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DAY OF THE WEEK EFFECTS ON RETURNS, PRICE VOLATILITIES, AND TRADED VOLUME IN FOREIGN CURRENCY FUTURES

By
Theoharry Grammatikos
European Investment Bank

Abstract

Day-of-the-week effects are documented in five foreign currency futures, the German mark, the Swiss franc, the British pound, the Canadian dollar, and the Japanese yen. Patterns on price volatility and traded volume are detected which are distinct from the pattern on mean returns. In particular, the overnight return from Tuesday's closing to Wednesday's opening is significantly higher than overnight returns in other weekdays while trading returns are the same over different weekdays. On the other hand, there is evidence that the trading volatility of futures prices is lower on Mondays than the other weekdays, and traded volume appears to be highest on Tuesdays and lowest on Fridays.

1. Introduction

A number of authors have documented that asset returns are not constant across days of the week. Early evidence on the so called day-of-the-week effect has been obtained from studies of close-to-close returns in broad market indices (see e.g., French [1980], Gibbons and Hess [1981], and Lakonishok and Levi [1982]). More recently, and in an effort to shed additional light on the phenomenon, authors have analysed firms of different size (Keim [1984], Keim and Stambaugh [1984], Rogalski [1984], and Harris [1986a]), and studied intradaily returns on a stock index (Smirlock and Starks [1984]), and on firm disaggregated data (Harris [1986a]). In all of these studies asset returns on Mondays are found to be significantly lower than returns in other weekdays. Lower Monday returns are found not only in the U.S. stock market but also in returns on treasury bills (Gibbons and Hess [1981]) and orange juice futures (Roll [1984]), while Jaffe

* The author alone is responsible for the opinions expressed in this paper.

and Westerfield [1985] document a different pattern, namely lower Tuesday returns, for the Japanese and Australian stock markets.

Although interesting, the comparison of mean returns over days of the week is not complete because it ignores other trading characteristics such as price (return) volatility and trading volume, which may follow similar daily patterns. Related work by Fama [1965] and more recently by French and Roll [1985] documents that equity returns are more volatile during exchange trading hours than during non-trading hours. Moreover other studies (see e.g. Harris [1986b], and Grammatikos and Saunders [1986] show that price volatility and traded volume are positively correlated. However, no study to date has sought to investigate whether mean returns, price volatility and volume are related in a day-of-the-week fashion. Hence the first objective of this paper to examine the characteristics of asset returns when the markets are open and closed, and to test for day-of-the-week patterns in mean returns, price (return) volatilities and trading volume.

In non-equity markets McFarland, Pettit, and Sung [1982] examine the distributional characteristics and day-of-the[1]week effects on a sample of seven spot and four forward series of foreign exchange price changes. They are able to reject normality for all series examined and find high price changes on Mondays and Wednesdays and low on Thursdays and Fridays. Although Jaffe and Westerfield [1985] also find high Wednesday returns for spot exchange rates, they fail to find high Monday returns. In the only study on futures markets Cornell [1985] finds evidence that the Monday effect does not exist in the SP500 futures although it persists in the underlying spot index. Thus, the second objective of this study is to provide evidence on whether futures on foreign exchange follow similar patterns with those detected in their spot counterparts by previous authors.

The rest of the paper is organised as follows: The second section describes the data and presents distributional characteristics of the returns series. The third section provides evidence on the day-of-the-week effects on futures' returns while similar findings for price volatilities are given in section four. The fifth section presents the results for the traded volume, and finally the last section is a summary and conclusion.

