ENERGY SHOCKS AND FINANCIAL MARKETS

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INTRODUCTION

Throughout modern history, oil has played a prominent role in shaping the economic and political developments of industrialized economies. The 1991 international crisis in the Persian Gulf is a further testimony to the importance of oil. Not surprisingly, a large literature is devoted to the study of energy and its effects on macro-economic variables such as economic stability, economic growth, and international debt. For example, Hamilton (1983) concludes that increases in oil prices are responsible for declines in real GNP. Gilbert and Mork (1984) model the macro effects of an oil supply disruption and survey alternative policy options for dealing with the problem. Mork, Olsen, and Mysen (1994) assert that "the negative correlation between oil prices and real output seems, by now, to have been accepted as an empirical fact."

In sharp contrast to the extensive investigation of the macro-economics of energy issues, little research has been devoted to the

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repercussions of energy shocks on financial markets. The objective of this study is to examine the effects of energy shocks from the financial markets perspective. Specifically, the dynamic interactions between oil futures prices traded on the New York Mercantile Exchange (NYMEX) and U.S. stock prices is investigated.

If oil plays an important role in the U.S. economy as suggested by Hamilton (1983); Gilbert and Mork (1984); Mork, Olsen, and Mysen (1994), and others, one would expect changes in oil prices to be correlated with changes in stock prices. If the oil futures market and the stock market are efficient, oil futures prices and stock prices will be contemporaneously correlated, as each market quickly reacts to information shocks in other markets and as investor expectations are capitalized. In efficient markets, one market could lead or lag the market reaction to new information, but, on average, one would expect the relationship among these markets to be contemporaneous. This study examines the extent to which these markets are contemporaneously correlated. Particular attention is paid to the association of oil prices with stock market indices and with selected individual stock prices for companies that are likely to be particularly sensitive to oil price shocks. If no statistical association is found, the results would indicate that the much-vaunted economic impact of oil prices on the rest of the economy is more myth than reality.

The article also examines a second important issue that bears on the efficiency of oil futures and stock markets; namely, the extent to which price changes or returns in one market lead returns in the others. If oil affects real GNP, it will affect earnings of companies for which oil is a direct or indirect cost of operation. Thus, an increase in oil prices will cause expected earnings to decline, and this will bring about an immediate decrease in stock prices if the stock market efficiently capitalizes the cash flow implications of the oil price increase. If the stock market is not efficient, there may be lags in adjustment to oil price changes. In addition, transaction costs or other barriers to arbitrage might allow prices in one market to lead those in the other markets. For example, if information shocks hit the oil market before other markets, price changes in oil futures would tend to lead those in other markets. This article tests for such inefficiencies.

Links across markets could potentially appear not only in returns but also in return volatility. Ross (1989) argues that the volatility of price changes can be an accurate measure of the rate of information flow in a financial market. It is possible that no significant lead or lag cross-correlations are observable in the returns, but the price volatility—the rate of information flow—in one market leads volatility in the others. Evidence that volatility is correlated across markets would imply dependence in the information processes. This issue is investigated by examining the degree to which volatility is correlated across markets.

This study sheds light on the general question of the information transmission mechanism linking oil futures with stock prices. There are many possible scenarios as to how these markets might be linked informationally. In the unlikely event that the relevant information affecting each of these markets is informationally segmented from the other, oil futures prices and stock prices will be unrelated. At the other extreme, when information induces common price movements in both markets, prices will be highly contemporaneously correlated. Between the two extremes lies the interesting phenomena of feedback effects, lead–lag relationships, and market price and volatility spillovers across markets.

A multivariate vector autoregressive (VAR) approach is used to investigate possible lead, lag, and feedback effects in the oil and stock markets. This procedure was popularized by Sims (1972) and is based on earlier work by Granger (1969). The VAR representation provides a highly flexible framework for examining dynamic interactions among price changes of different financial instruments. Its usefulness here results from its consistency with a variety of economic models which describe the possible dynamic behavior of oil futures and stock prices. Thus, the analysis is not predicated on à priori restrictions of a specific model, but instead is designed to detect stylized facts present in the actual data.

A study by Jones and Kaul (1992) also examines the effect of oil prices on stock prices. They find an effect of oil prices on aggregate real stock returns, including a lagged effect, in the period 1947 to 1991. Their article has a macroeconomic focus, using quarterly data and employing the Producer Price Index for fuels as its measure of oil prices. In contrast, this study uses daily data on stock prices and oil futures prices, and draws conclusions which do not support a relationship between oil returns and aggregate stock returns in the 1980s.

The empirical objective is similar to that found in studies of lead–lag relationships between stock index futures and the stock index, such as Stoll–Whaley (1990) and Chan–Chan–Karolyi (1991). Stoll and Whaley find that stock index futures lead the underlying stock prices within the day even after controlling for infrequent trading of stocks. Chan–Chan–Karolyi investigate leads and lags in volatility between index futures and cash markets using a GARCH framework. Lead-lag relationships between daily stock returns of large and small firms have also been investigated. Lo and MacKinley (1990) document that the stock returns of large firms lead those of small firms. Conrad, Gultekin, and Kaul (1991) find that the stock price volatility of large firms leads that of small firms.

The current study is structured as follows. In the next section the linkage between oil futures and stock prices is discussed. A description of the oil futures market is then presented. The third section contains the data sources and characteristics, evidence on the cross-correlation and serial correlation structure of raw returns is presented in the fourth. The VAR framework is presented, statistical tests based on the VAR framework are undertaken to determine whether oil returns lead stock returns are presented, and corresponding tests assessing whether oil volatility leads stock volatility are presented. The article provides evidence on the bid–ask spreads of stocks of individual companies and assesses its economic significance on the association of oil prices and stock prices. A summary of the results and some conclusions are reported.

OIL AND STOCK PRICES

This section describes the theoretical linkage between oil and stock prices. Instead of pursuing a specific model of oil and stock prices, the approach here is to describe the economic relationship at a general and intuitive level. This approach is consistent with the subsequent empirical analysis that is also not confined to a specific model but is valid for a variety of underlying economic relationships.

Stock prices are discounted values of expected future cash flows or more formally,

$$p = \frac{E(c)}{E(r)} \tag{1}$$

where p is the stock price, c is the cash flow stream, r is the discount rate, and $E(\cdot)$ is the expectation operator. It follows that realized stock returns, R, can be expressed approximately as

$$R = \frac{d(E(c))}{E(c)} - \frac{d(E(r))}{E(r)} \tag{2}$$

where $d(\cdot)$ is the differentiation operator. Thus, stock returns are affected by systematic movements in expected cash flows and discount rates.

Future oil prices can affect expected cash flows and possibly discount rates for various reasons. For example, expected cash flows are affected because oil is a real resource and is an essential input to the production of many goods, similar to labor and capital. As such, expected changes in energy prices cause like changes in expected costs and opposite changes in stock prices. The effect on a specific stock price would depend on whether the company is a net producer or net consumer of oil. For the world economy as a whole, oil is an input and increases in oil prices would depress aggregate stock prices. A dynamic neoclassical model of Kim and Loungani (1992) provides a specific example of how oil price shocks affect aggregate production, leading to business cycles.

