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Futures Price Variability: A Test of Maturity and Volume Effects*

This study uses contract disaggregated data on futures prices to obtain evidence on the relation between price variability and volume of trading. Strong positive contemporaneous correlations between trading volume and price volatility are documented consistent with the mixture of distributions hypothesis. It is concluded that maturity is not a suitable surrogate for the common directing variable. Specifically, while maturity has a strong effect on volume, no such relation is found for price variability. Finally, while in the majority of cases price variability and trading volume are contemporaneously correlated, there are a significant number of cases in which a sequential relation appears to be present.

I. Introduction

A number of previous studies have examined the contemporaneous relation between asset price variability and volume traded. For example, Clark (1973), Cornell (1981), and Tauchen and Pitts (1983) have investigated this relation for futures markets and Epps and Epps (1976), Harris (1984*a*, 1984*b*), and Smirlock and Starks (1984) for the stock market. Underlying this empirical research is a theoretical framework that suggests that price variability (or the absolute change in prices) and volume traded should be positively correlated. According to this theoretical framework, the so-called mixture of distributions hypothesis (MDH),[1] the correlation between price variability and volume should be positive because of joint dependence on a common directing variable or event.

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1. See Clark 1973; and Harris 1984*a*, 1984*b*.

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In studies by Harris (1984*a*, 1984*b*) this directing variable is the rate of information flow over the period (day); so that when new, unexpected information arrives trading is generated as market participants revise expectations regarding the true (equilibrium) price. As a result, both the price and trading volume change contemporaneously in response to this new information.[2] Furthermore, Harris suggests that, since variations in the directing variable may be random, deterministic, or seasonal, price variances may be changing through time.[3] Such a possibility may exist in the case of futures contracts, in which information arrival may be maturity dependent. For example, a given type of information such as money supply announcements may have no value 180 days from contract maturity (i.e., will not change price expectations) but may have important effects 28 days from maturity simply because of resolution of uncertainty as the contract approaches maturity. Thus while the rate of flow of information may be random over the contract's length, the rate of flow of valuable (price expectation changing) information may be maturity dependent. It is this information that is relevant for the MDH.[4]

Previous empirical tests of the contemporaneous relations between price variability and volume have encountered a number of data and methodological problems. For example, Clark (1973), Cornell (1981), and Tauchen and Pitts (1983) aggregate prices for different delivery dates into a "price" for a single "composite" futures contract. They also aggregate the volume of all existing contracts so that neither price nor volume is based on an identifiable contract. A further measurement problem is generated by the estimation of daily price "variability." The square of the daily price change, the rate of price change, the absolute value of the percentage change in daily closing prices, and the variance of closing prices over a fixed period have all been used as estimators of daily price variability. As will be discussed below, however, these estimators may well be poor measures of true price variability, thereby further clouding the empirical results. Thus the first objective of this paper is to reexamine the contemporaneous relation

2. This implies that the unconditional joint distribution of (daily) price changes/variability and volume is a mixed normal distribution, with the distribution of the directing variable, information arrival, determining the mixture of the conditional normal distributions.

3. See Harris 1984*b*, p. 4.

4. Samuelson (1965, 1976) has argued that futures prices become increasingly volatile as a futures contract approaches maturity. However, while Castelino (1981) and Milonas (1984) have found (strong) support for a maturity effect on price variability, studies by Segall (1956), Rutledge (1977, 1978), and Dusak (1979) have yielded mixed results. It should also be pointed out that contract maturity may have an effect on the flow of valuable information for futures contracts but not for stocks. Since stocks are "infinite" assets (contracts), the possibility of maturity-related information flows does not apply.

between price variability and volume in futures markets, using disaggregated data and improved measures of price variability. By looking at disaggregated data it may be possible to identify, more clearly, the presence of any common maturity effect on these variables; that is, whether maturity is the common directing variable.

