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The day of the week effect on stock market volatility and volume: International evidence

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Abstract

This study investigates the day of the week effect on the volatility of major stock market indexes for the period of 1988 through 2002. Using a conditional variance framework, we find that the day of the week effect is present in both return and volatility equations. The highest volatility occurs on Mondays for Germany and Japan, on Fridays for Canada and the United States, and on Thursdays for the United Kingdom. For most of the markets, the days with the highest volatility also coincide with that market's lowest trading volume. Thus, this paper supports the argument made by Foster and Viswanathan [Rev. Financ. Stud. 3 (1990) 593] that high volatility would be accompanied by low trading volume because of the unwillingness of liquidity traders to trade in periods of high stock market volatility.

JEL classification: G10; G12; C22
Keywords: Day of the week effect; Volatility; GARCH; Volume

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1. Introduction

Calendar anomalies (weekend effect, day of the week effect, and January effect) in stock market returns has been widely studied and documented in finance literature. These investigations have covered equity, foreign exchange, and the T-bill markets. Studies by Cross (1973), French (1980), Gibbons and Hess (1981), Keim and Stambaugh (1984), Lakonishok and Levi (1982), and Rogalski (1984) demonstrate that there are differences in distribution of stock returns for each day of the week.

Other researchers have investigated the time series behavior of stock prices in terms of volatility by using generalized autoregressive conditional heteroskedasticity (GARCH) models.[1] For example, French et al. report that unexpected stock market returns are negatively related to the unexpected changes in volatility. Campbell and Hentschel (1992) argue that an increase in stock market volatility raises the required rate of return on common stocks and hence lowers stock prices. These studies generally report that returns in stock markets are time varying and conditionally heteroskedastic. None of these studies, however, test for the possible existence of day of the week variation in volatility.

For a rational financial decision maker, returns constitute only one part of the decision-making process. Another part that must be taken into account when one makes investment decisions is the risk or volatility of returns. It is important to know whether there are variations in volatility of stock returns by the day of the week and whether a high (low) return is associated with a correspondingly high (low) volatility for a given day. If investors can identify a certain pattern in volatility, then it would be easier to make investment decisions based on both return and risk. For example, Engle (1993) argues that investors who dislike risk may adjust their portfolios by reducing their investments in assets whose volatility is expected to increase. Uncovering certain volatility patterns in returns might also benefit investors in valuation, portfolio optimization, option pricing, and risk management.

This study investigates the day of the week effect in stock market volatility and volume using the major stock market indexes of Canada, Germany, Japan, the United Kingdom, and the United States. This paper also examines whether the observed volatilities on various days of the week are related to trading volume, indirectly testing the Admati and Pfleiderer (1988) and Foster and Viswanathan (1990) models. Empirical findings show that the day of the week effect is present in both the return and the volatility equations. We observe the highest volatility of returns on Mondays for Germany and Japan, on Fridays for Canada and the United States, and on Thursdays for the United Kingdom. The lowest volatility of returns occurs on Mondays for Canada, Tuesdays for Germany, Japan, the United Kingdom, and the United States. The lower trading volumes occur on Mondays and Fridays for Japan, the United Kingdom, and the United States, and the highest trading volume occurs on Tuesdays for each market. The findings support the Foster and Viswanathan argument that the high volatility would be accompanied with low trading volume due to unwillingness of liquidity traders to trade in periods where the prices are more volatile.

[1] Among these studies are Akgiray (1989), Campbell and Hentschel (1992), French, Schwert, and Stambaugh (1987), Glosten, Jagannathan, and Runkle (1993), and Hamao, Masulis, and Ng (1990).

2. Literature review

The presence of the day of the week effect in stock market returns has been widely documented in the finance literature. Cross (1973), French (1980), Gibbons and Hess (1981), Keim and Stambaugh (1984), Lakonishok and Levi (1982), and Rogalski (1984) demonstrate day of the week patterns in stock returns. For example, average returns on Mondays are significantly less than average returns during the other days of the week. The studies of calendar anomalies are not limited to the U.S. equity markets. Numerous researchers have investigated equity, fixed income, and derivative markets both here and abroad. For example, Aggarwal and Rivoli (1989), Athanassakos and Robinson (1994), Chang, Pinegar, and Ravichandran (1993), Dubois (1986), Kato and Schallheim (1985), Jaffe and Westerfield (1985a, 1985b), and Solnik and Bousquet (1990) show that the distribution of foreign stock returns varies by day of the week, and Corhay, Fatemi, and Rad (1995), Flannary and Protopapadakis (1988), Gay and Kim (1987), and Gesser and Poncet (1997) indicate that return distribution of futures and foreign exchange markets also varies by day of the week.