Expected oil prices also affect stock returns via the discount rate. The expected discount rate is composed of the expected inflation rate and the expected real interest rate, both of which may, in turn, depend on expected oil prices. For example, since the United States is a net importer of oil, higher oil prices would cause the balance of payments to be adversely affected, putting downward pressure on the U.S. dollar's foreign exchange rates, and upward pressure on the expected domestic inflation rate. Thus, a higher expected inflation rate is positively related to the discount rate and as a consequence is negatively related to stock returns. At the same time, since oil is a commodity, changes in oil prices track the inflation rate, and expected oil price changes can be a proxy for the expected inflation rate. Thus, if the expected inflation rate causes stock price declines as well as rises in oil prices, since oil is a physical commodity, there can be a spurious negative correlation, which could explain some of the earlier empirical results, especially when more time aggregated data is employed.

The real interest rate is also influenced by oil prices since oil is a major resource in the economy. For example, higher oil prices relative to the general price level could cause the real interest rate to rise, forcing an increase in the hurdle rate on corporate investment. The higher hurdle rate then leads to a decline in the stock prices.

THE OIL FUTURES MARKET

Oil futures contracts have been traded on the New York Mercantile Exchange (NYMEX) since October 1974 when the NYMEX introduced the heating oil futures contract. This contract was for many years the most actively traded. Crude oil futures were introduced in March, 1983, and this contract is now the most heavily traded energy contract and the most heavily traded of all nonfinancial futures contracts. In the year ending September, 1990, 22,804,637 crude oil futures contracts were traded; whereas, 6,775,585 heating oil contracts were traded. The crude oil contract is based on pipeline delivery in Cushing, Oklahoma of 1000 barrels of West Texas Intermediate oil. Crude oil and heating oil delivery dates occur monthly with actual trading in the contracts terminating on the third business day prior to the 25th calendar day (for crude oil) or the last business day (for heating oil) of the month preceding the delivery month. Early termination of trading reflects the practice of allowing oil delivery over the entire settlement month.

The October 1973 Arab–Israeli War and the accompanying embargo of oil shipments to the U.S. by OPEC nations dramatically changed the oil market and provided the impetus for the introduction of oil futures contracts. Interest in oil futures trading was initially modest, in part because long-term forward contracts continued to be widely used. With the oil shock of 1979, which followed the Iranian revolution, spot oil prices again rose sharply. As a result of these disruptions and the declining reliability of long-term forward contracts, these contracts took on a less important position, and the use of futures contracts increased. Oil prices remained high in the early 1980s, but they declined sharply in 1986 with the breakdown of the OPEC oil cartel. By that time, the use of long-term forward contracts had also declined significantly.

Several articles have examined different features of the crude oil futures market. Gibson and Schwartz (1990) address the pricing of crude oil futures. Gemmill (1988) examines the reasons behind the popularity of the NYMEX contract while a competing contract issued by the International Petroleum Exchange in London initially was poorly received. Chassard and Halliwell (1986) find that NYMEX crude oil futures are unbiased predictors of subsequent spot prices. Additional studies have examined other oil related futures contracts and their relationship to spot oil products. For example, Bopp and Sitzer (1987) and Gjolberg and Johnsen (1986) investigate heating oil futures, and Chen et. al (1987) examine the hedging effectiveness of crude oil, heating oil, and leaded gasoline futures contracts. Ng and Pirrong (1992) explore the spot and futures price relationships in refined petroleum products.

Bailey and Chan (1990) explore the monthly relationship between various commodity futures prices including heating oil and a number of macroeconomic variables and between the futures basis and stock and bond market yields. They find that heating oil futures prices are positively correlated with the corporate bond spread and negatively correlated with the dividend yield.

DATA

Oil Futures Data

The analysis is based on daily closing prices for the nearby oil futures contract on the NYMEX for the period starting on October 9, 1979 (for heating oil), and April 11, 1983 (for crude oil), through March 16, 1990. Prices for the futures contract closest to delivery are used until the contract reaches the fifth trading day of the month preceding the settlement month. Then, prices of the next closest contract to settlement are substituted. Price data overlap one trading day to facilitate the transition from one contract to the next. The transaction data are chosen to precede the expiration of options on these futures contracts, which occurs on the second Friday of the month prior to delivery. Daily closing prices for oil futures contracts are from the NYMEX.

The first difference in the log of the futures price is defined as the rate of return on a futures contract.[1] The returns are also multiplied by 100 to state them as percentages. As previously noted, the crude oil futures contract is more heavily traded than heating oil futures, but the latter contract has a longer data series. Given that the correlation between the returns on the two contracts is only 0.86, linking the two data series is likely to introduce spurious results. Instead, the returns of the two contracts are analyzed separately.

Stock Returns and Interest Rates

The linkages between oil prices and the stock market are examined at three levels; first, for a market wide stock price index, the S&P 500 index; second, for 12 stock price indices based on SIC codes; third, for 3 individual oil company stock price series. Prices of the S&P 500 stock index, collected daily at 3:00 PM (EST), are from the monthly S&P 500 Bulletin. The 3:00 PM price corresponds closely to the closing time of oil futures trading which occurs at 3:10 PM EST. Percentage returns are calculated as the first difference in the natural log of the index price multiplied by 100 and are not adjusted for cash dividends.

The returns of the 12 industry price indices are constructed by equally weighting returns of stocks classified according to the first two digits of their SIC codes. The grouping procedure follows the categorization used by Sharpe (1982) and Breeden, Gibbons, and Litzenberger

[1] Strictly speaking, returns on futures contracts are not defined since there is no investment in a futures contract.

(1989). The individual daily percentage stock returns are obtained from CRSP NYSE/AMEX file and are based on 4:00 PM (EST) NYSE closing prices (or, in some cases, a later price if the stock trades on the Pacific Stock Exchange).

The three stocks from the oil industry that appear in the Major Market Index—Chevron, Exxon, and Mobil—are also used for the study, and daily percentage stock returns (based on 4 PM EST closing time) were obtained from CRSP. The CRSP individual stock returns are adjusted for cash dividends, stock dividends, and splits.

The daily interest rates are used as control variables in the analysis. One-month Treasury bill returns quoted by dealers at 3:00 PM EST are from Interactive Data Corporation (IDC). Since interest rates are highly positively autocorrelated, the analysis uses a realized daily return defined as the negative of the change in the annualized one month rate divided by 12.[2]

Descriptive Statistics

Table I provides means and standard deviations for the three types of time series over the period October 9, 1979, through March 16, 1990. All the series contain 2584 observations except crude oil futures which has only 1721 observations, reflecting its later start date of April 11, 1983. There are 56 instances in the sample for which stock return data are available but either oil or t-bill data are missing. In these cases, the returns are calculated so that the return for each series spans the entire period.