It has also been argued that price variability and volume may not be jointly determined, in a contemporaneous fashion, as under the MDH but rather that there may be a sequential relation between price changes and volume (see Copeland 1976; Jennings, Starks, and Fellingham 1981; and Smirlock and Starks 1984). In the sequential information models there are intermediate equilibriums prior to the final complete information equilibrium. By contrast, in simultaneous information arrival models there is only a "final" equilibrium. This difference has empirical implications (see Smirlock and Starks 1984), in that with simultaneous information arrival there is no information in past price variability that can be used to forecast volume and vice versa. The sequential model, on the other hand, implies that price variability (volume) may improve forecasts of volume (price variability).[5] In testing for sequential relations, Rutledge (1977, 1978) applied causality tests, following Sims (1972), on 17 different commodities and found weak evidence that price variability caused volume of trading. Rogalski (1978) applied a method devised by Haugh (1976) on a sample of 10 common stocks and their associated warrants. Rogalski's conclusion was that, while there is positive dependence between actual price change and volume, it is not possible to distinguish between contemporaneous determination or bi- or unidirectional causality. Finally, Smirlock and Starks (1984), using stock transactions data, also found some evidence of "causality." However, they could not reject the simultaneous model in a number of cases. Given this ambiguity over the underlying causal (correlation) relations between price variability and volume, the second objective of the paper is to examine these relations in the context of the disaggregated futures data and improved measures of price variability discussed above.

The remainder of the paper is organized as follows. In Section II the data and methodology for obtaining estimators of price variability are first described; then descriptive statistics and tests for a contemporaneous relation between price variability and volume are presented. This is followed, in Section III, by results from causality tests between price variability and volume. Finally, Section IV is a summary and conclusion.

5. Improving forecasts of futures price variability may have important applications, such as in pricing options on futures.

II. The Contemporaneous Relation between Futures Price Variability and Volume

Estimation of Daily Price Variances

Classical estimation of variance is based on daily closing prices. The major problem with this estimation method is that it ignores other readily available information that may contribute to estimator efficiency. Garman and Klass (1980) and Parkinson (1980) have developed a number of estimators based on observed daily high, low, opening, and closing prices. In their analysis "price" means "logarithm of original price" and "variance" means "variance of the logarithm of the original prices," while futures prices are assumed to follow a Brownian motion with zero drift, and the price path follows this process irrespective of whether the market is open or closed.[6]

The classical variance estimator based on closing prices (C) is

$$\sigma_0^2 = (C_t - C_{t-1})^2.$$

This can be compared to the Garman and Klass (1980) estimator derived from daily high (H), low (L), closing (C), and opening (O) prices:

$$\sigma_1^2 = .511(u - d)^2 - .019[c(u + d) - 2ud] - .383c^2,$$

where

$$\begin{aligned} u &= H_t - O_t = \text{high} - \text{open}, \\ d &= L_t - O_t = \text{low} - \text{open}, \\ c &= C_t - O_t = \text{close} - \text{open}. \end{aligned}$$

Garman and Klass show that σ_1^2 has an efficiency of 7.4 in comparison to σ_0^2 (i.e., its estimation variance is 7.4 times lower). Since the price path cannot be monitored when markets are closed, however, the σ_1^2 estimator is still biased downward because the observed highs and lows are smaller in absolute magnitude than the actual highs and lows. Garman and Klass (1980) estimate this potential bias using simulation analysis and show that the bias decreases with an increasing number of transactions. For example, with 500 transactions the σ_1^2 estimator is only 11% smaller than the true variance. Nevertheless, using the Garman and Klass simulation results reported in their table 1, it was relatively easy to adjust our estimates of daily variances to eliminate this source of bias.[7]

6. This hypothesis may not be valid for the stock market. In a recent paper French and Roll (1984) provide evidence that stock return variability is higher during trading than during nontrading hours.

7. Also, observations were dropped if daily volume traded was five contracts or less since it was not possible to adjust σ_1^2 for bias in any meaningful way.

The Data

The sample consists of daily observations for five different foreign currency futures traded on the International Monetary Market (IMM): the German mark, the Swiss franc, the British pound, the Canadian dollar, and the Japanese yen. Daily observations on high, low, opening, and closing prices, volume traded, and open interest (as an alternative measure of trading activity) were obtained from Commodity Systems, Incorporated (CSI), the commodity data bank, and the Interactive Data Corporation over the period March 1978–March 1983. Although most foreign currency futures started trading in 1972, the markets in the early years were rather thin. Consequently, the period selected has been characterized by relatively high daily volume (the daily volume had reached over 1,000 contracts on average by 1978) in order to minimize potential biases to our volatility estimators. At any point in time there are at least four contracts outstanding with delivery in March, June, September, and December. In order to identify any possible maturity effects on price variability (and volume) each contract was observed from 6 months before maturity until the beginning of the delivery month. To control for "delivery complications" we omitted those days that fell in the delivery month.[8] Days in which prices hit the limit were also dropped from the sample.

