International Trading/NonTrading Time Effects on Risk Estimation in Futures Markets

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I. INTRODUCTION

A growing body of academic literature exists on trading versus nontrading time effects on the risk and return characterisitics of securities traded in U.S. financial markets. Trading time refers to the period over which a security is openly traded in either a central market (e.g., NYSE, CBOT) or an active over-the-counter market. For example, the U.S. stock markets' trading time is usually designated as the period between 9:30 A.M.–4:00 P. M. EST. Nontrading time is often defined as that period in which the principal market where a security is traded is closed. For weekdays, the U.S. stock markets' nontrading time is usually designated as the period between 4:00 P.M.–9:30 A.M. EST.

Trading and nontrading time studies of U.S. security markets have been conducted in the cash (French and Roll (1986)) as well as futures markets (Chiang and Tapley (1983)).[1] Cornell (1985, 1981) and Dyl and Maberly (1986) have focused on differing returns and/or variances between weekdays and weekends. Recent studies by Chiang and Tapley (1983), Ferris and Chance (1987), French and Roll (1986), however, have tested also for differences in the risk and return relationship between overnight and day trading a well as in intra-day return patterns.

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[1]The actual definition of trading and nontrading times in empirical studies is somewhat dependent on the researchers' view of an inactive market. For example, trading time in the U.S. stock market has been those hours when the NYSE is open, despite the fact that some U.S. equity securities are traded over other time intervals on the Pacific Stock Exchange and in London and Tokyo.

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While extensive analysis is available on the trading and nontrading time effects for the U.S. furtures and cash markets, little research exists on the return and risk characteristics of instruments actively traded in international markets. For instance, U.S. Treasury Bonds and U.S. Treasury Bond futures are traded not only in the United States but also in the United Kingdom and the Far East (U.S. Treasury Bond futures are traded on the London International Financial Futures Exchange (LIFFE), Sydney Futures Exchange (SFE), and Singapore International Monetary Exchange (SIMEX)). Eurodollar futures are traded not only in the United States but also in the United Kingdom (LIFFE) and Singapore (SIMEX).

Empirical studies which focus only on the trading and nontrading periods of the U.S. security market fail to properly address the question of the effect of open markets in other countries on the time pattern of risk for those assets which are traded internationally. This article analyzes empirically the risk distributions of U.S. Treasury Bond and Eurodollar futures across the various international markets. Results show that the reported variance of price changes differs both between trading and nontrading hours and between the trading hours on different markets. In contrast to a trading time or calendar time hypothesis for explaining risk/return distributions over time, results tend to confirm an informational and transaction cost explanation for the relative reported variances between markets; that is, *ex post* measures of variance are neither the same over all trading periods around the world (i.e., trading time hypothesis) nor strict multiplies of the number of hours in each trading interval (i.e., calendar time hypothesis). In contrast, variances during trading periods seem to be greatest for those markets which are open during the largest information flows. Results also indicate the impact of weekend effects when comparing risk measures across trading periods.

The next section of this article contains a review of alternative theories for the nonstationarity of return distributions across trading and nontrading times. Section III outlines the data and methodology used in this analysis.

The analysis of volatility over the varying trading and nontrading periods is presented in section IV. Results of tests of adjusted variances of price changes are reported in the Appendix.

II. CALENDAR/TRADING TIME HYPOTHESES

Evidence of nonstationary of asset risk is documented in several studies in both cash and futures markets (Chiang and Tapley (1983), Cornell (1985, 1981), Dyl and Maberly (1986), and French and Roll (1986)). This nonstationarity in an asset's variance is often discussed in the context of calendar time and trading time. The calendar time hypothesis posits that the stationarity of the asset return generating process operates continuously in calendar time with independent and identically distributed returns. If returns and variances are generated according to the calendar time hypothesis, then returns and variances over varying calendar time periods should be simple multiples of one another. For example, the return or variance of a three day weekend, Friday's close to Monday's close, should be three times the return or variance of any single calendar day. In contrast to the calendar time hypotheses, the trading time hypothesis maintains that the return generating process operates continuously during trading time only. If the trading time hypothesis is correct, weekend return and variance measures which include one nontrading interval (e.g., Friday close to Monday close) should be equal to return and variance measures on other weekdays which also link one trading day to the next.

Various hypotheses exist including market structure (Goldman and Sosin (1979) and Jordan et al. (1988)) and information impact (Grossman (1979) and Ross (1989)) to explain the trading/nontrading time effects. The information explanation assumes that volatility changes in response to the arrival and assimilation of information that is nonuniform across trading and nontrading hours. French and Roll (1986) empirically analyze the effect of information on traders and trading and nontrading time stock return variance. Grossman (1979) shows that information is gathered until the expected gain from trading on that information is greater than the cost of obtaining the information (e.g., transaction costs). Ross (1989) shows that in an arbitrage-free economy, the volatility of prices is directly related to the rate of flow of information to the market. As a result, because of the relative lack of information flows on U.S. securities during nontrading hours or nonU.S. trading hours, reported price movements for U.S. securities during nontrading hours or nonU.S. trading hours should be smaller than price movements during U.S. trading hours. For foreign securities, price movements would be greatest during the trading hours of the foreign country's domestic market (see Ito (1987)).

III. DATA AND METHODOLOGY

To test the relative importance of the calendar and trading time hypotheses, this article focuses on empirical evidence collected on the Eurodollar and U.S. Treasury Bond futures. Table I lists the time periods (in Chicago time) during which the Eurodollar and U.S. Treasury Bond futures are actively traded. It should be noted that other markets also list the contracts (e.g., SFE and SIMEX but these contracts are presently inactive.) The times presented in Table I may vary due to changes in daylight savings time, etc. Also, the trading hours in various markets may overlap (e.g., LIFFE and CBOT U.S. Treasury Bond futures contract and LIFFE and CME Eurodollar futures contract). These overlapping time periods provide arbitrage opportunities between markets and are analyzed in previous studies (e.g., Emmanual et al. (1986)). These arbitrage relationships ensure that the prices existing in two open markets are within the boundaries of transaction costs.

