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The Dynamics of S&P 500 Index and S&P 500 Futures Intraday Price Volatilities

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Abstract

This paper empirically examines the dynamics of both intraday price changes and volatilities in the S&P 500 Index and S&P 500 futures markets. Causality tests on the correlation in price changes and volatility across these two markets are also performed, and the tests are robust to changing volatility. Results show that while futures prices lead spot prices for the first 15 minutes of trading, the evidence is weak for spot prices to have a significant impact on futures prices. We also show that there exists some feedback in the S&P 500 futures and Index intraday volatilities relation.

I. Introduction

The stochastic behavior of stock index futures price and the ability of index futures to predict stock index levels always have been of practical and academic interest. Recently, there is considerable evidence that stock market movements show substantial time-varying volatility, and these movements have been attributed to stock index futures and the role of program trading. Studies have shown that stock market returns exhibit clustering of predictive variances, so that large changes tend to be followed by large changes, small by small, of either sign.[1] Engle, Ito, and Lin [1988] interpret such volatility process as either the arrival of information or the time required by market participants in processing new information. Market response is, therefore, said to exhibit autoregressive conditional heteroscedastic (ARCH) behavior. Since it has been alleged that futures trading destabilizes cash markets and, hence, induces the volatility of cash prices, one would infer that futures price volatility exhibits the same temporal dynamics as the cash price volatility. Thus, any change in the conditional variance of the futures market, which is caused by the arrival of new information or time taken for prices to reflect the differing information of traders in the markets, would be expected to have an impact on the volatility in the stock markets. If these markets are effectively linked by arbitrageurs, then the variance of the rate of return on the index futures contracts should be equal to the variance of the rate of return on the underlying cash index.[2]

While a great deal of attention has been focused on modeling the dynamics of conditional means,[3] very little work has been done on modeling the dynamics of conditional variances in the futures markets. In this paper, we attempt to empirically examine the dynamics of both the intradaily price changes and volatility in the S&P 500 Index and S&P 500 futures markets. Our primary goal is to determine the predictive information in the relation between stock index futures and the underlying stock index, in light of the heteroscedastic intraday price volatilities in these markets. Evidence of the nature and existence of this relationship should provide useful information to both investors and practitioners, enabling them to take advantage of any perceived arbitrage opportunities in the markets.

Most studies that focus on the relationship between price changes in the stock index and stock index futures contracts assume that price volatilities

[1] For example, French, Schwert, and Stambaugh [1987], Ng [1990], and Bollerslev [1987] have modeled the stock market volatility to follow a GARCH process.
[2] This assumes that the expected rate of return from a stock index futures contract is equal to the expected rate of return from the corresponding index plus a constant rate of carrying cost.
[3] See, for example, Zeckhauser and Niederhoffer [1983], Kawaller, Koch, and Koch [1987], Herbst, McCormack, and West [1987], Ng [1987], Stoll and Whaley [1990], and Laatsch and Schwarz [1989].

are homoscedastic. Given evidence that the volatility in the stock markets is time-varying and if volatility in the index futures market also changes with time, then earlier inferences based on time-invariant volatility would be misleading.[4] In this study, we perform causality tests on the correlation in price changes and volatility across the stock markets and stock index futures market, using minute-by-minute transaction data on nearby S&P 500 futures contracts. The "causality" tests used in this context are interpreted as Granger's [1969] causality tests of incremental predictive ability of one time-series variable for another, as opposed to the philosophical definition of cause and effect.[5] The tests for causal relationship between the conditional second moments in the futures market and the spot market presented in this study stem from Granger, Robins, and Engle's [1986] concept of causality in the variance. The concept of causation can be viewed as an extension of the well-know Granger's [1969] causality in the mean. This Granger causality framework allows us to examine both the contemporaneous and lagged correlations between a pair of intraday series in price changes and in volatility.

The remainder of the paper proceeds as follows. The next section describes the data employed. In Section III, we model the dynamics of intraday price changes in the S&P 500 Index and S&P 500 futures with the volatility process assumed to follow a generalized ARCH formulation. Unlike previous studies, the model simultaneously takes into account (1) the temporal volatility clustering in index futures and spot prices, (2) the nonsynchronous trading that causes the index to be more autocorrelated than the underlying index value, and (3) the overnight/weekend relative price changes. Section IV presents the univariate analysis of the cash index and index futures intraday price volatilities. The cross-sectional behavior of the intraday volatility in the futures and spot markets is also examined. Section V introduces a new statistical methodology that tests the forecast performance of index futures volatility for spot index volatility. The results are given in Section VI, and the conclusions are contained in Section VII.