While the focus of the above studies has been on the patterns in mean returns, other studies have investigated the time series behavior of stock prices in terms of volatility by using variations of GARCH models. French et al. (1987) examine the relationship between stock prices and volatility and report that unexpected stock market returns are negatively related to the unexpected changes in volatility. Campbell and Hentschel (1992) report similar results and argue that an increase in stock market volatility raises the required rate of return on common stocks and hence lowers stock prices. Glosten et al. (1993) and Nelson (1991), on the other hand, report that positive unanticipated returns reduce conditional volatility whereas negative unanticipated returns increase conditional volatility. Baillie and DeGennaro (1990) find no evidence of a relationship between portfolio mean returns and variance. These findings are further supported by Chan, Karolyi, and Stulz (1992), who report a significant foreign influence on the time-varying risk premium for U.S. stocks but find no significant relationship between the conditional expected excess return on the S&P 500 and its conditional variance. Corhay and Rad (1994) and Theodossiou and Lee (1993) find no significant relationship between stock market volatility and expected returns for major European stock markets. Most of the studies referenced above report that the expected returns in stock markets are time varying and conditionally heteroskedastic.[2]

Another stream of research has investigated temporal patterns in volatility of asset pricing. The question of why asset prices fluctuate has been investigated on two fronts. The first one is that volatility is mainly caused by the arrival of public information (i.e., macroeconomic news) while the second front ties the arrival of private information to volatility. French and Roll (1986) point out that asset prices are more volatile during trading hours than nontrading hours and variances for the days following an exchange holiday are larger than for other days.

[2] Hence, the use of the class of GARCH models is appropriate for this study.

They hypothesize that more public information arrives during normal business hours and that informed traders are more likely to trade when the exchanges are open. Harvey and Huang (1991) observe higher volatility in interest rates and foreign exchange futures markets during the first few trading hours on Thursdays and Fridays. They interpret their results as evidence of more public information (i.e., macroeconomic data announcements) arriving on Thursdays and Fridays.[3]

Admati and Pfleiderer (1988) and Foster and Viswanathan (1990) develop models to explain time-dependent patterns in security trading caused by the arrival of private information. Both studies demonstrate how information is incorporated into pricing and how various groups of investors influence prices. Specifically, both Admati and Pfleiderer and Foster and Viswanathan take into account the roles of liquidity and informed traders in explaining variations in volume and volatility. Accordingly, traders would try to minimize their trading costs and therefore trade when the trading costs are lower (or liquidity is higher). The difference between the Admati and Pfleiderer and Foster and Viswanathan models lies in the assumption about the trading patterns of informed and liquidity traders. While the Admati and Pfleiderer model predicts that both informed and liquidity traders trade together, the Foster and Viswanathan model predicts that private information is short lived and liquidity traders avoid trading with informed traders. The implications of these two models are as follows: Foster and Viswanathan suggest that liquidity traders avoid trading with informed traders when private information is intense. The resulting volume would be low and this would imply low volume comes with high volatility. Admati and Pfleiderer speculate that trading volume would be high when price volatility is high.

Following these theoretical models, Foster and Viswanathan (1993) find that for actively traded firms, trading volume, adverse selection cost, and return volatility are higher in the first-half hour of trading day. Furthermore, they find higher trading costs and lower trading volume on Mondays. Similarly Chang, Pinegar, and Schachter (1997) observe U-shaped volatility patterns across weekdays in selected commodity futures markets and find that return variance is the highest while volume is the lowest on Mondays, supporting Foster and Viswanathan's (1990) model. Recently, Wei and Zee (1998) find higher volatility on Fridays and lower volume on both Mondays and Fridays in their study of the currency futures markets, providing partial support to the Foster and Viswanathan (1990) argument. Berument and Kiymaz (2001) use the S&P 500 index data and document that there are differences in stock market volatility across the days of the week, with the highest volatility observed on Fridays.