The data in this article consists of the opening and closing prices for the Eurodollar and U.S. Treasury Bond futures markets in Chicago, London, and Singapore. While the securities listed in Table I are traded in some over-the-counter markets around the clock, it is assumed that the transaction costs and liquidity are such that during these times trading is relatively thin. Thus, the return movement is grouped into the nontrading time period. Tests of differential variances between trading and nontrading time periods follow the approach in French and Roll (1986). Hourly openings and closings are reported as of Chicago time (i.e., CDT).

Opening and closing prices are used to ascertain the price change movements in each market.[2] The use of opening and closing prices adds certain restrictions to the time periods of analysis. Following the opening of night trading on the CBOT on April 30, 1987, opening prices of the CBOT listed in the *Wall Street Journal* are as of 6 P.M. of the previous night. As a result, morning opening prices of the CBOT futures contracts are not easily available. Alternatives include obtaining cash market quotes and adjusting for the cheapest-to-deliver conversion factor; however, difficulties in determination of the cash

[2]Since no investment above initial margin is required for futures markets, price change is often used as a measure of investment return (Black (1976)). Other empirical studies (Yau et al. (forthcoming)) show little differences in relative parameter estimates when price changes or percentage price changes are used. The adoption of a particular return measure depends primarily on the objective of the user and the user's personal loss function. Additional tests of calendar/trading time effects using percentage price give similar results. These results are available from the authors.

Table I

INTERNATIONAL TRADING/NONTRADING TIME FOR U.S. TREASURY BOND/EURODOLLAR SPOT AND FUTURES MARKETS (CHICAGO TIME, CDT)

			(a) Spot Markets Trading Hours			
	U.S.		**Japan**		**London**	
	8 A.M.–5:30 P.M.		6:30 P.M.–2:30 A.M.		2 A.M.–10 A.M.	
Open U.S. 8 A.M. Day T	Close U.S. 5:30 P.M.	Open Japan 6:30 P.M.	Open London 2 A.M.	Close Japan 2:30 A.M.	Open U.S. 8 A.M. Day $T + 1$	Close London 10 A.M.
			(b) U.S. Treasury Bond Futures Markets Trading Hours			
	CBOT				**LIFFE**	
	8 A.M.–2 P.M.	6 P.M.–9:30 P.M.			2:15 A.M.–10:10 A.M.	
Open CBOT 8 A.M. Day T	Close CBOT 2 P.M.	Open CBOT 6 P.M.	Close CBOT 9:30 P.M.	Open LIFFE 2:15 A.M.	Open U.S. 8 A.M. Day $T + 1$	Close LIFFE 10 A.M.
			(c) Eurodollar Futures Markets Trading Hours			
	CME		**SIMEX**		**LIFFE**	
	7:20 A.M.–2 P.M.		6:30 P.M.–2:20 A.M.		2:30 A.M.–10 A.M.	
Open CME 7:20 A.M. Day T	Close CME 2 P.M.	Open SIMEX 6:30 P.M.	Close SIMEX 2:20 A.M.	Open LIFFE 2:30 A.M.	Open U.S. 7:20 A.M. Day $T + 1$	Close LIFFE 10 A.M.

CME = Chicago Mercantile Exchange.
CBOT = Chicago Board of Trade.
LIFFE = London International Financial Futures Exchange.
SIMEX = Singapore International Monetary Exchange.

market cheapest-to-deliver security prevents that solution. In this article, for U.S. Treasury Bond futures the prices at the close of the LIFFE at 10 A.M. are used as an alternative to 8:00 A.M. U.S. prices.

The time periods chosen in this analysis are July and August of 1986, 1987, and 1988. These years are analyzed separately and similar months are used to reduce any impact due to year/calendar effects (Milonas and Vora (1985)). Pre-April 1987, post-April 1987, and post-September 17, 1987 periods are tested separately to assess the impact of the opening of evening trading at the CBOT in April, 1987 and its revision to include Sunday night trading in September, 1987. These impacts are reflected in periods post-April 1987 and post-September 1987, respectively. The trading and nontrading periods analyzed in this study are given in Table II.[3]

In the pre-April 1987 period, the nontrading session for both U.S. Treasury Bond and Eurodollar futures is approximately 2 P.M.–2:30 A.M. In the post-April 1987 and post-September 1987 periods, the nontrading session for U.S. Treasury Bond futures is considered to be from 2 P.M. to 6 P.M. and from 9 P.M. (9:30 P.M. for the post-September 1987 period) to 2:15 A.M. For Eurodollar futures the nontrading session is from 2 P.M. to 6:30 P.M. because the SIMEX has an active Eurodollar futures contract that trades between 6:30 P.M. and 2:20 A.M.[4]

IV. RESULTS

Empirical results are presented in Table III for the July/August 1986 period for both U.S. Treasury Bond and Eurodollar futures. Results for the July/August 1987 and July/August 1988 periods for the U.S. Treasury Bond futures and Eurodollar futures are presented in Tables IV and V, respectively.[5] Results from Tables III–V are presented graphically in Figures 1–3. (Due to scaling differences, standard deviations are used in graphs instead of variances).