The Data and Distributional Characteristics of Returns

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, and volume traded were obtained from the Commodity Systems, Incorporated (CSI), 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 characterised by relatively high daily volume in order to minimise potential biases to our estimators. At any point in time there are four contracts outstanding with delivery in March, June, September and December. In order to avoid using overlapping observations two series are formed: the first consists of data on the nearby contract (i.e. with maturity between 0 and 3 months), while the second of data on the next-to-nearby contract (i.e., with maturity between 3 and 6 months). Due to space considerations only the results on the nearby contract are reported below as those on the next-to-nearby contract were essentially the same. To control for "delivery complications" those days that fall in the delivery month are omitted[1]. Days in which prices hit the limit are also dropped from the sample. Finally, days following a holiday are dropped from the sample, so that the calculated returns from Tuesday through Friday are one *day* returns while those for Monday are *three day* returns (from the previous Friday to Monday). Daily returns are computed as the natural logarithm of the ratio of successive closing prices. The daily (close to close) returns are then decomposed into trading and non-trading day returns. Trading (close to open) returns are calculated as the natural logarithm of the ratio of the closing price to the opening price while non-trading or overnight (open to close) returns are estimated as the logarithm of the ratio of the opening price to the preceding closing price. Overnight Monday returns are estimated from Monday's opening and (previous) Friday's closing prices. Table I presents some distributional characteristics on the above variables.

The mean daily (close to close) and overnight returns are negative reflecting a general strengthening of the U.S. dollar relative to the five foreign currencies over the sample period. The ratio of variances between trading and non-trading (overnight) returns is 86%, 92%, 144% and 54% respectively for the mark, franc, pound, Canadian dollar and the yen. Since these futures trade for 5 hours per day (currently from 8:30 to 1:30) the *per hour* variance during trading hours is much larger than the *per hour* variance during non-trading hours. Similar evi-

Table I

Summary Statistics of Percent Returns

Foreign Currency	Number of Observat.	Mean	Standard Deviation	Skewness	Kurtosis	K-S Z	P
A. Daily Returns (close to close)							
Mark	1282	-0.034	.615	.058	.874	1.895	.002
Franc	1289	-0.025	.807	.129	.458	1.446	.031
Pound	1295	-0.008	.633	-.106	.918	1.811	.003
Can. Dollar	1306	-0.011	.263	.051	.324	1.011	.259
Yen	1302	-0.107	.739	.246	.360	1.518	.020
B. Overnight Returns (open to previous close)							
Mark	1282	-0.037	.458	-.045	1.402	2.085	.000
Franc	1289	-0.023	.606	-.045	1.308	1.760	.004
Pound	1295	-0.024	.477	.601	9.355	2.408	.000
Can. Dollar	1306	-0.007	.182	.089	1.674	1.270	.080
Yen	1302	-0.014	.591	.141	1.266	1.967	.001
C. Trading Returns (close to open)							
Mark	1282	0.003	.424	.001	1.625	1.900	.001
Franc	1289	-0.002	.582	.142	2.321	1.846	.002
Pound	1295	0.016	.465	-.689	7.787	2.081	.000
Can Dollar	1306	-0.004	.218	.118	1.255	1.408	.038
Yen	1302	-0.003	.434	.323	1.889	1.968	.001

dence for equity returns is provided by Fama [1965], Oldfield and Rogalski [1980], and French and Roll [1985]. French and Roll attribute the larger return volatility when the exchange is open to private information which only affects prices through the trading of informed investors. Nevertheless this argument is less likely to apply in foreign currency markets because informed investors can easily trade in the inter-bank U.S. market or even in foreign markets after IMM's closing (at 1:30)[2]. Due to the time-zone differences between the U.S. and foreign markets, U.S. opening prices should incorporate all or essentially all private information generated overnight.

Previous studies by Stevenson and Bear [1970], Dusak [1973], McFarland, Pettit and Sung [1982], and Helms and Martell [1984] among others reject the hypothesis that commodity price changes are normally distributed. Normality is tested for our return series using the Kolmogorov-Smirnov non-parametric goodness of fit test. The last two columns in Table I present respectively the Kolmogorov-Smirnov Z's and their associated p-values. With the exception of the daily (close to close) and overnight returns for the Canadian dollar normality is rejected for all the other cases at the 5% level. This observation prompts the use of non-parametric tests in the examination of day-of-the-week effects instead of parametric tests applied by previous authors.