This study investigates the day of the week effect in stock market volatility and volume using the major stock market indexes of Canada, Germany, Japan, the United Kingdom, and the United States. Previous studies have not investigated day of the week effect in stock market volatility internationally using a conditional variance framework. This paper also investigates whether the observed return volatilities on various days of the week are related to

[3] Harvey and Huang also consider the possibility that volatility may be induced by the concentration of trading by investors with private information. Since the private information traders have access to FX markets almost 24 hours a day, they argue that volatility increases are mostly induced by the release of macroeconomic information.

trading volume, indirectly testing the Admati and Pfleiderer (1988) and Foster and Viswanathan (1990) models.

3. Data and methodology

The data consist of the daily prices of TSE-Composite (Canada), DAX (Germany), Nikkei-225 (Japan), FT-100 (UK), and NYSE-Composite (NYSE) indexes from January 1, 1988, to June 28, 2002. Returns in each market (R_t) are expressed in local currencies and are calculated as the first differences in the natural logarithms of the stock market indexes.

$$R_t = [\log(P_t) - \log(P_{t-1})] \tag{1}$$

where P_t is the price level of an index at time t.

Most studies investigating the day of the week effect in returns employ the standard OLS methodology by regressing returns on five daily dummy variables. The use of this methodology, however, has two drawbacks. First, errors in the model may be autocorrelated resulting in misleading inferences. The second drawback is that error variances may not be constant over time. To address the autocorrelation problem, we can include lagged values of the return variable in the equation. In such a model, returns have the following stochastic process:

$$R_t = \alpha_0 + \alpha_{\mathrm{M}}\mathrm{M}_t + \alpha_{\mathrm{T}}\mathrm{T}_t + \alpha_{\mathrm{H}}\mathrm{H}_t + \alpha_{\mathrm{F}}\mathrm{F}_t + \sum_{I=i}^{n} \alpha_i R_{t-i} + \varepsilon_t \tag{2}$$

where R_t represents returns on a selected index, M_t, T_t, $\mathrm{H}_{t,}$, and F_t are the dummy variables for Monday, Tuesday, Thursday, and Friday at time t, and n is the lag order.[4]

To address the second drawback, we allow variances of errors to be time dependent to include a conditional heteroskedasticity that captures time variation of variance in stock returns.[5] Thus, error terms now have a mean of zero and a time changing variance of $h_t^2[\varepsilon_t \sim (0,h_t^2)]$.

There are different types of modeling for conditional variances suggested in the literature. A model, developed by Engle (1982), allows the forecasted variances of return to change with the squared lagged values of the error terms from the previous periods ($h_t = V_c + \sum_{j=1}^{q} V_j \varepsilon_{t-j}^2$). This is known as the autoregressive conditional heteroskedastic model (q) [ARCH (q)]. The

[4] One way to determine n is to use the final prediction error criteria (FPEC) that determines n such that it eliminates autocorrelation in the residual term. If the residuals were autocorrelated, ARCH-LM tests would suggest the presence of heteroskedasticity in the residual term even if the residuals were homoskedastic (see Cosimano and Jansen, 1988). We exclude Wednesday's dummy variable from the equation to avoid the dummy variable trap.

[5] The GARCH model proposed initially by Engle (1982) and further developed by Bollerslev (1986) has been extensively used in analyzing the behavior of the time series over time. Various types of ARCH specifications are used in the literature. Bollerslev, Chou, and Kroner (1992) offer an extensive survey of these studies.

generalized version of ARCH (q) is suggested by Bollerslev (1986) and makes the conditional variance a function of lagged values of both h_t^2 and ε_t^2.

$$h_t = V_c + \sum_{j=1}^{q} V_{ja}\varepsilon_{t-j}^2 + \sum_{j=1}^{p} V_{jb}h_{t-j}^2 \tag{3}$$