[2]The quoted return (at discount) on a 30 day t-bill is defined as

$$R_t = \frac{F - P_t}{F} \frac{360}{60}$$

where F is the final value of the bill and P_t is its price at t. The change in the return is

$$R_{t+1} - R_t = \left[\frac{F - P_{t+1}}{F} - \frac{F - P_t}{F} \right] \frac{360}{30}$$

and

$$-(R_{t+1} - R_t)\frac{30}{360} = \left[\frac{P_{t+1} - P_t}{F} \right]$$

which is approximately a one-day realized return.

TABLE I
Summary Statistics for Daily Percentage Returns of Oil Futures, Spot Interest Rate, S&P 500, SIC Categories, and Oil Companies

Asset	*Number of Observations*	*Mean % Return*	*Standard Deviation*
Crude oil	1721	0.03146	1.96096
Heating oil	2584	0.00615	1.74127
Treasury bill	2584	0.00008	0.00092
S&P 500	2584	0.04331	1.04649
Petroleum	2584	0.07752	1.32102
Fin/real est	2584	0.07149	0.80118
Con durables	2584	0.07882	0.96360
Basic ind	2584	0.07994	0.94754
Food/tobacco	2584	0.10280	0.80838
Construction	2584	0.08010	0.98707
Capital goods	2584	0.06593	0.96237
Transportation	2584	0.08029	1.09367
Utilities	2584	0.07937	0.64237
Textiles/trade	2584	0.09021	0.84901
Services	2584	0.09450	1.03008
Leisure	2584	0.08939	0.96127
Chevron	2584	0.07555	1.92210
Mobil	2584	0.07872	1.96774
Exxon	2584	0.08523	1.51320

CORRELATION STRUCTURE

Cross-Correlation

The first step in the analysis examines the correlation of stock returns with past, contemporaneous, and future oil returns. The results for various stock indexes and for the three oil stocks are contained in Table II. Table IIA is based on the heating oil futures contract and Table IIB is based on the crude oil futures contract.

The results are particularly surprising in two respects. First, there is a striking lack of correlation between stock returns, other than oil company returns, and oil futures returns. None of the contemporaneous correlation coefficients other than for oil company returns is statistically significant. Despite the frequently cited importance of oil to the health of the general economy, these results indicate that changes in oil prices seem to have very little immediate effect on the general economy as reflected in stock prices. Chen, Roll, and Ross (1986), using the producer price index for oil, also find that oil price changes have no effect on financial asset prices. Jones and Kaul find an effect of fuel prices on stock prices but that effect disappears when future industrial

TABLE IIA

Cross-Correlations Between Stock Returns (r_t^s) and Past, Contemporaneous, and Future Returns of Heating Oil Futures (r_{t+k}^o)

Stock	Lag k −6	−5	−4	−3	−2	−1	0	1	2	3	4	5	6
S&P 500	.010	.017	.004	−.008	−.002	.037	.024	−.004	.008	−.011	−.028	.004	.001
	.608	.397	.844	.673	.909	.061	.232	.854	.696	.594	.155	.854	.974
Petroleum	.026	.014	.029	.025	.024	.139	.148	.023	−.027	−.002	−.012	.002	.008
	.189	.483	.140	.201	.230	.000	.000	.241	.163	.918	.538	.908	.686
Fin/real est	.016	.026	−.011	−.001	−.003	.017	.020	.001	−.019	−.012	−.023	.006	−.010
	.425	.180	.576	.967	.889	.393	.318	.946	.340	.554	.242	.771	.624
Con durables	.017	.021	−.006	−.006	−.021	.017	.003	−.010	−.025	−.005	−.022	.006	−.006
	.386	.298	.768	.751	.284	.394	.867	.608	.212	.811	.258	.757	.760
Basic ind	.008	.022	−.009	−.018	−.024	.031	.024	.007	−.018	−.009	−.036	−.003	−.002
	.673	.264	.652	.370	.215	.118	.229	.738	.360	.665	.064	.890	.916
Food/tobacco	.029	.024	−.011	−.001	−.010	.019	.002	.006	−.030	−.024	−.017	.015	−.005
	.145	.224	.565	.964	.611	.347	.922	.749	.134	.221	.392	.443	.801
Construction	.015	.008	−.011	−.019	−.029	.016	.008	−.006	−.007	−.020	−.029	.013	−.014
	.437	.703	.572	.336	.139	.410	.679	.773	.711	.302	.148	.493	.488
Capital goods	.016	.025	−.004	−.004	−.020	.032	.022	.002	−.017	−.005	−.017	.007	−.009
	.419	.212	.830	.837	.310	.101	.257	.902	.400	.817	.382	.709	.660
Transportation	.015	.020	−.012	−.003	−.026	−.008	−.013	.007	−.017	.016	−.015	.002	−.007
	.448	.305	.538	.885	.185	.681	.507	.709	.377	.404	.436	.910	.724
Utilities	.016	.016	−.005	.010	−.004	.019	.023	.021	.004	−.008	−.024	.015	−.015
	.408	.428	.799	.612	.838	.345	.246	.298	.847	.701	.224	.451	.437
Textiles/trade	.007	.019	−.002	.001	−.012	.015	.007	−.004	−.015	−.010	−.023	.007	−.008
	.705	.324	.922	.940	.541	.434	.741	.825	.443	.629	.251	.722	.683
Services	.029	.027	−.010	−.009	−.019	.014	.024	−.004	−.017	−.016	−.030	.003	−.006
	.144	.174	.595	.637	.342	.492	.232	.857	.397	.416	.128	.875	.753
Leisure	.011	.033	.007	−.006	−.013	.019	.014	−.003	−.018	−.019	−.015	.021	−.018
	.594	.093	.707	.750	.502	.343	.477	.862	.357	.345	.461	.285	.349
Chevron	.011	−.017	.029	−.015	−.013	.099	.154	.040	−.017	.007	−.010	−.001	.022
	.593	.398	.143	.438	.493	.000	.000	.044	.392	.715	.606	.945	.269
Mobil	−.008	−.012	.010	.022	−.027	.081	.131	.060	−.008	−.003	−.038	−.019	.015
	.673	.536	.614	.275	.169	.000	.000	.002	.679	.877	.051	.346	.457
Exxon	.018	−.010	.028	−.008	.001	.059	.095	.023	−.014	.024	−.010	.000	−.014
	.366	.619	.149	.693	.968	.003	.000	.241	.481	.229	.622	.991	.487

The first row for each stock shows the bivariate correlations and the second row shows the associated p-values.