To test whether trading and overnight returns are identically distributed the Wilcoxon matched-pairs signed-ranks test is applied. This non-parametric test analyses the differences between the paired observations, also taking into account the magnitude of the differences.

Table II

Tests on Whether Trading and Overnight Returns are Identically Distributed

Foreign Currency	Wilcoxon Z	p
Mark	-2.264	.024
Franc	-0.811	.417
Pound	-2.478	.013
Can. Dollar	-0.821	.412
Yen	-0.491	.623

As seen in Table II the results are mixed. The hypothesis that the trading and overnight returns are identically distributed is rejected for the mark and the pound but accepted for the franc, Canadian dollar and the yen.

Finally, estimated correlation coefficients are computed between trading and overnight returns for the five currencies. Four of the correlation coefficients are negative with those for the franc (-.077), pound (-.097), and Canadian dollar (-.145) being statistically significant at the 5% level. Thus, there is some evidence of serial dependence between trading and overnight returns.

The Day-of-the-Week Effects on Futures' Returns

Table III displays the mean and standard deviation of the various returns for each day of the week. No clear pattern is evident for the daily (close to close) or the trading (open to close) returns for the five foreign currency futures examined.

Table III

Average Percent Returns Over Days of the Week[a]

Foreign Currency	Monday	Tuesday	Wednes.	Thursday	Friday	K-W Chi-Square	p
A. Daily Returns (close to close)							
Mark	-.086	-.002	.035	-.102	-.018	9.460	.051
	(.692)	(.598)	(.577)	(.605)	(.594)		
Franc	-.067	-.045	.108	-.118	-.009	12.745	.013
	(.922)	(.741)	(.735)	(.827)	(.791)		
Pound	-.014	.011	.065	-.044	-.059	5.982	.201
	(.701)	(.606)	(.611)	(.625)	(.617)		
Can Dollar	-.051	-.007	-.010	.007	.001	6.994	.136
	(.288)	(.260)	(.241)	(.257)	(.267)		
Yen	-.002	.083	-.010	-.108	-.042	10.033	.033
	(.833)	(.729)	(.720)	(.687)	(.720)		
B. Overnight Returns (open to previous close)							
Mark	-.059	-.033	.034	-.081	-.048	14.843	.005
	(.576)	(.455)	(.418)	(.405)	(.420)		
Franc	-.047	-.021	.103	-.120	-.034	23.455	.000
	(.751)	(.598)	(.571)	(.533)	(.544)		
Pound	.005	-.023	.042	-.070	-.075	12.019	.017
	(.654)	(.409)	(.418)	(.463)	(.398)		
Can. Dollar	-.024	-.021	.007	-.014	.012	9.072	.059
	(.184)	(.180)	(.165)	(.189)	(.191)		

Yen	.012	.054	.031	-.081	-.082	14.644	.006
	(.700)	(.582)	(.596)	(.532)	(.527)		
C. Trading Returns (close to open)							
Mark	-.027	.032	.001	-.021	.031	5.031	.284
	(.456)	(.426)	(.429)	(.423)	(.386)		
Franc	-.020	-.024	.005	.002	.025	1.944	.746
	(.612)	(.582)	(.549)	(.611)	(.558)		
Pound	-.019	.033	.023	.025	.016	0.295	.990
	(.564)	(.443)	(.426)	(.447)	(.439)		
Can. Dollar	-.027	.013	-.107	.021	-.011	9.340	.053
	(.230)	(.218)	(.221)	(.208)	(.210)		
Yen	-.014	.028	-.041	-.027	.040	6.500	.165
	(.465)	(.440)	(.396)	(.432)	(.436)		

[a] Standard deviations in parenthesis.