The trading time hypothesis suggests that the variances of the various trading sessions are expected to be equal; that is, for the pre-April 1987 period, the variances for U.S. Treasury Bond Futures and Eurodollar futures are expected to be similar for sessions (1), (2), and (3). The trading time hypothesis suggests that for the post-April 1987 period, the trading time variances for U.S. Treasury Bond futures are expected to be similar for sessions (1), (3), and (4), and for Eurodollar futures that the trading time variances are expected to be similar for sessions (1), (2), (3), and (4). The calendar time hypothesis suggests that the variances of the various trading sessions are expected to be a strict mul-

[3]Hereafter, the terms trading/nontrading periods and trading/nontrading sessions are used interchangeably to avoid possible confusions with the calendar periods.

[4]It is assumed that the time difference between the SIMEX close (2:20 A.M.) and the LIFFE opening (2:30 A.M.) is not significant and LIFFE opening prices are substituted. Opening and closing hours reported in Table II are obtained from the *Exchanges and Corporate Finance: Futures and Options Director-A Euromoney Supplement* (March, 1988). It is important to note that these hours may change. For example, the CBOT increased its evening session hours to 9:30 P.M. on September 17, 1987 and evening hours will change to 5:00 P.M.–8:30 P.M. CST during fall and winter. The change to standard time only affects the evening CBOT trading hours since they adjust to keep in track with the SIMEX open. This adjustment adds one hour to the nontrading session (2) and reduces the nontrading session (5) by one hour. Since the results are discussed primarily in trading sessions versus nontrading sessions and since the change in hours does not overlap with any systematic information releases, the effects of an additional hour in nontrading session (2) and one less hour in nontrading session (5) should have little impact on reported results.

[5]The impact of trading on the SIMEX is not reported in Table III. Results are available from authors. The SIMEX lists both U.S. Treasury Bond futures contracts and Eurodollar futures contracts. The U.S. Treasury Bond futures contract was not active during the latter part of this study and was therefore not included in the analysis. (The Sydney Futures Exchange also has an inactive U.S. Treasury Bond futures contract).

Table II
TRADING/NONTRADING TIME FOR TREASURY BOND/EURODOLLAR FUTURES

(a) Pre-April 1987 Period

Treasury Bond Futures

Open (LIFFE)	Open (CBOT)	Close (LIFFE)	Close (CBOT)
2:15 A.M.	(1) 8 A.M.	(2) 10:10 A.M.	(3) 2 P.M.

(4) Nontrading period from 2 P.M.–2:15 A.M.

Eurodollar Futures

Open (LIFFE)	Open (CME)	Close (LIFFE)	Close (CME)
2:30 A.M.	(1) 7:20 A.M.	(2) 10 A.M.	(3) 2 P.M.

(4) Nontrading period from 2 P.M.–2:30 A.M.*

(b) Post-April 1987 Period

Treasury Bond Futures

Open (LIFFE)	Close (LIFFE)	Close (CBOT)	Open (CBOT)	Suspended (CBOT)
2:15 A.M.	(3) 10:10 A.M.	(4) 2 P.M.	6 P.M.	(1) 9 P.M.**

(5) (2) Nontrading period from 2 P.M.–6 P.M. and 9 P.M.**–2:15 A.M.

Eurodollar Futures

Open (SIMEX)	Close (SIMEX)	Open (LIFFE)	Open (CME)	Close (LIFFE)	Close (CME)
6:30 P.M.	(1) 2:20 A.M.	2:30 A.M.	(2) 7:20 A.M.	(3) 10 A.M.	(4) 2 P.M.

(5) Nontrading period from 2 P.M.–6:30 P.M.

( ) Numbers in parentheses are referred to as sessions here and after.

*Eurodollar futures are traded on the SIMEX (6:30 P.M. to 2:20 A.M.) but are not included in this period's analysis in order to focus analysis on approximately equal trading periods.

**Starting September 17, 1987, the evening session was extended to 9:30 P.M. and Sunday night trading began.

tiple of the hours in each trading session.[6] For example, for the post-April 1987 period, the calendar time hypothesis suggests that the variance of the eight hour trading session (3): 2:15 A.M. to 10:10 A.M. trading period is expected to be twice that of the four hour trading session (4): 10:10 A.M. to 2:00 P.M. The informational hypothesis suggests that the variances are expected to be multiples of the informational activity in

[6]Given the assumption of independence and uncorrelated returns between periods, the variance of a period would be a strict multiple of the number of hours in that period and the hourly variance (VAR_h); that is, $VAR_p = VAR_h$* no. of hours. In the Appendix, the trading and nontrading period variances are divided by the number of hours in each period. Results show that even after a strict hourly adjustment, the calendar time hypothesis does not hold.

Table III
MEANS/VARIANCES OF PRICE CHANGES OVER VARYING TRADING AND NONTRADING SESSIONS JULY 1–AUGUST 27, 1986

(a) Treasury Bond Futures

Session:	(1)	(2)	(3)	(4)
Incl. Fridays μ:	−.142	−.011	.143	.009
σ^2:	.183	.282	.392[a]	.152
Excl. Fridays μ:	−.136	−.035	.146	.003
σ^2:	.185	.258	.433[a]	.158

a: Using standard *F*-test comparisons, the variance of session (3) is significantly greater than those of sessions (1) and (4) at 5% level.
Trading Sessions
(1) 2:15 A.M.–8 A.M. (Open LIFFE–Open CBOT)
(2) 8 A.M.–10:10 A.M. (Open CBOT–Close LIFFE)
(3) 10:10 A.M.–2 P.M. (Close LIFFE–Close CBOT)
Nontrading Session
(4) 2 P.M.–2:15 A.M. (Close CBOT–Open LIFFE: Next Day)

(b) Eurodollar Futures

Session:	(1)	(2)	(3)	(4)
Incl. Fridays μ:	−.003	.004	.002	.013
σ^2:	.0004	.0012	.001	.001
Excl. Fridays μ:	−.003	.004	.004	.012
σ^2:	.0004	.0012	.001	.001