TABLE IIB

Cross-Correlations Between Stock Returns (r_t^s) and Past, Contemporaneous, and Future Returns of Crude Oil Futures (r_{t+k}^o)

	Lag k												
Stock	−6	−5	−4	−3	−2	−1	0	1	2	3	4	5	6
S&P 500	.010	.018	−.002	−.024	.004	.030	−.021	−.004	.018	−.045	−.043	−.016	−.013
	.676	.461	.921	.316	.859	.215	.378	.864	.465	.060	.074	.518	.596
Petroleum	.023	.014	.056	.026	.043	.186	.178	−.001	−.023	−.028	−.019	.010	.007
	.332	.562	.020	.279	.073	.000	.000	.983	.338	.241	.442	.694	.786
Fin/real est	.018	.022	−.015	−.015	−.006	.013	−.003	−.007	−.011	−.040	−.047	−.003	−.015
	.453	.362	.544	.528	.795	.581	.888	.774	.643	.098	.050	.895	.531
Con durables	.019	.021	−.006	−.016	−.016	.006	−.024	−.018	−.019	−.030	−.044	−.001	−.012
	.427	.374	.789	.506	.504	.802	.320	.459	.435	.217	.071	.969	.622
Basic ind	.006	.029	.002	−.019	−.017	.039	.003	.000	−.009	−.028	−.050	−.009	−.008
	.818	.227	.937	.433	.476	.107	.902	.988	.702	.241	.037	.721	.731
Food/tobacco	.024	.017	−.020	−.011	−.009	.002	−.026	−.003	−.028	−.040	−.034	.001	−.019
	.316	.487	.406	.653	.696	.919	.281	.909	.239	.099	.160	.955	.442
Construction	.003	.002	−.018	−.028	−.034	.012	−.016	−.020	.000	−.035	−.060	.006	−.019
	.907	.924	.448	.239	.154	.610	.513	.406	.993	.144	.014	.809	.420
Capital goods	.012	.025	.005	−.018	−.013	.032	.001	−.006	−.009	−.026	−.032	.004	−.021
	.632	.294	.838	.447	.587	.181	.951	.796	.696	.274	.190	.865	.374
Transportation	.019	.024	−.026	−.017	−.019	−.007	−.046	−.009	−.011	.006	−.025	.002	−.026
	.422	.327	.278	.481	.429	.779	.056	.718	.635	.812	.305	.945	.288
Utilities	.015	.011	−.018	−.005	−.018	.003	−.021	.006	.007	−.023	−.053	.003	−.025
	.536	.642	.463	.852	.463	.891	.390	.817	.785	.347	.028	.902	.306
Textiles/trade	.008	.015	−.005	−.009	−.011	.007	−.020	−.009	−.013	−.027	−.040	.003	−.007
	.756	.541	.844	.707	.646	.783	.414	.713	.590	.268	.094	.916	.785
Services	.031	.031	.006	−.019	−.020	.007	−.007	−.006	−.009	−.023	−.057	−.006	−.011
	.203	.198	.791	.422	.414	.770	.765	.815	.721	.337	.019	.815	.661
Leisure	.003	.034	.006	−.024	−.014	.007	−.022	−.016	−.019	−.035	−.033	.002	−.018
	.895	.164	.806	.313	.572	.786	.356	.502	.438	.150	.172	.937	.451
Chevron	−.015	.000	.039	−.021	.003	.115	.173	.027	.004	−.001	−.007	−.007	.035
	.547	.993	.104	.374	.912	.000	.000	.261	.874	.979	.774	.764	.148
Mobil	−.002	.004	.026	.022	−.035	.119	.157	.045	−.022	.000	−.049	−.010	.027
	.923	.882	.274	.370	.144	.000	.000	.063	.353	.988	.042	.688	.264
Exxon	.015	.005	.024	−.026	.000	.062	.085	.009	−.003	.021	−.029	−.012	−.019
	.533	.852	.324	.283	.999	.010	.000	.724	.895	.388	.234	.613	.428

The first row for each stock shows the bivariate correlations and the second row shows the associated *p*-values.

production is included in the analysis. The results differ from those of Jones and Kaul. It is possible that their focus on quarterly data and a broad index of fuel prices picks up a macroeconomic association that reflects a few key events such as the oil crisis of the early 70s and the concomitant stock market decline. Alternatively, the fuel price index in their study may act as a proxy for inflation, which is known to be negatively related to real stock returns.[3] The results are consistent with the finding of Dusak (1973) and Bodie and Rosansky (1980) that the return of almost any futures contracts is not correlated with the return on the stock market. These findings imply that futures contracts, including oil futures, provide diversification in a portfolio.

The second interesting finding is that the returns of the petroleum stock index and the three oil stocks are significantly correlated with current and lag one oil futures returns. The probability that the contemporaneous correlation occurs by chance is less than .001 in all cases. The probability level at lag 1 is also less than .001 in all cases except Exxon, where the level is .003 in the case of heating oil and .010 in the case of crude oil. The significant contemporaneous positive correlation is not surprising. One expects oil companies to benefit from increases in oil prices. Surprising is the lag one correlation—the fact that oil returns over one trading day are positively correlated with oil stock returns on the next trading day. This lagged cross-correlation, if substantiated under further investigation, implies the presence of a potentially profitable market inefficiency. The data suggest that, after a positive daily oil futures return, which is known at 3:10 PM, it would be profitable to purchase oil stocks before the stock market close at 4 PM, thereby benefiting from the subsequent day's positive return on oil stocks. In practice, trading costs may make it difficult to exploit this apparent opportunity, but the correlation is suggestive.

Several other points should be made about the cross-correlation results. The careful reader will have noted a positive correlation between the S&P 500 stock index return and the lag one heating oil futures return (although not the crude oil return). This positive correlation, which has a p value of .061, may reflect the fact that oil stocks are contained in the index, and the lagged association could reflect the slow response of indexes due to infrequent trading of component stocks. However, the fact that no association of the S&P 500 index is found with crude oil futures, which cover a different time period, suggests that the result may be sample specific. A few other significant or nearly

[3]See Fama and Schwert (1977) and Kaul (1987).

significant correlations between oil futures returns and non-oil stock returns may be found in the data, but this is to be expected by chance in a large sample of correlation coefficients. Somewhat puzzling is the number of significant correlations between returns of different stock indexes and returns of crude oil futures four days later. In view of the fact that the correlations are not observed for heating oil, this pattern may reflect sample specific events during the crude oil sample or special patterns in crude oil.

The cross-correlations of raw returns in Table II are striking, but before accepting these results and their economic implications, it is important to determine if they could be spurious or the result of complex interactions that are not modelled. One possibility that is investigated in the next section is that some of the returns—stock index returns in particular—are serially correlated. Serial correlation in a series might generate a lagged effect of the type that is observed between oil futures and oil stocks.

Serial Correlations

Serial correlations are estimated by regressing the current return of series k on its own prior six days' returns. That is, the following regression is estimated:

$$r_t^k = \alpha_1 r_{t-1}^k + \alpha_2 r_{t-2}^k + \alpha_3 r_{t-3}^k + \alpha_4 r_{t-4}^k + \alpha_5 r_{t-5}^k + \alpha_6 r_{t-6}^k + \epsilon_t^k \tag{3}$$

The coefficient estimates along with White's heteroskedasticity adjusted t statistics are presented in Table III. All the stock indexes exhibit significant positive serial correlation at a one-day lag, something that is likely to be the result of infrequent trading of the component stocks.[4] T-bill returns, Chevron returns, and heating oil returns also exhibit significant lag one correlation, but Mobil, Exxon, and crude oil returns do not. Significant serial correlations are observed at some longer lags, but none is evident at lag six.

The presence of serial correlation gives rise to the possibility that some of the observed cross-correlations, particularly at lag one, are due to delayed reaction in one of the series. The cross-correlation results and the serial correlation results could be further confounded by particular

[4]See Lo and MacKinlay (1988); Stoll and Whaley (1990); and Miller, Muthuswamy, and Whaley (1991) for a discussion of the infrequent trading problem and for alternative solutions.