This specification is known as GARCH (p,q) modeling.[6] It is possible that the conditional variance, as proxy for risk, can affect stock market returns. We consider various models to investigate the day of the week effect in both return and volatility equations. Our first model consists of the following two equations:

$$R_t = \alpha_0 + \alpha_M M_t + \alpha_T T_t + \alpha_H H_t + \alpha_F F_t + \sum_{I=1}^{n} \alpha_i R_{t-i} + \lambda h_t + \varepsilon_t \tag{2$'$}$$

$$h_t^2 = V_c + V_{1a}\varepsilon_{t-1}^2 + V_{1b}h_{t-1}^2 \tag{3$'$}$$

where λ is a measure of the risk premium. If λ is positive, then risk averse agents must be compensated to accept higher risk. Here, we take into account the possibility that the lagged values of the squared residuals and the conditional variances might be too restrictive.

Some of the studies in the literature also suggest the inclusion of some exogenous variables into the GARCH specification. For example, Karolyi (1995) includes the volatility of foreign stock returns to explain the conditional variance of home country stock returns. Hsieh (1988) includes the day of the week effect in volatility for various exchange rates. Following Hsieh and Karolyi, we model the conditional variability of stock returns by incorporating the day of the week effect into our volatility equation. Thus, we allow the constant term of the conditional variance equation to vary for each day. Therefore, our second model is specified as follows:

$$R_t = \alpha_0 + \alpha_M M_t + \alpha_T T_t + \alpha_H H_t + \alpha_F F_t + \sum_{I=1}^{n} \alpha_i R_{t-i} + \lambda h_t + \varepsilon_t \tag{2$'$}$$

$$h_t^2 = V_c + V_M M_t + V_T T_t + V_H H_t + V_F F_t + V_{j1}\varepsilon_{t-1}^2 + V_{1b}h_{t-1}^2 \tag{4$'$}$$

Here we use the quasi-maximum likelihood estimation (QMLE) method introduced by Bollerslev and Wooldridge (1992) to estimate parameters.[7]

[6] This specification requires that $\sum_{j=1}^{q} V_{ja}+\sum_{j=1}^{p} V_{jb}<1$ in order to satisfy the nonexplosiveness of the conditional variances. Furthermore, each of V_c, V_{jb}, and V_{ja} has to be positive in order to satisfy the nonnegativity of conditional variances for each given time t.

[7] Pagan (1984) argues that the use of a stochastic regressor gives biased estimates. Furthermore, Pagan and Ullah (1988) suggest the use of the full information maximum likelihood estimation (MLE) technique to estimate the system of equations to avoid bias. Bollerslev and Wooldridge (1992), on the other hand, question the assumption concerning the normality of the standardized conditional errors (ε_t/h_t) and argue that this assumption may cause misspecification of the likelihood function. Bollerslev and Wooldridge suggest the use of the QMLE method to avoid the misspecification problem. They formally show that QMLE is generally consistent and has a limited distribution. Following their discussion, we use QMLE method in our estimation.

In summary, we employ two different types of specifications for the return and volatility equations. The first one investigates the day of the week effect for only the return equation by using the GARCH (1,1) specification. The second model incorporates the day of the week effect for both the return and volatility equations by using the Modified-GARCH (1,1) specification.[8]

4. Empirical results

Table 1 reports the descriptive statistics for returns and volumes for each of the markets. The first column of Table 1 reports the daily mean, standard deviation, skewness, and kurtosis measures for the entire sample for each market. The second through sixth columns of Table 1 show the same measures for each day of the week.

An examination of the characteristics displayed in Table 1 shows that, overall, average daily returns are positive for Canada (0.00036), Germany (0.00015), the United Kingdom (0.00012), and the United States (0.00016) and negative for Japan (−0.00031). The lowest returns are observed on Tuesdays for Japan (−0.02411), on Wednesdays for Canada (−0.03841), the United Kingdom (−0.01888), and the United States (−0.01607), and on Fridays for Germany (−0.02238). The highest returns occur on Tuesdays for the United States (0.02388), on Wednesdays for Japan (0.02195), on Thursdays for Germany (0.01962) and the United Kingdom (0.02974), and on Fridays for Canada (0.02627). Panel A also reports skewness and excess kurtosis for the return series of each market. All sample distributions are negatively skewed, indicating that they are nonsymmetric. Furthermore, they all exhibit high levels of kurtosis, indicating that these distributions have thicker tails than normal distributions. These initial findings show that daily returns are not normally distributed; they are leptokurtic and skewed. We use Bartlett's test (not reported) to see whether the constancy of the variances can be rejected. We reject the null hypothesis that the variances are the same across different days of the week.