Trading Sessions
(1) 2:30 A.M.–7:20 A.M. (Open LIFFE–Open CME)
(2) 7:20 A.M.–10 A.M. (Open CME–Close LIFFE)
(3) 10 A.M.–2 P.M. (Close LIFFE–Close CME)
Nontrading Session
(4) 2 P.M.–2:30 A.M. (Close CME–Open LIFFE: Next Day)

each market.[7] For U.S. Treasury Bond futures and Eurodollar futures, the informational hypothesis implies that the greatest variances should appear surrounding the opening and closing of U.S. financial markets. Relative to the periods during which the U.S. financial markets (both cash and futures markets) are open, a lower variance should exist during the period for which nonU.S. markets (e.g., Japan) are open and U.S. cash markets are closed (6 P.M.–9:30 P.M. Chicago time). The lowest variance is expected during those hours when both the U.S. cash and futures markets are closed (e.g., 9 P.M. (9:30 P.M. after Sept. 17, 1987)–2:15 A.M. for U.S. Treasury Bond futures).

Results shown in Tables III, IV, and V are consistent with the informational/transaction hypothesis and not consistent with strict calendar trading time hypothesis. A strict calendar time hypothesis suggests that the variance of each period is a strict hourly multiple of each other. Results in Tables III–V and Appendix (variances are normalized for hours) show that for many sessions the assumed hourly variances are not equal. In addition,

[7]The exact risk/information release relationship cannot be easily modeled *ex ante* because each session is impacted by the unique information set available at that time period. Tests are presently being conducted on the link between variance and information release. In this article, variances are obtained using opening and closing prices. Future analysis will compare that measure of variance with one obtained using high/low prices.

Table IV
MEANS/VARIANCES OF PRICE CHANGES OVER VARYING TRADING AND NONTRADING SESSIONS

Treasury Bond Futures

July 1–August 26, 1987 & 1988

(a) Fridays & Weekends Included

Session:	(1)	(2)	(3)	(4)	(5)
			1987		
μ:	−.086	.033	−.045	.061	−.071
σ^2:	.035	.013	.159[a]	.168[a]	.092[b]
			1988		
μ:	−.001	.005	−.062	.025	−.039
σ^2:	.012	.005	.141[a]	.131[a]	.034[b]

a: Using standard F-test comparisons, the variances of sessions (3) and (4) are significantly greater than those of sessions (1), (2), and (5) at 5% level.
b: Using standard F-test comparisons, the variance of session (5) is significantly greater than those of sessions (1), and (2) at 5% level.

(b) Fridays & Weekends Excluded

Session:	(1)	(2)	(3)	(4)	(5)
			1987		
μ:	.086	.021	−.046	−.001	.023
σ^2:	.040	.012	.152[a]	.176[a]	.018
			1988		
μ:	.003	.002	−.062	.016	−.037
σ^2:	.013	.005	.130[a]	.149[a]	.039[b]

a: Using standard F-test comparisons, the variances of sessions (3) and (4) are significantly greater than those of sessions (1), (2), and (5) at 5% level.
b: Using standard F-test comparisons, the variance of session (5) is significantly greater than those of sessions (1) and (2) at 5% level.
Trading Sessions
(1) 6 P.M.–9 P.M. (9:30 P.M.) (Open CBOT–Suspend CBOT)
(3) 2:15 A.M.–10:10 A.M. (Open LIFFE–Close LIFFE)
(4) 10:10 A.M.–2 P.M. (Close LIFFE–Close CBOT)
Nontrading Sessions
(2) 9 P.M. (9:30 P.M.)–2:15 A.M. (Suspend CBOT–Previous Day*–Open LIFFE)
(5) 2 P.M.–6 P.M. (Close CBOT–Open CBOT)**

*In session (2) the 9 P.M. price is from the previous day.

**Since Sunday night trading began in September 1987, the 1987 period of analysis does not include Monday trading hours. Thus session (5) is from 2 P.M. of the previous Friday to 6 P.M. Monday night.

they also show that the variances across alternative calendar periods are not equal. As shown in the analysis of U.S. Treasury bond futures data in Table III(a), the periods with the highest variance are sessions (2): 8 A.M. (CBOT)–10:10 A.M. (LIFFE) and (3): 10:10 A.M. (LIFFE)–2 P.M. (CBOT), which encompass the principal part of the U.S. trading period. For U.S. Treasury Bond futures the period with the next highest variance is session (1): 2:15 A.M. (LIFFE)–8 A.M. (CBOT), which includes the trading

Table V
MEANS/VARIANCES OF PRICE CHANGES OVER VARYING TRADING AND NONTRADING SESSIONS

Eurodollar Futures

July 1–August 8, 1987 & 1988

(a) Fridays & Weekends Included

Session:	(1)	(2)	(3)	(4)	(5)
			1987		
μ:	−.004	.002	−.001	.001	−.000
σ^2:	.0004	.0004	.0012[a]	.0015[a]	.0005
			1988		
μ:	−.005	−.004	−.007	−.004	−.002
σ^2:	.0002	.0002	.0016[a]	.0007[a]	.0001

a: Using standard F-test comparisons, the variances of sessions (3) and (4) are significantly greater than those of sessions (1), (2), and (5) at 5% level.

(b) Fridays & Weekends Excluded

Session:	(1)	(2)	(3)	(4)	(5)
			1987		
μ:	−.002	.002	−.006	−.001	.000
σ^2:	.0004	.0004	.0012[a]	.0015[a]	.0004
			1988		
μ:	−.006	−.006	.001	−.001	−.004
σ^2:	.0002	.0002	.0005[a]	.0007[a]	.0001

a: Using standard F-test comparisons, variances of sessions (3), and (4) are significantly greater than those of sessions (1), (2), and (5) at 5% level.