TABLE III
Regressions of Returns of Oil Futures, S&P 500, SIC Categories, and Oil Companies on Own Lag Returns.

	Lag k *Regression Coefficient*					
Asset	1	2	3	4	5	6
Crude oil	0.027	−0.010	−0.004	0.087	−0.129	0.062
	0.518	−0.243	−0.085	1.903	−2.754	1.393
Heating oil	0.074	−0.048	−0.024	0.049	−0.106	0.032
	1.947	−1.465	−0.737	1.510	−3.222	1.057
Treasury bill	−0.099	−0.066	−0.043	−0.026	−0.006	−0.003
	−3.325	−2.581	−1.651	−0.979	−0.211	−0.103
S&P 500	0.122	−0.082	−0.016	0.017	0.000	0.025
	2.929	−1.728	−0.352	0.629	−0.003	0.731
Petroleum	0.221	0.009	−0.003	0.016	0.039	0.029
	4.936	0.207	−0.067	0.420	1.066	0.983
Fin/Real est	0.238	−0.023	0.011	0.030	0.075	0.025
	4.234	−0.235	0.140	0.679	1.182	0.619
Con durables	0.255	0.008	0.001	0.042	0.052	0.036
	3.842	0.106	0.015	0.807	0.906	0.889
Basic ind	0.237	0.007	−0.009	0.025	0.063	0.026
	3.451	0.085	−0.130	0.529	1.166	0.702
Food/tobacco	0.219	−0.041	0.024	0.009	0.087	0.032
	3.888	−0.489	0.364	0.279	1.623	0.832
Construction	0.240	0.011	0.002	0.043	0.069	0.038
	3.821	0.121	0.023	1.035	1.307	0.924
Capital goods	0.245	0.002	−0.009	0.048	0.063	0.036
	3.635	0.023	−0.130	0.960	1.120	0.988
Transportation	0.211	−0.021	0.015	0.042	0.001	0.037
	3.915	−0.342	0.327	1.136	0.022	1.253
Utilities	0.257	−0.072	0.015	−0.010	0.075	0.007
	4.142	−0.734	0.224	−0.254	1.268	0.180
Textiles/trade	0.240	0.005	0.025	0.046	0.054	0.052
	3.422	0.055	0.313	0.931	0.881	1.165
Services	0.219	−0.001	0.020	0.050	0.042	0.034
	3.340	−0.015	0.318	1.105	0.850	0.878
Leisure	0.209	−0.008	−0.006	0.058	0.076	0.012
	3.070	−0.082	−0.074	1.087	1.207	0.297
Chevron	0.070	−0.064	−0.008	−0.059	0.012	−0.011
	2.452	−2.944	−0.344	−2.306	0.399	−0.460
Mobil	−0.006	−0.077	−0.041	−0.032	−0.012	0.005
	−0.134	−2.008	−1.381	−1.232	−0.401	0.190
Exxon	−0.053	−0.110	−0.062	−0.072	0.002	−0.010
	−0.695	−2.421	−1.826	−1.979	0.065	−0.293

The first row of each asset shows the regression coefficients and the second row shows the associated heteroskedasticity-adjusted *t*-values.

events such as the crash of 1987, weekly seasonals, or the linking procedure that is used for developing the time series of futures contract returns. To deal with these and other problems, the VAR approach of Sims (1972) is adopted.

THE VAR FRAMEWORK

The VAR model takes account of the simultaneous interaction of the time series of oil futures returns, stock returns, and t-bill returns. T-bill returns are incorporated into the VAR system to control for the effect of interest rate changes on the variables of interest—stock returns and oil futures returns. For example, stock prices depend on expected earnings discounted to the present. Oil price changes might affect stock prices by affecting expected earnings, but it is important to control for interest rate changes that could also affect stock prices which directly affect the discount rate on expected earnings. Also, interest rates can affect futures prices relative to cash prices through the cost-of-carry model. Earlier studies of stock returns have shown that stock returns exhibit a number of important seasonalities. These seasonalities are accounted for in the analysis by introducing dummy variables in the VAR model.

Let r_t^o be returns of heating oil or crude oil futures, let r_t^s be one of 16 stock returns, let r_t^b be returns of Treasury bills, and let D_t^j designate dummy variable j. The VAR representation can be expressed as a three-equation system:

$$r_t^o = m^o + \sum_{i=1}^{6} a_i^o r_{t-i}^o + \sum_{i=1}^{6} b_i^o r_{t-i}^s + \sum_{i=1}^{6} c_i^o r_{t-i}^b + \sum_{j=1}^{18} d_j^o D_t^j + u_t^o \tag{4}$$

$$r_t^s = m^s + \sum_{i=1}^{6} a_i^s r_{t-i}^o + \sum_{i=1}^{6} b_i^s r_{t-i}^s + \sum_{i=1}^{6} c_i^s r_{t-i}^b + \sum_{j=1}^{18} d_j^s D_t^j + u_t^s \tag{5}$$

$$r_t^b = m^b + \sum_{i=1}^{6} a_i^b r_{t-i}^o + \sum_{i=1}^{6} b_i^b r_{t-i}^s + \sum_{i=1}^{6} c_i^b r_{t-i}^b + \sum_{j=1}^{18} d_j^b D_t^j + u_t^b \tag{6}$$

where u_t^l is a vector of error terms that is orthogonal to r_{t-i}^l, $l = o, s, b$. Of the 18 dummies, 11 are monthly dummies for months other than January, 4 are crash dummies for the days October 16, 19, 20, and 21, respectively, in 1987, one is a dummy for returns that span a weekend, one is a dummy for returns that span a holiday, and one is a dummy for oil futures contract replacement days on which the contract nearing settlement is replaced with the contract one month older. The number of lags is limited to six on the basis of the serial correlation results which indicate no significant lag beyond five days.

The approach is to estimate the system of eqs, (4) to (6), and to test a series of hypotheses about the lead–lag relationship of stock returns and futures returns. The important benefit of the VAR system (4) to (6) is that it controls for factors, such as, own serial correlation, dependencies with interest rates, seasonalities, and other events captured by the dummy variables. It is also possible to distinguish one-way leads or lags from feedback relationships. For example, if lagged r_t^b and r_t^s are insignificant in forecasting r_t^o, but lagged r_t^o have power in predicting r_t^b and r_t^s, then the results suggest that oil returns exhibit a one-way lead over returns of stock index and bond futures.

The null hypothesis that oil futures do not lead stocks and interest rates can be stated in the context of the VAR model as[5]

$$H_0^1\colon a_i^s = a_i^b = 0, \qquad i = 1, \ldots, 6 \tag{7}$$

The likelihood ratio under the null is asymptotically distributed as chi-square. The null hypothesis that stocks and interest rates do not lead oil futures can be stated in the context of the VAR model as

$$H_0^2\colon b_i^o = c_i^o = 0, \qquad i = 1, \ldots, 6 \tag{8}$$

An F-test can be used to examine the exclusion restrictions in (8).