Panel B of Table 1 summarizes the descriptive statistics on volumes.[9] Average volumes are consistently lower on Mondays. The highest volumes are observed on Wednesdays for the United States and on Thursdays for Canada and the United Kingdom. Moreover, excess skewness and kurtosis are present on each day of the week for all markets.

[8] One disadvantage of modeling the conditional variance as a GARCH (1,1) with day of the week dummies is the possibility of being too restrictive. In order to assess the conditional variance better, we included additional terms in the conditional variance equation. Specifically, we included (a) additional lag values for the ARCH term, [GARCH (1,2)], (b) additional lag values for the GARCH coefficient [GARCH (2,1)], and (c) threshold GARCH (1,1) values for the innovation effect. T-GARCH modeling allows us to differentiate good news (increases stock prices) from bad news (decreases stock prices). Such an effect on volatility will be determined by γ being different from zero. The results for Japan, the United Kingdom, and the United States indicate the presence of the innovation effect as modeled by T-GARCH. These results are robust with our previous findings and these findings are not tabulated and reported.

[9] We are able to obtain volume data for Canada, U.K., and U.S. markets and volume analysis is limited to these three markets.

Table 1
Summary statistics

	All days (1)	Monday (2)	Tuesday (3)	Wednesday (4)	Thursday (5)	Friday (6)
Panel A: Returns						
Canada						
Mean	0.00036	0.00274	0.02065	−0.03842	−0.00853	0.02627
S.D.	0.61212	0.59909	0.63018	0.61340	0.64972	0.61951
Skewness	−0.05402	−0.05598	0.01321	−0.14822	−0.25882	0.21288
Kurtosis	1.75185	1.50293	1.35572	1.49027	1.54715	1.98045
Germany						
Mean	0.00015	0.01029	−0.01680	0.01000	0.01962	−0.02238
S.D.	0.59824	0.58861	0.60177	0.60196	0.55433	0.58441
Skewness	−0.08769	−0.06011	−0.33699	0.11168	0.15665	−0.26807
Kurtosis	1.81980	2.21441	2.34358	1.95357	1.62339	1.74210
Japan						
Mean	−0.00031	−0.00439	−0.02410	0.02195	−0.01392	0.01898
S.D.	0.73891	0.66842	0.73966	0.74599	0.72390	0.71206
Skewness	−0.03430	−0.09864	0.92273	−1.34192	0.50697	0.78032
Kurtosis	7.934	6.318	17.074	4.483	5.178	6.945
United Kingdom						
Mean	0.00012	−0.00983	0.00221	−0.01888	0.02974	−0.00266
S.D.	0.60660	0.56984	0.60360	0.62215	0.61413	0.62219
Skewness	0.00667	0.05442	−0.06383	0.03149	0.01412	−0.00067
Kurtosis	1.70740	1.94075	1.52989	2.05611	1.43811	1.60797
United States						
Mean	0.00016	−0.00971	0.02388	−0.01607	0.00766	−0.00498
S.D.	0.43828	0.45006	0.44586	0.42324	0.43585	0.43592
Skewness	−0.06901	−0.42258	0.49523	−0.09034	0.21379	−0.55717
Kurtosis	4.96983	6.29549	5.05765	4.14555	4.55251	4.45292
Panel B: Volumes						
Canada						
Mean	6.732896	5.91325	6.67170	6.65133	6.71020	6.58692
S.D.	0.91372	2.22773	1.200989	1.16492	1.071737	1.43107
Skewness	−0.87103	−1.86386	−2.55239	−2.54420	−2.21433	−2.91849
Kurtosis	0.79859	2.42846	10.94117	11.2584	10.6153	10.6911
United Kingdom						
Mean	5.00113	4.40126	4.95522	5.00674	5.01006	4.82530
S.D.	0.72677	1.62520	0.94161	0.86990	0.83957	1.10318
Skewness	−0.80011	−1.88034	−2.52482	−1.96197	−2.13454	−2.45806
Kurtosis	0.69978	2.61089	10.34441	7.69710	9.25416	8.28687
United States						
Mean	4.73966	4.35493	4.64865	4.71215	4.63393	4.55240
S.D.	0.88080	1.53687	1.04045	1.02052	1.15395	1.22894