Trading Sessions
(1) 6:30 P.M.–2:30 A.M. (Open SIMEX–Open LIFFE)
(2) 2:30 A.M.–7:20 A.M. (Open LIFFE–Open CME)
(3) 7:20 A.M.–10 A.M. (Open CME–Close LIFFE)
(4) 10 A.M.–2 P.M. (Close LIFFE–Close CME)
Nontrading Session
(5) 2 P.M.–6:30 P.M. (Close CME*–Open SIMEX)

*Over a weekend, the 2 P.M. price in session (5) is from the previous Friday.

session of the LIFFE before the opening of the U.S. cash and futures markets. The period with the lowest reported variance for U.S. Treasury Bond futures is session (4) which falls in the time interval when both the United Kingdom and U.S. futures and cash markets are closed (5:30 P.M.–2:00 A.M.).[8] The variance of session (3) is significantly greater than those of session (1) and (4) at the 5% level.

Tests of Eurodollar futures volatility as given in Table III(b), show similar results. Two of the sessions with the highest variance (sessions (2): 7:20 A.M. (CME)–10 A.M. (LIFFE) and (3): 10 A.M. (LIFFE)–2 P.M. (CME)) are also the sessions with the highest variance for U.S. Treasury Bond futures. In contrast to U.S. Treasury Bond

[8]The *Wall Street Journal* began carrying LIFFE U.S. Treasury Bond futures contracts as of June, 1988. The U.S. Treasury Bond and Eurodollar futures contracts used in this analysis are the September contracts of 1986, 1987, and 1988.

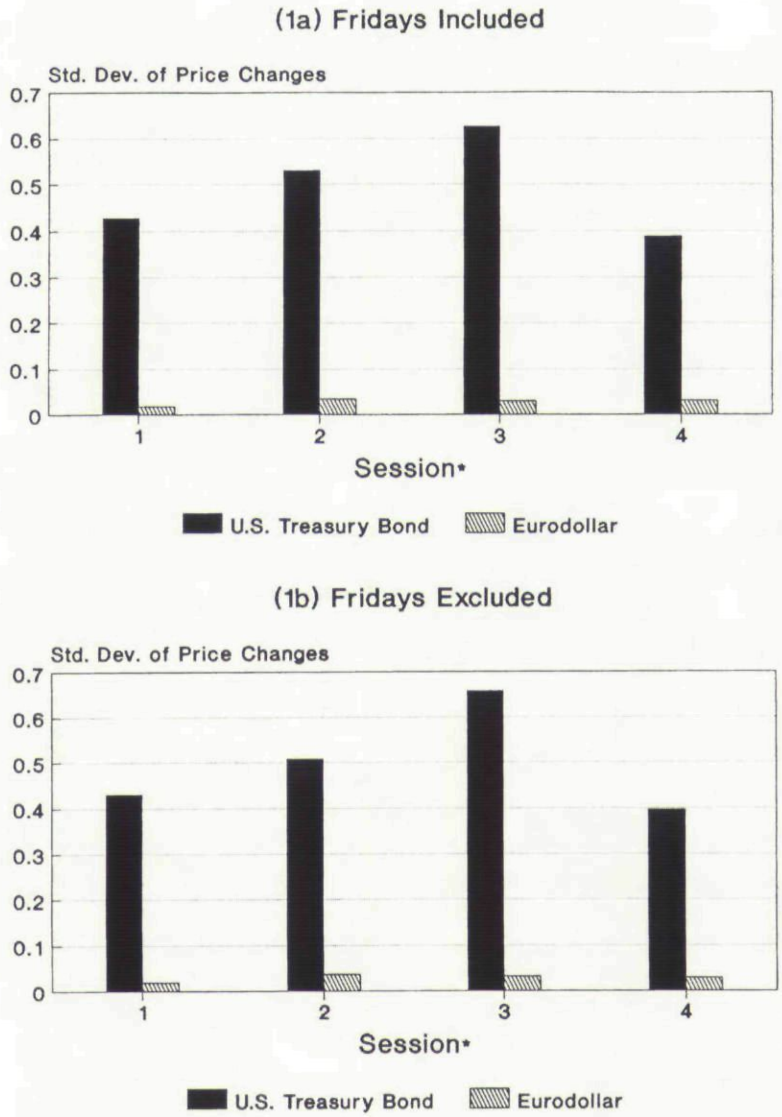

Figure 1

Standard Deviations of Price Changes for U.S. Treasury Bond Futures and Eurodollar Futures. (July, 1986–August, 1986)

*Sessions are as indicated in Table III.

**Due to scaling differences, standard deviations are used in graphs instead of variances.

futures, however, Eurodollar futures exhibit a greater variance during the U.S. nontrading period after close of the CME to the next day opening of the LIFFE (session (4): 2 P.M. (CME)–2:30 A.M. (LIFFE)) than during the exclusive LIFFE trading hours (session (1): 2:30 A.M. (LIFFE)–7:20 A.M. (CME)). One reason for this result is the impact of the SIMEX, which has an active Eurodollar futures market and is open during the hours included in session (4): 2:00 P.M. (CME)–2:30 A.M. (LIFFE). Thus, for Eurodollar futures, session (4) in Table III(b) is not a "true" nontrading period. The impact of the SIMEX is explored in Table V. Another reason for the greater reported variance in session (4) over that in session (1) is that U.S. cash markets remain open until