LEADS AND LAGS IN RETURNS

The VAR model estimates for the various time series of returns are presented in Table IV. The results for H_0^1 are very striking in that the petroleum industry stock index and the three oil company stocks are the only series for which it is possible to reject the null hypothesis that oil futures do not lead Treasury Bill rates and stock returns. These results are highly significant and invariant to which of the two oil futures contracts is used in the analysis. For example, the smallest chi-square statistics are for Exxon—38.07 for heating oil and 28.74 for crude oil. The probability of a chi-square value larger than 28.74 is .004. For the other stock indexes, including the S&P 500, there is no statistically significant evidence of a lead of oil futures. None of the chi-squares are statistically significant. Tests of H_0^2—that stocks and t-bills do not lead oil futures—do not reject the null. The F-statistics are extremely small. These results imply that, while oil futures lead stocks, there is no feedback from stocks to oil futures.

The test results in Table IV focus on the lead–lag relationship between oil futures and the time series of stock and t-bill returns. Since the emphasis is on stock returns, the issue of whether the lead of oil futures disappears if t-bills are eliminated from the analysis is

[5]The terminology frequently used in such a situation is that oil futures do not "Granger-cause" stocks and interest rates, after Granger (1969).

TABLE IV

VAR Tests of Granger Causality Between Returns on Oil Futures and Returns on Treasury Bills and Stocks

	Heating Oil				Crude Oil			
	H_0^2: *Treasury Bill and Stock Do Not Lead Oil*		H_0^1: *Oil Does Not Lead Treasury Bill and Stock*		H_0^2: *Treasury Bill and Stock Do Not Lead Oil*		H_0^1: *Oil Does Not Lead Treasury Bill and Stock*	
Stock	*F-Stat.*	*P-Val.*	χ^2	*P-Val.*	*F-Stat.*	*P-Val.*	χ^2	*P-Val.*
S&P 500	0.20	1.00	15.86	0.20	0.87	0.58	12.48	0.41
Petroleum	0.48	0.93	53.22	0.00	0.55	0.88	81.73	0.00
Fin/real est	0.22	1.00	13.86	0.31	0.68	0.78	12.06	0.44
Con durables	0.22	1.00	13.41	0.34	0.59	0.85	9.89	0.63
Basic ind	0.31	0.99	16.88	0.15	0.59	0.86	15.91	0.20
Food/tobacco	0.40	0.96	15.95	0.19	0.63	0.82	9.86	0.63
Construction	0.36	0.98	15.22	0.23	0.95	0.49	12.31	0.42
Capital goods	0.19	1.00	16.10	0.19	0.46	0.94	14.31	0.28
Transportation	0.32	0.99	11.25	0.51	0.39	0.97	9.65	0.65
Utilities	0.43	0.95	13.19	0.36	0.74	0.71	9.45	0.66
Textiles/trade	0.17	1.00	11.97	0.45	0.47	0.93	8.83	0.72
Services	0.23	1.00	14.71	0.26	0.69	0.76	11.45	0.49
Leisure	0.38	0.97	14.37	0.28	0.56	0.87	12.96	0.37
Chevron	0.60	0.84	45.18	0.00	0.51	0.91	41.00	0.00
Mobile	0.97	0.48	43.96	0.00	0.90	0.54	55.89	0.00
Exxon	0.37	0.97	38.07	0.00	0.50	0.92	28.74	0.00

investigated. The estimation is carried out for a less general VAR model than (4) to (6), consisting of two returns equations, one for oil futures and one for stocks. The test results are unaffected. The lead of oil futures is observed for the same stock series and the results continue to be highly significant. Therefore, the evidence indicates that the leads observed in Table IV of oil futures over stocks continue to hold and that this relationship is not influenced by interest rates.[6]

One potential criticism of the results is that they are sample specific—that a fortuitous set of historical price changes explains the findings. While one can never definitively rule this out, the question is investigated by splitting the sample into two and repeating the analysis. The split occurs at January 1, 1986, so that the period of the dramatic oil price decline in 1986 is separated from the earlier period. The prior results remain unaffected. Oil futures lead the petroleum stock index and the three petroleum stocks in each subperiod and do not lead or lag anything else.

The results of the analysis indicate that oil futures returns lead—or "Granger-cause"—stock returns of oil companies, a conclusion that is fully consistent with the results of the simple cross-correlation analysis carried out earlier. It appears that oil specific information is first reflected in the market where it has the most effect—the oil futures market—and is transmitted with some lag to oil stocks. Surprisingly, as shown in the simple cross-correlations, oil returns do not lead—"Granger-cause"—all other stock returns. Even stocks of transportation companies, firms one would expect to be dependent on oil, exhibit no lead–lag relationship with oil futures.

It is impractical to present all the estimated coefficients for the three equations (4) to (6). Including dummy variable coefficients, there are 37 coefficients in each regression, there are three regressions, and the system is estimated for each of the 16 stock return series and the two oil futures series, which would make a total of 3552 coefficients. However, Table V presents the coefficients on lagged oil futures returns for eq. (5) in the case of the four stock series in which a significant lead of oil futures exists. These coefficients provide evidence on the nature of the lead. As was the case in the simple cross-correlations shown in Table II, a statistically significant one-day lag is estimated in the VAR framework. Even after accounting for own serial correlation,

[6]Interest rate variability is probably not as important over the one-day intervals examined as it is for the analysis in Sims (1982), where the importance of including interest rates is stressed.

TABLE V
Coefficients of Oil Futures Returns From Regressions for Petroleum Industry and Individual Oil Companies

	Regression Coefficient of Lag k *Oil Futures Return*					
Asset	1	2	3	4	5	6
			Heating oil			
Petroleum	0.088	-0.003	0.015	0.018	-0.007	0.021
	5.666	-0.230	1.121	1.457	-0.550	1.459
Chevron	0.118	-0.018	0.006	0.048	-0.024	0.030
	5.935	-0.864	0.279	2.476	-1.220	1.406
Mobil	0.118	-0.026	0.045	0.021	-0.013	0.008
	5.561	-1.284	1.999	0.981	-0.700	0.371
Exxon	0.076	0.002	0.004	0.034	-0.010	0.030
	4.847	0.140	0.272	2.207	-0.710	1.830
			Crude oil			
Petroleum	0.098	0.012	0.004	0.026	-0.013	0.011
	5.438	0.884	0.324	2.093	-1.043	0.691
Chevron	0.108	0.011	-0.005	0.054	-0.006	0.003
	5.111	0.560	-0.230	2.828	-0.343	0.115
Mobil	0.132	-0.021	0.034	0.040	0.008	0.024
	5.987	-0.989	1.510	1.931	0.422	1.062
Exxon	0.074	0.003	-0.013	0.025	0.001	0.024
	4.132	0.215	-0.726	1.525	0.049	1.315

The first row of each asset shows the regression coefficients and the second row shows the associated heteroskedasticity-adjusted *t*-values.

interdependencies, seasonalities, and other factors, a statistically significant one-day lead of oil futures returns over oil stock returns is observed. The magnitude of the coefficients in Table V suggests, however, that the economic significance of the lead is limited. For example, the lag one coefficient of 0.108 for Chevron implies that a 1% return in crude oil futures is, on average, followed by a 0.108% return in Chevron. Suppose the price of Chevron is \$50. The predicted dollar return is \$0.054, which is less than the dollar bid–ask spread in Chevron.