II. Data

The data used in this study were obtained from the Chicago Mercantile Exchange (CME). The CME provided the S&P 500 Index and index futures data for the period April 1982 (the first trading date of the futures contract) to June 1987. The futures prices are actual transaction prices for all trades during a day. The data include the contract identification, time stamp, and price of every futures transaction, in which the price has changed from the previously recorded transaction. The exchange offers contracts maturing in March, June, September, and December. Futures trading opens at 8:30 a.m. CST (9:00 a.m. CST before October 1, 1985) and closes at 3:15 p.m. CST.

The S&P 500 Index quotes are time-stamped approximately one minute apart. Although the index is updated continuously using the most recent transaction prices of the component stocks recorded, a general move in prices of smaller, less active stocks may not be recorded in a given interval

[4] Using daily data on S&P 500 futures contracts, Ng [1987] applies Hansen's generalized method of moments to adjust for heteroscedasticity.
[5] See Zellner [1979] for a critique of philosophical definitions of causality.

of time. This infrequent trading tends to induce serial correlation in the stock index, and thus causes the index to lag the true value of the underlying 500 stocks.[6] This nonsynchronous trading problem becomes more severe when prices are analyzed over very short intervals.

In this study, we focus on nearby futures contracts for which trading volume is high. We employ quotes that are approximately 15 minutes apart, and look at the nearest quotes available after the quarter-hour mark. This results in 24 (26 after September 30, 1985) equal periods of 15 minutes each within a trading day. Each index futures contract is followed from the expiration date of the previous contract until its expiration. Unlike the index futures market, markets for all S&P 500 stocks close at 3:00 p.m. CST. Although the index futures market closes 15 minutes later, the quarter-hour price series is constructed until 3:00 p.m. Consistent with previous studies, we only focus on the futures contract beginning September 1983.[7] Thus, there are 16 futures contracts used in this study.

Table 1 reports summary statistics for the first differences in the logarithm of S&P 500 Index levels and in the logarithm of S&P 500 futures prices by contract using the 15-minute interval. We ignore the changes of the logarithm of prices during the turn-of-the-week and/or the turn-of-the-day intervals. The first-order autocorrelation estimates for the changes in the logarithm of futures price are close to zero, and the sign of these estimates

Table 1. Summary statistics for the first differences in the logarithm of S&P 500 futures and S&P 500 Index prices using 15-minute interval transaction data.

		S&P 500 Futures		S&P 500 Index	
Contract	Number of observations	Standard deviation[a]	First-order autocorrelation	Standard deviation[a]	First-order autocorrelation
Sep 1983	1512	0.163	0.022	0.128	0.408
Dec 1983	1512	0.125	−0.001	0.095	0.409
Mar 1984	1488	0.147	−0.005	0.119	0.313
Jun 1984	1440	0.150	−0.010	0.114	0.369
Sep 1984	1632	0.176	−0.011	0.149	0.289
Dec 1984	1536	0.155	−0.055	0.114	0.213
Mar 1985	1368	0.145	−0.078	0.112	0.156
Jun 1985	1632	0.115	−0.079	0.093	0.178
Sep 1985	1512	0.108	−0.020	0.083	0.249
Dec 1985	1654	0.128	−0.065	0.102	0.184
Mar 1986	1612	0.172	−0.029	0.137	0.410
Jun 1986	1638	0.171	−0.005	0.142	0.103
Sep 1986	1638	0.202	−0.018	0.173	0.045
Dec 1986	1664	0.182	−0.021	0.147	0.079
Mar 1989	1612	0.219	−0.136	0.168	0.038
Jun 1987	1612	0.219	0.048	0.214	0.086

[a]Standard deviation is multiplied by 100.

[6] See, for example, Scholes and Williams [1977] and Fisher [1966], who have shown how the nonsynchronous trading in individual stocks can induce serial correlation in the returns of stock portfolios and stock indexes.
[7] Previous studies such as Figlewski [1984] had reported that earlier contracts display erratic behavior.