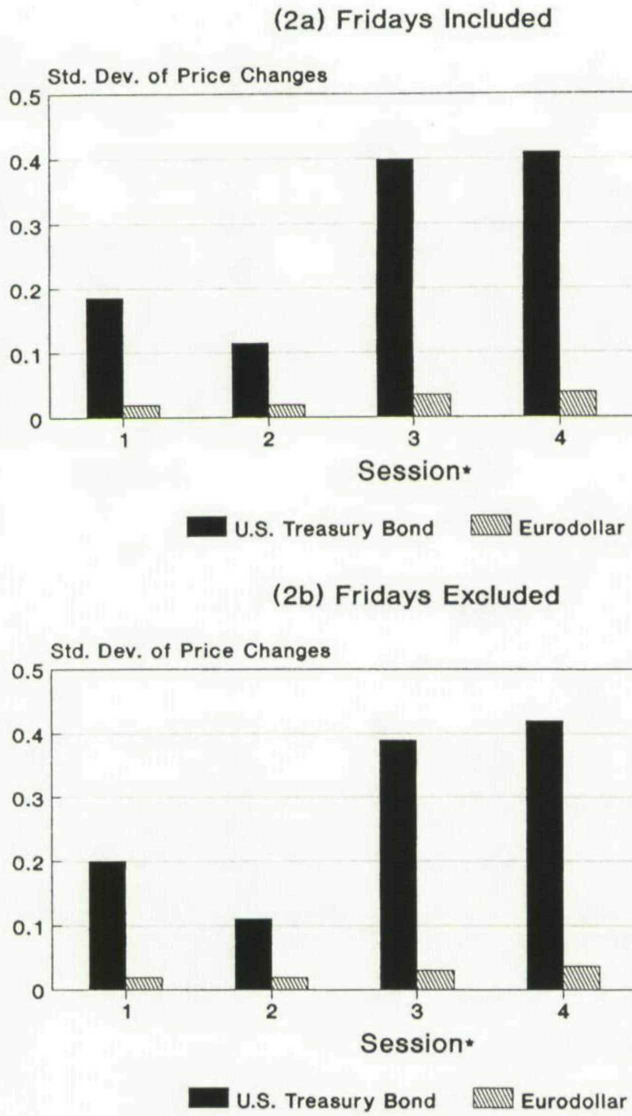

Figure 2

Standard Deviations of Price Changes for U.S. Treasury Bond Futures and Eurodollar Futures. (July, 1987–August, 1987)

*Sessions are as indicated in Table IV.

**Due to scaling differences, standard deviations are used in graphs instead of variances.

approximately 5:30 P.M. The active cash market, even without an active futures market, may result in greater reported volatility due to the informational and resultant price activity during the cash market trading hours.[9]

Tables IV(a) and V(a) pertain to July/August in both 1987 and 1988, and reveal results similar to those in Table III for the U.S. Treasury Bond and Eurodollar futures,

[9]As noted in this article, the lower reported variances during nontrading time periods, may simply reflect greater transaction costs and *ex ante* variance estimates may in fact be higher than those existing during trading periods. Moreover, the higher reported variance in trading periods may in fact not reflect greater risk if greater information and liquidity are considered important risk characteristics.

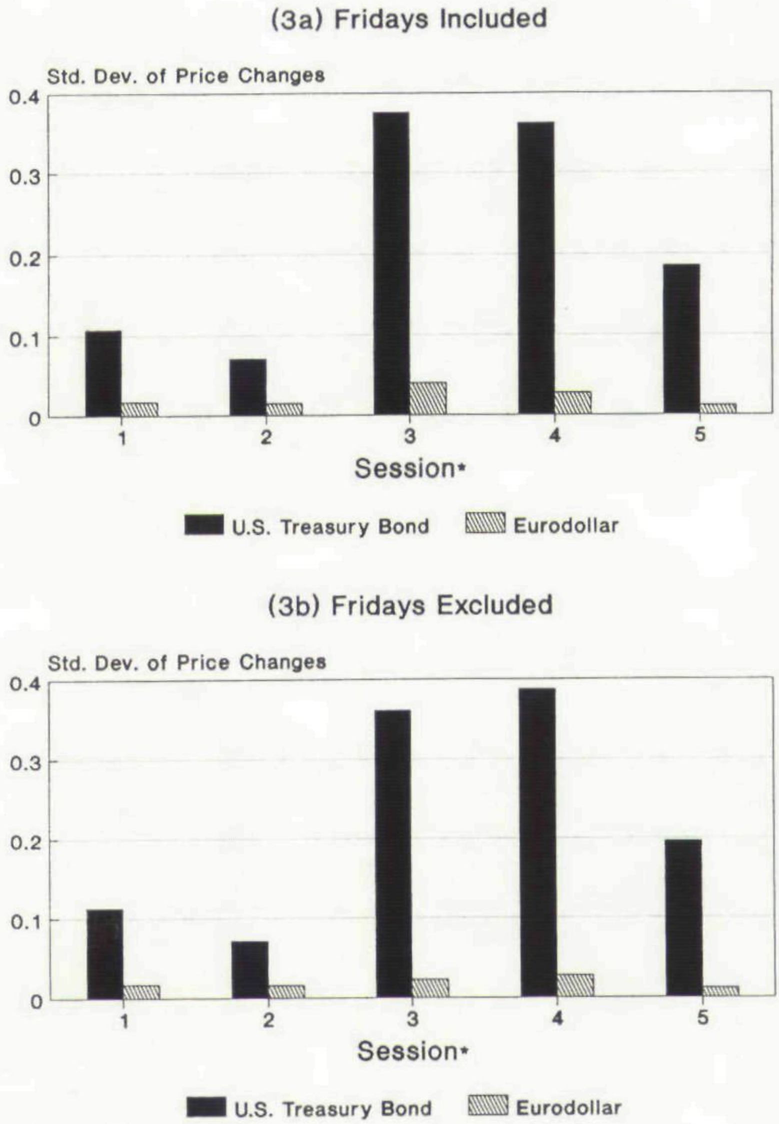

Figure 3

Standard Deviations of Price Changes for U.S. Treasury Bond Futures and Eurodollar Futures. (July, 1988–August, 1988)

*Sessions are as indicated in Table V.

