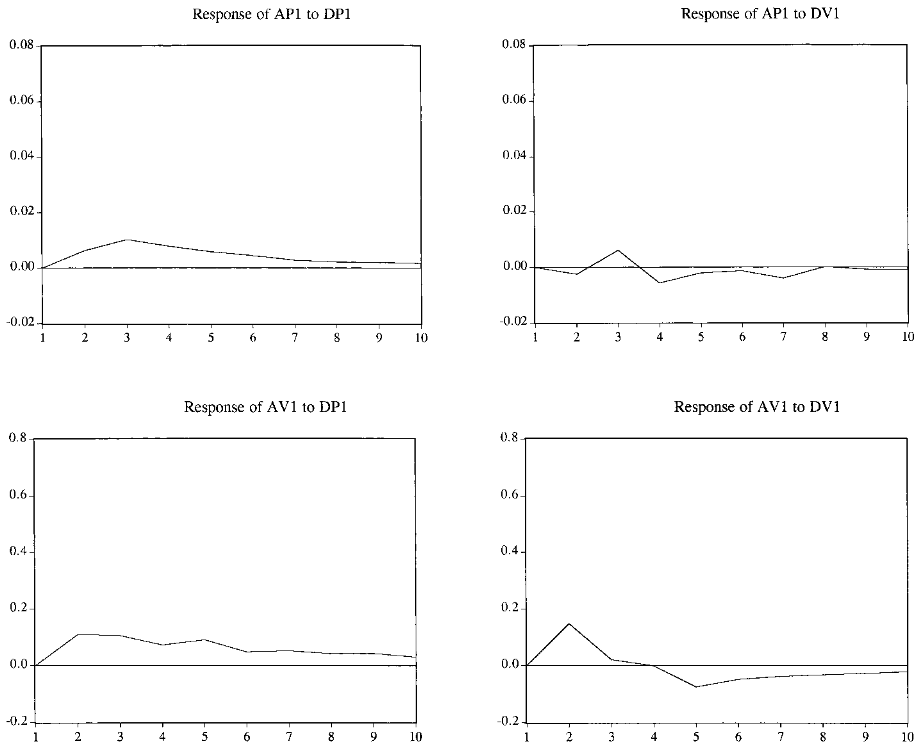

FIGURE 1
Selected impulse responses to one standard deviation innovations: one-month contract.

ple compared to the large p-values in the second subsample. Nevertheless, the evidence over the full sample suggests daytime price innovations tend to Granger-cause ACCESS price-volume behavior, supporting a daytime price-leadership hypothesis.

Some final insights on the market-leadership model are gained by examining selected impulse response functions from the structural VAR system. Figures 1 and 2 plot the cross-market responses implied by daytime market leadership for the one- and two-month contracts, respectively. The plots in each row show the response of ACCESS variables to a one standard deviation shock in the daytime variables over a ten-day period. Overall, the shocks tend to show larger impacts on the two-month contract. Specifically, ACCESS volume and price volatility for the two-month contract are by far more responsive to shocks in daytime volume than they are for the one-month contract. However, these responses taper off by the end of the five-day trading week. In turn, the significant impact of daytime price volatility is highly visible in the ACCESS price structure, and has a more agitating effect on the two-month contract. ACCESS

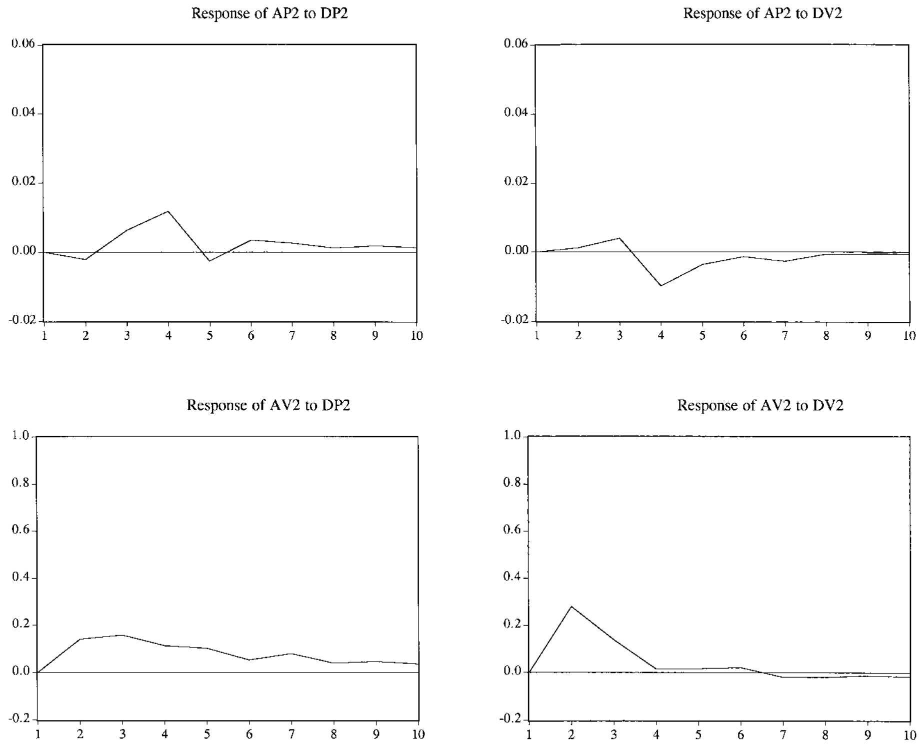

FIGURE 2
Selected impulse responses to one standard deviation innovations: two-month contract.

price responsiveness to daytime price volatility is an intriguing feature of the analysis, and gives emphasis to the informativeness of daytime price behavior on ACCESS price changes.

CONCLUSIONS

The examination of new market phenomena can be a sketchy process and, on occasion, can define new research topics. The study of NYMEX ACCESS and NYMEX daytime trading sessions is essentially a study of an emerging market phenomenon—observing and considering how day-and-night futures trading sessions perform alone or in tandem. In framing the behavioral implications of these evolving market structures, the present study uses a structural VAR model of futures trading. Unlike conventional VAR modeling techniques, the structural VAR identifies an economic theory of the informational relationships between ACCESS and daytime trading. The lead–lag market structure between the day-and-night markets suggests a potential networking of price-volume information, one where surprises in one market have predictable effects on the other.

Under a segmented-market structure, price shocks in each trading session are seen having significant negative impacts on trading volumes, especially in the ACCESS market. Further examination of cross-market behavior suggests that ACCESS variables are informative in predicting daytime volume but not daytime prices. Intuitively, the noninformativeness of ACCESS in explaining daytime price behavior points to a price-leadership characteristic of the daytime market, where information disclosure through face-to-face (mano-a-mano) matching is a uniquely exciting feature of the floor exchange. Granger-causality tests support this intuition, suggesting that daytime price behavior caused ACCESS contract pricing over the inaugural year of ACCESS trading.

However, market size alone does not necessarily make for price discovery. It is easy to imagine how surprises in even the thinnest after-hours session could at times be informative to floor traders the following day. This simple intuition is supported by the results of the study in the sense that ACCESS variables are a signal of trading volume the following day. While market watchers may not appreciate the intricacies of developing a structural VAR model to examine the informational network between trading sessions, they may benefit from a better awareness of this phenomenon. In short, more can be learned about the operation of futures trading by considering day-and-night sessions together than by simply focusing on one to the exclusion of the other. Hopefully, further research on price-volume relationships between regular and after-hours trading systems will broaden understanding of the workings of both systems, and yield a richer set of causal predictions than the ones considered in this study.

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