Table 1 shows the mean daily volume and open interest for the five foreign currencies as well as two measures of mean daily price variability: σ_0, the standard deviation of σ_0^2, and σ_1, the standard deviation of σ_1^2. A number of observations can be drawn from table 1. First, σ_0 is

8. By terminating our series at the beginning of the delivery month we do not investigate the peculiar pattern of price variability and volume close to contract expiration. In particular, it is observed that, in many futures markets as we move into the delivery month, trading volume (and open interest) shifts gradually to the contract with the next nearest delivery date. Three factors may help explain this behavior. First, in some markets, e.g., Treasury bond futures, the short position has a "quality option" whereby the contract can be satisfied by delivering one of a variety of specified assets. Since the value of this option is reduced as the contract approaches delivery (see Gay and Manaster 1984*a*, 1984*b*), futures prices and possibly speculative trading are affected around the delivery date. However, in the case of foreign exchange futures the quality option does not exist since settlement is in cash. Second, in discussions with traders it was suggested that new positions taken by hedgers and long-term speculators when the nearby contract is close to expiration are usually taken on the next nearest contract in order to avoid the transactions costs from having to roll over their position in the near future. This means that trading volume on the nearby contract falls as expiration approaches, resulting in higher transaction costs for the existing traders, which in turn motivates them to switch to the more liquid next nearest futures contract. Finally, in some exchanges internal regulations influence when most traders move to the next contract. For example, beginning on March 11, 1985, New York Futures Exchange regulations required open outcry prices on the stock index futures to refer to the June 1985 contract rather than the expiring March 1985 contract. The small number of traders who wish to continue trading in the nearby contract after the "rollover" day up until expiration tend to segregate themselves in one area of the pit. A fruitful area of future research might be to examine these effects on price-volume behavior around contract expiration.

TABLE 1 **Means and Standard Deviations of Foreign Currency Futures Price Variability, Volume, and Open Interest**

Currency	Volume	Open Interest	σ_0*	σ_1†	Observations (N)
Mark					2,563
Mean	1,980	4,518	.0047	.0040	
Standard deviation	2,611	4,765	.0042	.0022	
Franc					2,575
Mean	2,147	4,332	.0064	.0053	
Standard deviation	3,077	4,505	.0051	.0028	
Pound					2,587
Mean	1,796	4,842	.0049	.0044	
Standard deviation	2,277	4,865	.0042	.0024	
Canadian dollar					2,604
Mean	1,004	3,866	.0021	.0021	
Standard deviation	1,378	3,664	.0017	.0010	
Yen					2,586
Mean	1,544	3,988	.0059	.0043	
Standard deviation	2,270	4,649	.0047	.0022	

NOTE.—The σ_1 daily estimators were adjusted for downward bias using the simulation results reported by Garman and Klass (1980, table 1, p. 75).

* $\sigma_0 = [(C_t - C_{t-1})^2]^{1/2}$.

† $\sigma_1 = \{.511(u - d)^2 - .019[c(u + d) - 2ud] - .383c^2\}^{1/2}$, where $u = H_t - O_t$ = high-open, $d = L_t - O_t$ = low-open, and $c = C_t - O_t$ = close-open.

equal to or greater than σ_1 for all five currencies, suggesting that the classical variance estimator may exaggerate the true degree of price variability in these asset markets. Second, σ_1 also shows less interday variability than σ_0 over the sample period. Third, the Swiss franc, the currency with the largest average daily trading volume, has the largest price variability (measured by either σ_0 or σ_1), while the currency with the smallest trading volume (the Canadian dollar) has the lowest price variability.

Contemporaneous Correlations

Contemporaneous correlations among volume measures and price variability measures, for all five currencies, are shown in table 2. Both Spearman and Pearson correlation coefficients were estimated. Since they produced very similar results, however, only Pearson correlations are reported here. For the five currencies, the correlations between daily volume and variability (either σ_1 or σ_0)[9] are all positive and statistically significant at the 5% level. These positive correlations also hold when open interest is used instead of volume as an alternative measure of transactions activity. (Indeed, the open interest–volume correlations are extremely high; i.e., all exceed .812.) These strong positive contemporaneous correlations appear to be broadly consistent with the