**Due to scaling differences, standard deviations are used in graphs instead of variances.

respectively. For U.S. Treasury Bond futures greatest variances appear in session (4): 10:10 A.M. (LIFFE)–2 P.M. (CBOT) and (3): 2:15 A.M. (LIFFE)–10:10 A.M. (LIFFE) for 1987 and 1988, respectively. Both sessions cover the U.S. trading period. For July and August 1987 and 1988 the next two highest volatility sessions are (1): 6 P.M.–9 P.M. (9:30 P.M.) and (5): 2 P.M. (CBOT)–6 P.M. (CBOT). Session (1) covers the time interval the U.S. futures markets are open and cash markets closed, and session (5) includes the time interval when the U.S. futures markets are closed but the cash markets are open. As expected, the period with the lowest measured risk is session (2): 9 P.M. (9:30 P.M.) (CBOT)–2:15 A.M. (LIFFE) during which the U.S. cash and futures markets are closed. For Eurodollar futures, essentially similar risk patterns to those exhibited by U.S. Treasury Bond futures are observed, and they are reported in Table V(a). For July/August 1987 and 1988 sessions (1): 6:30 P.M. (SIMEX)–2:30 A.M. (LIFFE) and (5): 2 P.M. (CME)–6:30 P.M. (SIMEX) have the lowest variance (Fridays excluded). These are the periods for which the futures market is not open in any international market. The highest reported risk measure for July/August 1987 and 1988 is for session (4): 10 A.M. (LIFFE)–2 P.M. (CME) and session (3): 7:20 A.M. (CME)–10 A.M. (LIFFE), respectively. These two periods cover the period during which the U.S. futures markets are open.

Thus, for both U.S. Treasury Bond and Eurodollar futures, the highest reported variance occurs during the time when the U.S. futures and cash markets are simultaneously open. For U.S. Treasury bond futures, the period in which all markets are closed has the lowest variance. The only difference in the reported pattern of variance between the U.S. Treasury Bond and Eurodollar futures contracts occurs in the two post-April 1987 time periods. The lowest reported variance of the Eurodollar futures prices is for the afternoon period during which the cash market is open but the futures market is closed (session (5)). For U.S. Treasury Bond futures, that period (2 P.M.–6 P.M.) has a greater variance than that existing during the evening hours of the CBOT futures trading (6 P.M.–9:30 P.M.) and the following nontrading period (9:30 P.M.–2:15 A.M.). One reason for this pattern is that the longer maturity U.S. Treasury Bonds are more susceptible than the Eurodollar to information effects that occur during cash market hours (2 P.M.–5:30 P.M.).

Results in Tables III, IV(a), and V(a), however, may be affected by the inclusion of weekend effects.[10] Various studies (Phillips-Patrick and Schneeweis (1988), Ferris and Chance (1987), and French (1984)) have tested for the impact of the return from Friday close to Monday open or close. In general these studies have shown that the weekend data has a greater variance than that of the daily variance; however, not by the magnitude expected if a pure calendar time hypothesis existed.

The effect of removing Friday and weekend effects on reported variances is reported in Tables III, IV(b), and V(b). For U.S. Treasury Bond and Eurodollar futures, (session (4) in Table III and session (5) in Tables IV(b) and V(b) also exclude weekend returns) variances are similar to those when Friday price changes are included. Thus the close of the week has little impact in relative reported variances. There is some evidence, however, of weekend effects; for example, for the period July 1–August 26, 1987 (Tables IV(b) and V(b)), when weekends are removed, the variance for session (5) falls by over 50% for Treasury Bond futures and by about 20% for Eurodollar futures.

Finally, comments can be made on the relative magnitude of the trading/nontrading time variances and on the stationarity of the variances over the three years examined. While the impact of night trading on the CBOT may have increased the trading activity (volatility) during the evening hours, for U.S. Treasury Bond futures the reported variances in Table IV are generally lower than those reported for the 1986 time period. For Eurodollar futures the reported variances between the two periods are similar. In 1986 (Fridays and Weekends included) the average variance over all time periods for Treasury Bond and Eurodollar futures are .252 and .0009, respectively. In 1987 and 1988 the average variance for U.S. Treasury Bond and Eurodollar futures over comparable time periods are .079 and .00068, respectively. Lastly, as shown in the Appendix, the aver-

[10]Other results also show the impact of outlier effects. The reported variance for session (3) for Eurodollar futures in 1988 is about 50% less than those reported when Fridays are included. This differential is due primarily to single outliers in these periods of analysis.

age hourly variance of the trading period (e.g., after normalization on an hourly basis) is approximately 20 times greater than the average hourly variance of the nontrading period for U.S. Treasury Bond futures and 10 times greater than the average hourly variance of the nontrading period for Eurodollar futures.

V. SUMMARY

This article tests the effect of trading and nontrading times on the volatility of the two most actively traded futures contracts: U.S. Treasury Bonds and Eurodollars. Return measures are based on opening and closing prices. As expected, risk measures differed between trading and nontrading times. Several reasons may explain the variance differential between trading and nontrading periods. First, information flows during nontrading hours may be smaller than those generated during a security's principal trading session. A security's risk (e.g., variance) is not a strict function of calendar time but of information arrival and the resulting impact of that information. Thus not only should the risk of holding an asset vary between days but also within each day (Harris (1986)). Other causes of differing variance between trading and nontrading times include liquidity and transaction costs.