However, the overnight (close to open) Wednesday returns are uniformly positive while the overnight Thursday returns are negative for all five currencies. The last two columns present a test of equality in the mean returns over the different days of the week. The test is the non-parametric Kruskal-Wallis one-way ANOVA. The Chi-square and its associated p-values are given in columns (6) and (7)[3]. The test rejects the null hypothesis at the 5% level for the daily returns (close to close) of the franc and the yen, and for the overnight returns of the mark, the franc, the pound and the yen. The hypothesis is accepted for the trading returns of all foreign currencies. Thus, consistent with Rogalski [1984], the evidence shows that the day-of-the-week patterns in mean daily returns are generated by the overnight rather than trading returns.

Table IV presents the results of the Mann-Whitney U test of equality between the returns over each pair of weekdays. Overall for the daily and overnight returns there are statistically significant differences between Wednesdays and Thursdays and Fridays. The higher Wednesday returns found in this study are consistent with similar findings on spot foreign exchange rates by McFarland, Pettit and Sung [1982], and Jaffe and Westerfield [1985] who attribute this phenomenon to the settlement procedures existing in spot foreign exchange

Table IV

Mann-Whitney U Tests on Average Percent Returns[a]

Foreign Currensy	Monday	Tuesday	Wednesday	Thursday
A. Daily Returns (close to close)				
Mark	T W* Th F	W Th F	Th* F	F
Franc	T W* Th F	W* Th F	Th** F*	F
Pound	T W Th F	W Th F	Th* F*	F
Can. Dollar	T W Th* F*	W Th F	Th F	F
Yen	T W Th F	W* Th** F*	Th F	F
B. Overnight Returns (open to previous close)				
Mark	T W* Th F	W Th F	Th* F*	F
Franc	T W* Th F	W* Th* F	Th** F**	F
Pound	T W Th F	W Th F	Th** F**	F
Can. Dollar	T W* Th F*	W* Th F*	Th F	F
Yen	T W Th F*	W Th** F**	Th* F*	F
C. Trading Returns (close to open)				
Mark	T W Th F	W Th F	Th F	F
Franc	T W Th F	W Th F	Th F	F
Pound	T W Th F	W Th F	Th F	F
Can. Dollar	T* W Th* F	W Th F	Th* F	F
Yen	T W Th F	W* Th F	Th F	F

[a] * significant at the 5% level

** significant at the 1% level

markets (see also Levi [1978]). Interestingly, the Canadian dollar does not show any day-of-the-week patterns, also consistent with both of the previous studies. Thus, contrary to Cornell [1985], it is found that futures markets exhibit similar daily patterns with their underlying spots.

4. The Day-of-the-Week Effect on Future's Volatilities

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

$$s_0^2 = (C_t - C_{t-1})^2.$$

The major problem with this estimator is that it ignores other readily available information that may contribute to estimator efficiency. Moreover, it may be biased on Mondays since the previous closing price refers to the previous Friday, and thus the estimator captures the volatility over a three rather than a one day period.

Recently 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. Given that (as seen in Table II) for three out of the five currencies examined (franc, Canadian dollar and yen) there is evidence that the trading and overnight returns are drawn from the same underlying distribution, it seems plausible to apply the Garman and Klass estimators to our data.

One of the Garman and Klass estimators derived from daily high (H), low (L), closing (C), and opening (O) prices is:

$$s_1^2 = .511\,(u - d)^2 - .019\,[c\,(u + d) - 2ud] - .383c^2,$$

where

$$u = H_t - O_t = \text{high - open},$$

$$d = L_t - O_t = \text{low - open},$$

$$c = C_t - O_t = \text{close - open}.$$

Garman and Klass show that s_1^2 has an efficiency of 7.4 in comparison to s_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 s_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. Hence the classical

and the Garman and Klass estimators are calculated for each day and so and si, the standard deviations of so and s? are used for further analysis.

Table V presents the mean (and standard deviation) of the two volatility estimators over different days of the week. Columns (6) and (7) show the Chi-square and the p-values of the non-parametric Kruskall-Wallis test of equality across days of the week. Table VI displays the results of the Mann-Whitney U test of equality between the volatilities of each pair of week days.