Table 1 (*continued*)

	All days (1)	Monday (2)	Tuesday (3)	Wednesday (4)	Thursday (5)	Friday (6)
Panel B: Volumes						
United States						
Skewness	−0.45098	−1.71401	−1.39769	−1.30724	−1.70915	1.71530
Kurtosis	0.25830	2.58809	3.86576	3.90197	4.76073	4.24109

Tables 2 and 3 (returns only and returns and volatilities, respectively) report the day of the week effects and stock market volatilities for these five developed markets. Panel A of Table 2 displays the first estimates of return equation. The FPEC suggests that the order of return equation is one for Canada, Germany, the United Kingdom, and the United States and zero for Japan. The estimated coefficients of the Mondays' dummy variables for Japan (−0.1596), the United Kingdom (−0.0992), and Canada (−0.0054) are negative and statistically significant at the 1%, 1%, and 5% levels, respectively, suggesting that Mondays' returns are smaller than those of Wednesdays. The estimated coefficients for Germany and the United States are lowest on Mondays and Thursdays, respectively, but they are statistically insignificant. The finding of lowest return for the United States on Thursdays is contrary to some of the studies of the day of the week effect literature (see Cross, 1973; Gibbons & Hess, 1981).

The coefficient of the conditional standard deviation of the return equation (risk) is positive for Canada (0.0522), Germany (0.1167), the United Kingdom (0.0702), and the United States (0.0653) but negative for Japan (−0.0102). However, the estimated coefficients are statistically significant only for the United Kingdom and the United States. The null hypothesis that the day of the week dummy variables are jointly equal to zero (not reported) is rejected using the Likelihood Ratio Test. Hence, the day of the week effect is present for each country under consideration.

In Panel A of Table 2, we also report the estimates of the GARCH (1,1) coefficients. V_c is the estimated coefficient of the constant term for the conditional variance equation, while V_{1a} is the estimated coefficient of the lagged value of the squared residual term. V_{1b} represents the lagged value of the conditional variance. Each of these coefficients is statistically significant and positive for each country under consideration. Also, the sum of the V_{1a} and V_{1b} coefficients is less than one. Thus, our results suggest that conditional variances are always positive and are not explosive in our samples.

Panel B of Table 2 reports the Ljung−Box Q statistics for the normalized residuals at 5-, 10-, 15-, 20-, and 25-day lags. None of these coefficients are statistically significant. Therefore, we cannot reject the null hypothesis that the residuals are not autocorrelated. In Panel C, Engle's (1982) ARCH-LM test does not indicate the presence of a significant ARCH effect in any of the sampled markets. This finding indicates that the standardized residual terms have constant variances and do not exhibit autocorrelation. Thus, Panels B and C provide strong support for the absence of autocorrelation.

The conditional variance of the returns is then allowed to change for each day of the week by modeling the conditional variance of return equation as a modified GARCH. This is done to detect the existence of a day of the week effect in volatility. We exclude the dummy variable for Wednesdays to avoid the dummy variable trap and include four new day of the