Results from this analysis have implications for various trading strategies. If variance is nonstationary during the trading day, then models based on this risk measure must likewise adjust for the changing risk measure. Secondly, while lower reported variances exist during certain subperiods (e.g., when U.S. cash financial markets are closed) these subperiods may be even more susceptible to unusual changes in information. As a result, given the same magnitude of information release, large price changes may be expected to result in those periods for which the reported empirical measures of risk may be found on average to be relatively lower. Lastly, results indicate that the exclusion of even a single date (e.g., Friday) may affect reported variances. Future research is required to determine if these weekend effects are periodic or nonrepeating.

Appendix

VARIANCES OF PRICE CHANGES OVER VARYING TRADING/NONTRADING SESSIONS (NORMALIZED BY HOURS IN SESSION)

Treasury Bond Futures
July 1–August 27, 1886

Session:	(1)	(2)	(3)	(4)
Incl. Fridays σ^2:	.03	.13[a]	.10[a]	.012
Excl. Fridays σ^2:	.03	.12[a]	.11[a]	.012

a: Using standard F-test comparisons, the variances of sessions (2) and (3) are significantly greater than those of sessions (1) and (4) at 5% level.

Trading Sessions
(1) 2:15 A.M.–8 A.M. (Open LIFFE–Open CBOT)
(2) 8 A.M.–10:10 A.M. (Open CBOT–Close LIFFE)
(3) 10:10 A.M.–2 P.M. (Close LIFFE–Close CBOT)
Nontrading Session
(4) 2 P.M.–2:15 A.M. (Close CBOT–Open LIFFE: Next Day)

Eurodollar Futures
July 1–August 27, 1986

Session:	(1)	(2)	(3)	(4)
Incl. Fridays σ^2:	.008	.045[a]	.025[a]	.008
Excl. Fridays σ^2:	.008	.045[a]	.025[a]	.008

a: Using standard F-test comparisons, the variances of sessions (2) and (3) are significantly greater than those of sessions (1) and (4) at 5% level.

Trading Sessions
(1) 2:30 A.M.–7:20 A.M. (Open LIFFE–Open CME)
(2) 7:20 A.M.–10 A.M. (Open CME–Close LIFFE)
(3)10 A.M.–2 P.M. (Close LIFFE–Close CME)
Nontrading Session
(4) 2 P.M.–2:30 A.M. (Close CME–Open LIFFE: Next Day)

*For Eurodollars per hour variances are presented in percentage terms.

Treasury Bond Futures
July 1–August 26, 1987 & 1988
(a) Fridays & Weekends Included

Session:	(1)	(2)	(3)	(4)	(5)
		1987			
σ^2:	.012	.002	.020	.044[a]	.023
		1988			
σ^2:	.003	.001	.018	.034[a]	.009[b]

a: Using standard F-test comparisons, the variance of session (4) is significantly greater than those of sessions (1), (2), and (5) at 5% level.
b: Using standard F-test comparisons, the variance of session (5) is significantly greater than those of sessions (1) and (2) at 5% level.

(b) Fridays & Weekends Excluded

Session:	(1)	(2)	(3)	(4)	(5)
		1987			
σ^2:	.013	.003	.192[a]	.046[a]	.005
		1988			
σ^2:	.004	.001	.016[a]	.039[a]	.010[b]

a: Using standard F-test comparisons, the variances of sessions (3) and (4) are significantly greater than those of sessions (1), (2), and (5) at 5% level.
b: Using standard F-test comparisons, the variance of session (5) is significantly greater than those of sessions (1) and (2) at 5% level.

Trading Sessions
(1) 6 P.M.–9 P.M. (9:30 P.M.) (Open CBOT–Suspend CBOT)
(3) 2:15 A.M.–10:10 A.M. (Open LIFFE–Close LIFFE)
(4) 10:10 A.M.–2 P.M. (Close LIFFE–Close CBOT)
Nontrading Sessions
(2) 9 P.M. (9:30 P.M.)–2:15 A.M. (Suspend CBOT–Previous Day*–Open LIFFE)
(5) 2 P.M.–6 P.M. (Close CBOT–Open CBOT)**

*In session (2) the 9 P.M. price is from the previous day.

**Since Sunday night trading began in September 1987, the 1987 period of analysis does not include Monday trading hours. Thus session (5) is from 2 P.M. of the previous Friday to 6 P.M. Monday night.

Eurodollar Futures
July 1–August 8, 1987 & 1988
(a) Fridays & Weekends Included

Session:	(1)	(2)	(3)	(4)	(5)
		1987			
σ^2:	.005	.008	.045[a]	.038[a]	.010[b]
		1988			
σ^2:	.003	.004	.060[a]	.018[a]	.002

a: Using standard F-test comparisons, the variances of sessions (3) and (4) are significantly greater than those of sessions (1), (2), and (5) at 5% level.
b: Using standard F-test comparisons, the variance of session (5) is significantly greater than those of sessions (1) and (2) at 5% level.

(b) Fridays & Weekends Excluded

Session:	(1)	(2)	(3)	(4)	(5)
		1987			
σ^2:	.005	.008	.045[a]	.038[a]	.009
		1988			
σ^2:	.003	.004	.019[a]	.018[a]	.002

a: Using standard F-test comparisons, variances of sessions (3), and (4) are significantly greater than those of sessions (1), (2), and (5) at 5% level.
Trading Sessions
(1) 6:30 P.M.–2:30 A.M. (Opoen SIMEX–Open LIFFE)
(2) 2:30 A.M.–7:20 A.M. (Open LIFFE–Open CME)
(3) 7:20 A.M.–10 A.M. (Open CME–Close LIFFE)
(4) 10 A.M.–2 P.M. (Close LIFFE–Close CME)
Nontrading Session
(5) 2 P.M.–6:30 P.M. (Close CME*–Open SIMEX)
*Over a weekend, the 2 P.M. price in session (5) is from the previous Friday.

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