9. It might be noted that σ_1 and σ_0 are positively correlated with the largest correlation coefficient equalling .406.

TABLE 2 Pearson Correlation Coefficients

	σ_0	Maturity	Trend	Volume	Interest
Mark:					
σ_1	.349*	−.106*	.254*	.387*	.227*
σ_0		−.017	.128*	.184*	.098*
Maturity			−.039*	−.584*	−.594*
Trend				.453*	.408*
Volume					.817*
Franc:					
σ_1	.254*	−.023	.266*	.261*	.135*
σ_0		−.030	.064*	.128*	.038*
Maturity			−.035*	−.523*	−.564*
Trend				.507*	.478*
Volume					.865*
Pound:					
σ_1	.406*	−.029	.273*	.317*	.158*
σ_0		.004	.160*	.221*	.074*
Maturity			−.039*	−.565*	−.595*
Trend				.403*	.484*
Volume					.837*
Canadian dollar:					
σ_1	.382*	.009	.195*	.367*	.201*
σ_0		.037	.052*	.214*	.041*
Maturity			−.032	−.464*	−.557*
Trend				.368*	.486*
Volume					.812*
Yen:					
σ_1	.276*	.008	.224*	.247*	.127*
σ_0		−.002	.056*	.121*	.027
Maturity			−.028*	−.501*	−.561*
Trend				.450*	.457*
Volume					.886*

* Significant at the 5% level.

MDH and with the empirical evidence of Clark (1973), Tauchen and Pitts (1983), and Harris (1984*a*, 1984*b*).

As discussed in the introduction, the MDH implies the existence of a common directing variable underlying the joint distribution of price variability and volume. Since the maturity of the contract is changing continuously (daily) and "news" may (or may not) have a different value at different times along a contract's length, one candidate for the directing variable is contract time to maturity. However, from table 2, it is clear that contract maturity has contemporaneous effects on price variability and volume over the sample period that are inconsistent with the MDH. Specifically, time to maturity and volume are strongly negatively correlated; that is, as a foreign currency contract approaches maturity, the volume of trading increases (with correlations ranging from −.464 to −.584) for the five contracts. By comparison the correlations between price variability (σ_1) and maturity are quite weak, with only one, the mark (−.106), being significant at the 5% level.

At this point, however, no firm conclusions should be drawn about the existence of a maturity effect because there is also a strong positive time trend in both the price variability (σ_1 and σ_0) and the volume of trading series. Both σ_1 (correlations ranging from .195 to .273) and volume (correlations ranging from .368 to .507) are significantly positively correlated with time.[10] These trends may mask the underlying statistical relations between price variability and maturity and between volume and maturity.

To abstract from the possibly obscuring effects of a trend, two sets of regressions were run:[11]

$$\sigma_1 = b_0 + b_1 \text{ trend} + u$$

and

$$\text{volume} = a_0 + a_1 \text{ trend} + v.$$

The estimated prediction errors, $\hat{u}$ and $\hat{v}$, contain variations in σ_1 and volume not explained by the trend. Labeling these error terms, respectively, as $\hat{\sigma}_1(\hat{\sigma}_0)$ and $\hat{V}$, Pearson correlation coefficients were recalculated, and the results are presented in table 3. Table 3 shows that, after eliminating the positive trend, price variability ($\hat{\sigma}_1$ and $\hat{\sigma}_0$) and volume of trading are still positively and significantly correlated, with the yen exhibiting the smallest (.219) and the Canadian dollar the largest (.303) correlations between σ_1 and volume. Further, these correlations are very close to those reported in table 2. The correlations between $\hat{\sigma}_1$ and maturity and between $\hat{V}$ and maturity are also found to be broadly similar to those reported in table 2, implying that the time trend did not conceal an underlying maturity effect on volume and price variability that is consistent with the MDH. The net result is that maturity appears to have different direct effects on price variability and volume of trading. This also suggests that it cannot be the common directing variable (under the MDH) or implicitly that information arrival in futures markets is random across contract maturity.

III. Causality Tests

The previous section analyzed contemporaneous relations between foreign currency futures price variability and volume. As discussed in the introduction, however, sequential information arrival models imply

10. The finding that σ_1 trends upward is contrary to that of Tauchen and Pitts (1983), who report that the variance of Treasury bill futures decreased through time. This difference may be due to their price series being a weighted average of the individual futures prices. As a result, increasing individual variances may result in a smaller weighted variance if the individual prices become less correlated among themselves (i.e., if there is a larger diversification effect).