Table 2
Day of the week effect in return equation

	Canada	Germany	Japan	United States	United Kingdom
Panel A: Estimates of return equation and volatility					
Return equation					
Constant	0.0192	−0.0464	0.1101	0.0850	0.1103
	(0.0397)	(0.0765)	(0.0588)	(0.0544)	(0.0631)
	[.6281]	[.5443]	[.0612]	[.8187]	[.6394]
Monday	−0.0554*	−0.0497	−0.1596**	−0.0242	−0.0992**
	(0.0312)	(0.0511)	(0.0507)	(0.038)	(0.0425)
	[.0754]	[.3306]	[.0016]	[.5239]	[.0197]
Tuesday	−0.0278	−0.0318	0.0123	−0.0484	0.0112
	(0.0312)	(0.0587)	(0.0539)	(0.0388)	(0.042)
	[.3718]	[.5875]	[.8194]	[.2115]	[.7892]
Thursday	−0.0288	−0.0461	−0.0314	−0.0519	−0.0343
	(0.031)	(0.0568)	(0.0553)	(0.0392)	(0.0407)
	[.3533]	[.417]	[.5707]	[.1858]	[.3991]
Friday	−0.00803	−0.00313	−0.0903	−0.0322	−0.000519
	(0.0307)	(0.0549)	(0.0558)	(0.0365)	(0.0398)
	[.7938]	[.9545]	[.1054]	[.3772]	[.9896]
Return_{t-1}	0.1979**	0.0263	–	0.0707**	0.0571**
	(0.0174)	(0.0181)	–	(0.0167)	(0.0173)
	[.0000]	[.1468]	–	[.0000]	[.0009]
Risk	0.0522	0.1167	−0.0102	0.0653**	0.0702**
	(0.0527)	(0.0638)	(0.0436)	(0.1931)	(0.1158)
	[.3224]	[.0675]	[.8147]	[.00013]	[.00029]
Volatility					
V_c	0.00599**	0.06090**	0.01810**	0.00906**	0.01650**
	(0.00066)	(0.00564)	(0.00273)	(0.00143)	(0.00363)
	[.0000]	[.0000]	[.0000]	[.0000]	[.0000]
V_{1a}	0.06617**	0.11163**	0.09464**	0.05679**	0.07389**
	(0.00391)	(0.00649)	(0.00594)	(0.00453)	(0.00722)
	[.0000]	[.0000]	[.0000]	[.0000]	[.0000]
V_{1b}	0.92537**	0.85741**	0.90229**	0.93179**	0.90819**
	(0.00386)	(0.00922)	(0.00556)	(0.00572)	(0.00936)
	[.0000]	[.0000]	[.0000]	[.0000]	[.0000]
Log likelihood	13435.22	11406.36	11185.85	12965.83	12541.38

Lags	Canada	Germany	Japan	United States	United Kingdom
Panel B: Autocorrelation Q statistics					
5	2.494	2.784	0.988	6.553	2.935
	[.777]	[.733]	[.964]	[.256]	[.71]
10	8.370	9.147	8.950	10.545	7.012
	[.593]	[.518]	[.537]	[.394]	[.724]
15	11.194	15.8	10.434	22.183	12.606
	[.739]	[.395]	[.792]	[.103]	[.633]
20	14.724	18.005	16.250	24.555	20.511
	[.792]	[.587]	[.701]	[.219]	[.426]

Table 2 (*continued*)

Lags	Canada	Germany	Japan	United States	United Kingdom
Panel B: Autocorrelation Q statistics					
25	17.169	20.874	33.797	29.369	26.890
	[.876]	[.700]	[.112]	[.249]	[.361]
Panel C: ARCH-LM tests					
5	3.724	1.035	1.316	2.094	3.212
	[.589]	[.959]	[.933]	[.835]	[.667]
10	4.838	2.005	3.132	3.508	6.239
	[.901]	[.996]	[.978]	[.966]	[.794]
15	5.209	2.605	8.940	5.771	13.325
	[.990]	[.999]	[.880]	[.983]	[.577]
20	8.604	3.587	13.848	8.007	20.377
	[.987]	[.999]	[.838]	[.991]	[.434]
25	10.205	4.047	23.246	11.078	26.820
	[.996]	[.999]	[.563]	[.992]	[.364]

Standard errors are reported in parentheses and *p* values are reported in brackets.

* Statistically significant at the 5% level.

** Statistically significant at the 1% level.

week dummy variables. In this specification, we reexamine both the returns and the conditional variance equations. Findings are reported in Table 3. The day of the week effect results, with respect to returns, are similar to the previous findings reported in Table 2. The estimated coefficients of the Mondays dummy variables for Japan (−0.1753) and the United Kingdom (−0.0752) are negative and statistically significant, suggesting that returns on Mondays are statistically smaller than those observed on Wednesdays. The estimated coefficients for the United States, on the other hand, are significant on both Thursdays and Fridays, indicating that returns on these days are significantly lower than returns on Wednesdays. The estimated coefficients for Germany and Canada are negative on Mondays but they are statistically insignificant. The coefficients of the conditional standard deviation of the return equation (risk) are positive and statistically significant for Canada (0.1584), Germany (0.2429), Japan (0.1864), the United Kingdom (0.1949), and the United States (0.3467). These results would indicate that investors want to be compensated with higher returns for holding riskier assets. The estimated volatility coefficients for the constant terms, as well as the slope terms, are positive and statistically significant. This finding satisfies the nonnegativity of the conditional variances.