Table V

Price Volatility Over Days of the Week[a]

Foreign Currency	Monday	Tuesday	Wednes.	Thursday	Friday	K - W Chi-Square	p
A. Classical Volatility Estimator							
Mark	.519	.447	.429	.464	.445	4.937	.294
	(.465)	(.397)	(.387)	(.400)	(.394)		
Franc	.729	.562	.568	.655	.604	16.581	.002
	(.566)	(.484)	(.477)	(.517)	(.510)		
Pound	.547	.456	.454	.461	.458	9.915	.042
	(.437)	(.394)	(.414)	(.423)	(.416)		
Can. Dollar	.225	.204	.192	.203	.200	3.108	.540
	(.187)	(.161)	(.145)	(.158)	(.176)		
Yen	.649	.576	.534	.545	.563	8.249	.083
	(.521)	(.453)	(.482)	(.431)	(.449)		
B. Garman and Klass Volatility Estimator							
Mark	.389	.417	.419	.407	.423	5.394	.249
	(.229)	(.229)	(.234)	(.219)	(.231)		
Franc	.490	.549	.532	.510	.549	11.435	.022
	(.271)	(.263)	(.287)	(.295)	(.276)		
Pound	.413	.458	.422	.433	.452	6.445	.168
	(.231)	(.239)	(.218)	(.226)	(.256)		

Can. Dollar	.201	.218	.217	.215	.211	6.402	.171
	(.094)	(.100)	(.100)	(.096)	(.091)		
Yen	.386	.414	.410	.431	.450	11.782	.019
	(.195)	(.201)	(.199)	(.209)	(.258)		

[a] Standard deviations in parenthesis.

Table VI

Mann-Whitney U Tests on Price Volatility[a]

Foreign Currency	Monday	Tuesday	Wednesday	Thursday
A. Classical Volatility Estimator				
Mark	T W* Th F	W Th* F	Th F	F
Franc	T** W** Th F**	W Th* F	Th F	F
Pound	T* W** Th** F*	W Th F	Th F	F
Can. Dollar	T W Th F	W Th F	Th F	F
Yen	T W** Th* F	W Th F	Th F	F
B. Garman and Klass Volatility Estimator				
Mark	T W Th F*	W Th F	Th F	F
Franc	T** W* Th F**	W Th F	Th F	F
Pound	T* W Th F	W Th F	Th F	F
Can. Dollar	T* W* Th* F	W Th F	Th F	F
Yen	T W Th** F**	W Th F	Th F	F

[a] * Significant at the 5% level
** Significant at the 1% level

As seen in panel A, Table V, for all currencies the classical volatility estimator appears to be larger on Mondays than the rest of the weekdays and the evidence is statistically significant for the franc, the pound, and the yen (see Table VI). Nevertheless, Monday's variance is far from being three times as large as that of the rest of the weekdays as might be expected since it is estimated over a three day period.

The Garman and Klass volatility estimator is a better indicator of the "true" daily trading volatility on Mondays because it is calculated from values observed on Monday. As seen in panel B, Table V, the Garman and Klass estimator is uniformly lower on Mondays than the rest of the weekdays. The hypothesis if equality across the different days is rejected for the franc and the yen while the Mann-Whitney U test (see Table VI) reveals many statistically significant differences between the volatility on Monday and the volatility on each of the other weekdays[4]. Thus Monday's *trading* volatility appears to be lower than the trading volatility of the rest of the weekdays.

5. The Day-of-the-Week Effect on Traded Volume

Table VII, panel A, displays the mean and standard deviation of the traded volume over the different days of the week. For all currencies examined traded volume is highest on Tuesdays and lowest on Fridays. For example, the Tuesday (Friday) volume is 12%, 16%, 15%, 15% and 14% (10%, 13%, 15%, 13% and 11%) higher (lower) than the average of the four remaining weekdays for the mark, frank, pound, Canadian dollar and yen respectively. Because of large variability in the daily traded volume, the Kruskall-Wallis test does not reject the hypothesis of equality in traded volume across the different weekdays. The Mann-Whitney U test (see Table VII, panel B), however, reveals that for all currencies examined traded volume is significantly higher on Tuesdays than on Fridays[5]. The high volume on Tuesday may indicate an appropriate positioning by some traders in view of the expected higher overnight returns from Tuesday's closing to the opening on Wednesday.