11. The regressions were corrected for autocorrelation when necessary and were also applied to σ_0.

TABLE 3 Pearson Correlation Coefficients: Detrended $\hat{V}$, $\hat{\sigma}_0$, and $\hat{\sigma}_1$

	$\hat{\sigma}_0$	Maturity	$\hat{V}$
Mark:			
$\hat{\sigma}_1$	.258*	−.064*	.270*
$\hat{\sigma}_0$		−.010	.195*
Maturity			−.181*
Franc:			
$\hat{\sigma}_1$	.205*	−.010	.234*
$\hat{\sigma}_0$		−.025	.184*
Maturity			−.145*
Pound:			
$\hat{\sigma}_1$	.265*	−.011	.269*
$\hat{\sigma}_0$		.010	.290*
Maturity			−.180*
Canadian dollar:			
$\hat{\sigma}_1$	.333*	.015	.308*
$\hat{\sigma}_0$		.306	.262*
Maturity			−.163*
Yen:			
$\hat{\sigma}_1$	.248*	.011	.219*
$\hat{\sigma}_0$		.002	.208*
Maturity			−.158*

* Significant at the 5% level.

the possibility of observing lead (lag) relations between daily contract price variability and volume.

A number of different causality tests have been proposed and applied in the literature. Recently Geweke, Meese, and Dent (1983) compared eight alternative causality tests with a Monte Carlo experiment. They defined (1983, p. 161) causality as follows: "A time series $\{Y_t\}$ causes another time series $\{X_t\}$ if present X can be predicted better using past values of Y than by not doing so, other relevant information (including the past values of X) being used in either case."[12] Their major conclusion was that Wald variants of a lagged dependent variable version of the Sims' (1972) test is one of the two best-performing tests.

This Geweke et al. causality test methodology was applied twice: first, testing whether the volume of trading caused price variability (σ_1) and, second, testing whether price variability (σ_1) caused volume of trading.[13] In each case the regressions were run with three lead and three lag coefficients.

The results are summarized in table 4. Table 4 shows causality rela-

12. This definition of causality is known as Granger-Sims causality. For a discussion of various definitions of causality, see Zellner (1979). Specifically, these causality tests do not determine causality in an economic sense but rather characterize the correlation structure among variables.

13. It might be worth noting that the variability of spot exchange rates may also exert some influence on the variability of futures prices.

TABLE 4 Causality Test Results (110 Contracts)

	Number of Contracts with Significant F's at:		z-Statistic for Significant F's at:		
	10%	5%	10%	5%	χ^2
Volume causes σ_1	19	10	2.54*	1.97*	302.39*
σ_1 causes volume	30	16	6.04*	4.59*	381.98*

* Significant at the 5% level.

tions (in a Granger-Sims sense) for 21 futures contracts in the five different foreign currencies (i.e., 110 contracts in all) along with standard z-statistics and pooled chi-square statistics for overall significance tests. For 10 out of 110 contracts there was evidence at the 5% level of a significant effect running from lagged volume to current price variability (volume "causes" σ_1) and for 16 contracts evidence that price variability "causes" volume. In all, 24 out of the 110 contracts (or 22%) exhibited causality in one direction or another. Overall, neither the z- nor the chi-square test could reject the null hypothesis that volume (price variability) causes price variability (volume)—a finding that is consistent with the presence of significant bidirectional causality (correlations) in futures market transactions. It is also interesting to note that Smirlock and Starks (1984), analyzing Granger-Sims causality for (absolute) stock price changes and volume, found similar results. Specifically, they found evidence of significant bidirectional causality in approximately 25% of their sample. Contrary to our findings, however, they report a relatively stronger effect running from volume to price variability.

IV. Conclusions

This study used contract-disaggregated data on futures prices to obtain evidence on the MDH, on the maturity effect on price variability and volume of trading, and, finally, on the contemporaneous and sequential relation between these variables. Both classical and Garman-Klass estimators of price volatility were employed, and strong positive contemporaneous correlations between trading volume and price volatility were documented that appeared to be consistent with the MDH. The possibility that information arrival was directly linked with contract maturity producing a "maturity" effect on both price and volume was examined. It was found that, while maturity had a strong effect on volume, no such relation could be found for price variability. It was concluded that maturity was not a suitable surrogate for the common directing variable under the MDH. Finally, consistent with previous work with stock market data it was found that, while in the majority of cases futures contract price variability and trading volume were contemporaneously correlated, there was a significant number of cases in which a sequential relation between price variability and volume appeared to be present.

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