ECONOMIC SIGNIFICANCE OF OIL FUTURES LEAD OVER OIL STOCKS

To assess the economic significance of the statistically significant dependence between lag one oil futures returns and the returns of Chevron, Mobil, and Exxon, the bid–ask spreads for the three stocks are calculated. The data are taken from the data files maintained by the Institute for the Study of Security Markets (ISSM). For each day in the period, January 1, 1987, (the first day for which ISSM data is available) to March 16, 1990 (the last day of the oil and stock price data set), the quote prior to the last trade of the day is selected, and the average dollar and average percentage spread is calculated. The results in Table VI indicate that the average spreads substantially exceed the expected return associated with a 1% change in oil futures prices. Expected returns in the three stocks for a 1% change in oil futures prices are less than 0.12% while percentage bid–ask spreads are more than 0.60%.

As a second test of economic significance, the profitability of a simple trading rule net of the bid–ask spread trading cost is computed. If the oil futures price increases on day 1, which is known by 3:00 PM EST, the investor buys the stock at the ask before the stock market close at 4:00 PM EST and sells the stock at the end of the following day at the bid. If the oil futures price decreases on day 1, the investor sells short the stock and covers on the following day. The results are in Table VIIA. Not surprisingly, the average daily return to such a strategy is significantly negative in every year except 1979, for which only 3 months of data are available. The bid–ask spread is simply too great relative to the movement of oil and stock prices. The trading rule is repeated by applying a 1% oil price change filter to determine if large oil price changes have economically significant predictive power.[7] These results are reported in Table VIIB. Average daily returns are negative in almost every year, though usually less negative than when no filter was applied.

The conclusion from these tests is that market makers may be able to profit from the observed lead of oil futures over oil stock returns. However, public investors, who pay the bid–ask spread, cannot profit from it.

TABLE VI
Mean Daily Spreads

	Asset		
	Chevron	*Mobil*	*Exxon*
Dollar spreads	0.352	0.334	0.308
Percentage spreads	0.693	0.702	0.628

Best bid and offer eligible quotes more than 5 seconds away from the last trade are used to calculate the spreads. Dollar spreads are computed as ask minus bid quotes, and percentage spreads are measured as 100 times ask minus bid divided by price per share. The sample period starts on January 1, 1987, and ends on March 16, 1990.

[7]In Table VIIA, there are 2562 days of data for heating oil and 1687 for crude oil. After application of the 1% filter, 1097 days remain for heating oil and 679 for crude oil.

TABLE VIIA
Mean Percentage Daily Returns Net of Average Percentage Bid—Ask Spreads

	Heating Oil						*Crude Oil*					
	Chevron		*Mobil*		*Exxon*		*Chevron*		*Mobil*		*Exxon*	
Year	*Mean*	P-*Val.*	*Mean*	P-*Val.*	*Mean*	P-*Val.*	*Mean*	P-*Val.*	*Mean*	P-*Val.*	*Mean*	P-*Val.*
All	−0.549	0.000	−0.584	0.000	−0.554	0.000	−0.514	0.000	−0.550	0.000	−0.522	0.000
79	−0.277	0.184	0.063	0.833	−0.372	0.012	.	.	.	.	.	.
80	−0.486	0.002	−0.543	0.005	−0.460	0.000	.	.	.	.	.	.
81	−0.861	0.000	−0.767	0.000	−0.645	0.000	.	.	.	.	.	.
82	−0.441	0.004	−0.685	0.000	−0.672	0.000	.	.	.	.	.	.
83	−0.534	0.000	−0.524	0.000	−0.403	0.000	−0.415	0.001	−0.470	0.000	−0.379	0.000
84	−0.477	0.000	−0.585	0.000	−0.420	0.000	−0.464	0.000	−0.589	0.000	−0.345	0.000
85	−0.548	0.000	−0.654	0.000	−0.567	0.000	−0.464	0.000	−0.507	0.000	−0.484	0.000
86	−0.251	0.020	−0.269	0.012	−0.335	0.000	−0.284	0.009	−0.301	0.006	−0.327	0.000
87	−0.627	0.000	−0.724	0.000	−0.826	0.000	−0.623	0.000	−0.807	0.000	−0.820	0.000
88	−0.652	0.000	−0.643	0.000	−0.732	0.000	−0.666	0.000	−0.640	0.000	−0.719	0.000
89	−0.609	0.000	−0.570	0.000	−0.522	0.000	−0.558	0.000	−0.512	0.000	−0.572	0.000
90	−0.861	0.000	−0.663	0.001	−0.523	0.009	−0.948	0.000	−0.561	0.003	−0.333	0.087

The trading strategy assumes that the investor is long (short) in the asset for a day when the previous day's return on oil futures is positive (negative). The percentage bid–ask spreads are calculated for the sample period January 1, 1987, to March 16, 1990. *P*-values are for tests of the null hypothesis that mean returns adjusted for bid–ask spreads are equal to zero. Estimates for 1979 and 1990 are based on less than an entire year's data.

TABLE VIIB

Mean Percentage Daily Returns Net of Average Percentage Bid—Ask Spreads with the 1% Filter

	Heating Oil						Crude Oil					
	Chevron		*Mobil*		*Exxon*		*Chevron*		*Mobil*		*Exxon*	
Year	*Mean*	P-*Val.*	*Mean*	P-*Val.*	*Mean*	P-*Val.*	*Mean*	P-*Val.*	*Mean*	P-*Val.*	*Mean*	P-*Val.*
All	−0.448	0.000	−0.512	0.000	−0.512	0.000	−0.444	0.000	−0.479	0.000	−0.533	0.000
79	−0.090	0.750	0.161	0.674	−0.430	0.024	.	.	.	.	.	.
80	−0.526	0.084	−1.029	0.011	−0.384	0.054	.	.	.	.	.	.
81	−0.910	0.018	−0.486	0.122	−0.463	0.073	.	.	.	.	.	.
82	−0.107	0.595	−0.502	0.004	−0.493	0.000	.	.	.	.	.	.
83	−0.391	0.091	−0.367	0.089	−0.330	0.015	0.477	0.221	−0.078	0.851	0.030	0.932
84	−0.657	0.000	−0.672	0.001	−0.566	0.000	−0.226	0.402	−0.767	0.047	−0.404	0.157
85	−0.252	0.105	−0.423	0.002	−0.387	0.003	−0.412	0.008	−0.583	0.001	−0.466	0.002
86	−0.115	0.366	−0.126	0.340	−0.271	0.007	−0.219	0.100	−0.197	0.136	−0.287	0.005
87	−0.926	0.000	−0.990	0.002	−1.048	0.001	−0.456	0.001	−0.498	0.000	−0.595	0.000
88	−0.653	0.000	−0.616	0.000	−0.715	0.000	−0.711	0.022	−0.851	0.030	−0.953	0.013
89	−0.508	0.000	−0.545	0.000	−0.476	0.000	−0.612	0.000	−0.507	0.000	−0.665	0.000
90	−0.880	0.001	−0.635	0.010	−0.501	0.049	−0.965	0.001	−0.551	0.034	−0.478	0.051

The trading strategy assumes that the investor is long in the asset for a day when the previous day's return on oil futures is positive and greater than 1% and short in the asset for a day when the previous day's return on oil futures is negative and less than minus 1%. The percentage bid–ask spreads are calculated for the sample period January 1, 1987, to March 16, 1990. *P*-values are for tests of the null hypothesis that mean returns adjusted for bid–ask spreads are equal to zero. Estimates for 1979 and 1990 are based on less than an entire year's data.