6. Summary and Conclusions

Day-of-the-week effects are documented in five foreign currency futures, the German mark, the Swiss franc, the British pound, the Canadian dollar and the Japanese yen. The overnight return from Tuesday's closing to Wednesday's opening is significantly higher than overnight returns in other weekdays while trading returns are the same over different weekdays. Moreover, there is evi-

Table VII

Traded Volume Over Days of the Week

Foreign Currency	Monday	Tuesday	Wedns.	Thursday	Friday	K - W Chi-Square	p
A. Mean Daily Volume and Kruskal-Wallis Tests[a]							
Mark	3455	3765	3609	3553	3226	4.002	.406
	(2789)	(2904)	(2973)	(2899)	(2590)		
Franc	3755	4125	3855	3846	3468	5.250	.263
	(3538)	(3694)	(3570)	(3612)	(3329)		
Pound	3141	3340	3179	3096	2864	6.591	.159
	(2496)	(2499)	(2421)	(2507)	(2463)		
Can. Dollar	1623	1894	1729	1707	1569	4.446	.349
	(1403)	(1772)	(1661)	(1631)	(1402)		
Yen	2698	2946	2791	2667	2447	4.509	.342
	(2630)	(2764)	(2793)	(2647)	(2407)		

B. Mann-Whitney U Tests on Traded Volume[b]

Foreign Currency	Monday	Tuesday	Wednesday	Thursday
Mark	T W Th F	W Th F*	Th F	F
Franc	T W Th F	W Th F*	Th F	F
Pound	T W Th F	W Th F*	Th F	F
Can Dollar	T W Th F	W Th F*	Th F	F
Yen	T W Th F	W Th F*	Th F	F

[a] Standard deviations in parenthesis.

[b] * Significant at the 5% level.

dence that the trading volatility of futures prices is lower on Mondays than the other weekdays. Finally, traded volume appears to be highest on Tuesdays and lowest on Fridays. The high Tuesday volume may indicate positioning by traders to capture the positive overnight return after Tuesday's closing.

Surprisingly the low Monday volatility and low Friday volume are distinct from the pattern in mean returns and a connection among them is not apparent. Nevertheless, the study indicates that searching for patterns in volatilities and traded volume in equity and other asset markets may be a fruitful area for further research.

Footnotes

1. To avoid delivery, traders close their positions before maturity through reverse transactions. However, because most of the reverse transactions take place in the last trading days, they may have a disproportionate effect on the futures' trading characteristics.

2. The foreign exchange market is a global market and most of the transactions take place abroad. Recent studies show that the daily volume of foreign exchange trading in the Tokyo, London and New York markets has reached $48, $90, and $50 billion respectively (see the *Wall Street Journal* 8.20.86, p. 18).

3. An additional parametric test is also performed. The test is a regression model of the following form:

$$\text{Return},= b_0+bi\ \text{Trend} + b_2\ \text{Maturity} + b_3Di + b_4D_2 + b_5D_3 + b_6D_4 + E,$$

where Di, D_2, D3 and D4 are dummy variables that take the value of 1 respectively for Mondays, Tuesdays, Wednesdays and Thursdays. According to this representation the intercept captures the effect of each day over Friday. The Trend variable, the Maturity variable and the Monday, Tuesday and Thursday variables are generally insignificant. On the other hand, with the exception of the Canadian dollar, the Wednesday dummy is significantly positive (at the 5% level) for the overnight returns.

4. A regression model is also estimated (see footnote 3). The trend variable is significantly positive (at the 5% level) for all currencies, while the Monday dummy is significant for the mark, franc, pound and the yen.

5. A regression model is also estimated (see footnote 3). The trend variable and the Tuesday dummy are significantly positive (at the 5% level) for all currencies, while the rest of the variables are insignificant.

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