LEADS AND LAGS IN VOLATILITIES

The last question examined is the extent to which the volatility in oil futures returns leads or lags the volatility in the returns of stocks. Daily volatility is measured as the square of the unexpected daily return. There is no reason for the lead–lag relationship in volatility to be the same as in returns. In an efficient market, one does not expect returns in one market to lead those in that market or another market. Yet, it would be fully consistent with market efficiency for volatility in one market to lead volatility in another market or for there to be serial correlation in return volatility. For example, it is known that large stock price changes follow large stock price changes, but the direction of the change is not predictable. This is an example of a lead in volatility not accompanied by a lead in returns. On the basis of Ross (1989), who argues that volatility is a measure of information flow, the analysis can be viewed as an investigation of the extent to which the rate of information flow is correlated across markets.

The daily return volatility, $[e_t^k]^2$, of a series k is defined as

$$[e_t^k]^2 = [r_t^k - E(r_t^k)]^2, \quad k = o, s, b \tag{9}$$

where o refers to the two oil series, s refers to the 16 stock return series, and b refers to the t-bill series. The expected return is given by

$$E\left(r_t^k\right) = \alpha_1 r_{t-1}^k + \alpha_2 r_{t-2}^k + \alpha_3 r_{t-3}^k + \alpha_4 r_{t-4}^k + \alpha_5 r_{t-5}^k + \alpha_6 r_{t-6}^k + \sum_{j=1}^{18} \beta_j^k D_t^j \tag{10}$$

In effect, the measure of the volatility is the square of the residual from a regression of the return on its own lagged values and the dummy variables.

The leads and lags in volatility are assessed by applying the VAR model (4) to (6) to the squared residuals, and by testing hypotheses, H_0^1 and H_0^2, which are now to be understood as applying to volatilities rather than returns. The results of the tests, contained in Table VIII, are similar to the results in Table IV for returns. Specifically, the null hypothesis that oil futures volatility does not lead the petroleum stock index volatility is rejected. The chi-square value is 32.26 in the case of heating oil and 92.36 in the case of crude oil, both of which have extremely low probabilities of occurring by chance. The results are not as clearcut in the case of the individual stocks. Over the period covered

TABLE VIII

VAR Tests of Granger Causality Between Return Volatility on Oil Futures and Return Volatility on Treasury Bills and Stocks

	Heating Oil				Crude Oil			
	H_0^2: *Treasury Bill and Stock Do Not Lead Oil*		H_0^1: *Oil Does Not Lead Treasury Bill and Stock*		H_0^2: *Treauty Bill and Stock Do Not Lead Oil*		H_0^1: *Oil Does Not Lead Treasury Bill and Stock*	
Stock	F-*Stat.*	P-*Val.*	χ^2	P-*Val.*	F-*Stat.*	P-*Val.*	χ^2	P-*Val.*
S&P 500	0.50	0.91	7.21	0.84	0.73	0.72	2.15	1.00
Petroleum	1.16	0.30	32.26	0.00	1.35	0.18	92.36	0.00
Fin/real est	0.47	0.93	7.44	0.83	0.78	0.67	3.16	0.99
Con durables	0.48	0.93	7.70	0.81	0.77	0.68	2.59	1.00
Basic ind	0.48	0.93	7.86	0.80	0.72	0.74	2.86	1.00
Food/tobacco	0.63	0.82	8.57	0.74	0.90	0.55	4.32	0.98
Construction	0.45	0.94	7.28	0.84	0.76	0.69	2.29	1.00
Capital goods	0.48	0.93	7.26	0.84	0.77	0.68	3.01	1.00
Transportation	0.57	0.87	8.04	0.78	0.76	0.69	3.93	0.98
Utilities	0.55	0.89	8.15	0.77	0.91	0.54	5.46	0.94
Textiles/trade	0.49	0.92	7.79	0.80	0.88	0.56	3.13	0.99
Services	0.56	0.88	7.50	0.82	0.90	0.54	2.91	1.00
Leisure	0.49	0.92	7.85	0.80	0.77	0.69	3.16	0.99
Chevron	0.94	0.50	9.71	0.64	1.05	0.40	5.38	0.94
Mobil	0.87	0.57	19.17	0.08	0.83	0.62	16.10	0.19
Exxon	0.71	0.75	19.44	0.08	0.79	0.66	12.74	0.39

by crude oil futures, crude oil volatilities do not exhibit a statistically significant lead with respect to the volatilities of any of the individual stocks. Heating oil volatility leads the volatilities of Mobil and Exxon (at a p-value of .08), but does not lead Chevron. As in the case of returns, there is no evidence in the tests of H_0^2 that stock volatilities or interest rate volatilities feed back to oil volatilities. To the extent there is "Granger-causation" in volatilities, it is from oil to stocks, not the reverse.

The same diagnostics carried out for returns are performed here as well. A simpler VAR system, excluding t-bills, is estimated. As in the case of returns, the results for volatilities are little changed. The complete VAR system is also re-estimated for two subperiods—before and after the oil price decline of 1986. The results are the same for each subperiod.

CONCLUDING REMARKS

This study investigates the relationship of oil futures returns to stock returns during the 1980s. The vector autoregressive (VAR) approach is used to examine the lead–lag relationship between oil futures returns and stock returns while controlling for interest rate effects, seasonalities, and other effects. The conclusions from the VAR approach are the same as from the simpler bivariate cross-correlations estimated earlier in the study. Oil futures returns are not correlated with stock market returns, even contemporaneously, except in the case of oil company returns. Despite the frequently cited importance of oil for the economy, there is little evidence of such a link in the prices of stocks other than oil companies. In fact, the lack of correlation suggests that oil futures, like other futures contracts that also appear to have little correlation with stocks, are a good vehicle for diversifying stock portfolios.

In the case of a petroleum stock index and three individual oil stocks, oil futures returns lead oil stock returns by one day. Although the relationship is statistically significant, its economic significance is less striking. The profits available to investors, by buying oil stocks after oil futures prices rise and selling oil stocks after oil futures prices fall, are less than the bid–ask spread in stocks. Thus, information from the oil futures market may be useful to market makers in oil stocks, but is of much less use to public investors. Finally, the association between oil futures volatility and stock market volatility is also investigated. The relationship is similar to, albeit not as clearcut as, the relationship found for returns.

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