The results for conditional variance equation are reported in the lower part of Panel A of Table 3. The following results are observed. The highest volatility occurs on Fridays for Canada (0.2720) and the United States (0.0905), on Mondays for Germany (0.9100) and Japan (0.7610), and on Thursdays for the United Kingdom (0.0077). With the exception of that of the United Kingdom, all results are statistically significant. The lowest volatility occurs on Mondays for Canada (−0.0263) and the United Kingdom (−0.2470) and on Tuesdays for Germany (−0.6570), the United States (−0.4950), and Japan (−0.1170). The results for the United States, the United Kingdom, and Germany are statistically significant.

Table 3
Day of the week effect in return and volatility equations

	Canada	Germany	Japan	United States	United Kingdom
Panel A: Estimates of return equation and volatility equations					
Return equation					
Constant	−0.0517	−0.1711*	−0.1053	−0.2003**	−0.1054*
	(0.0548)	(0.077)	(0.0552)	(0.0516)	(0.0533)
	[.345]	[.0262]	[.0562]	[.0001]	[.048]
Monday	−0.0345	−0.1259	−0.1753**	−0.0245	−0.0752*
	(0.0344)	(0.0717)	(0.0547)	(0.0334)	(0.0303)
	[.316]	[.079]	[.0013]	[.4638]	[.0131]
Tuesday	−0.0421	−0.0146	−0.0326	−0.0319	−0.00432
	(0.0313)	(0.0514)	(0.0481)	(0.0329)	(0.0298)
	[.1780]	[.7769]	[.4982]	[.3316]	[.8848]
Thursday	−0.0074	−0.0203	−0.0184	−0.0721*	−0.0029
	(0.0305)	(0.0479)	(0.0489)	(0.0316)	(0.0335)
	[.8082]	[.6707]	[.7064]	[.0227]	[.93]
Friday	−0.0089	−0.0206	−0.0873	−0.1465**	−0.0171
	(0.0426)	(0.0501)	(0.0448)	(0.0348)	(0.0328)
	[.8346]	[.6805]	[.0516]	[.000]	[.6033]
Return_{t-1}	0.1214**	0.0255		0.0566**	0.0543**
	(0.0189)	(0.0170)		(0.0142)	(0.0127)
	[.0000]	[.1334]		[.0001]	[.000]
Risk	0.1584*	0.2429**	0.1864**	0.3467**	0.1949**
	(0.0740)	(0.0676)	(0.0476)	(0.0663)	(0.0655)
	[.0325]	[.0003]	[.0001]	[.000]	[.0029]
Volatility equation					
V_c	0.035	1.32*	0.94	2.87**	0.25**
	(0.026)	(0.562)	(0.542)	(0.198)	(0.024)
	[.1808]	[.0191]	[.0829]	[.000]	[.000]
V_{1a}	0.1653**	0.1754**	0.1699**	0.1517**	0.1527**
	(0.0128)	(0.0118)	(0.0104)	(0.0075)	(0.0091)
	[.0000]	[.0000]	[.0000]	[.0000]	[.0000]
V_{1b}	0.6133**	0.7248**	0.7894**	0.6008**	0.6019**
	(0.0177)	(0.0168)	(0.0104)	(0.0116)	(0.0177)
	[.0000]	[.0000]	[.0000]	[.0000]	[.0000]
Monday	−0.0263	0.9100**	0.7610**	−0.1770**	−0.2470**
	(0.0281)	(0.0792)	(0.0817)	(0.028)	(0.0279)
	[.3502]	[.0000]	[.0000]	[.0000]	[.0000]
Tuesday	0.0631*	−0.6570**	−0.1170	−0.4950**	−0.2090**
	(0.0307)	(0.0723)	(0.0953)	(0.0208)	(0.0221)
	[.0399]	[.0000]	[.2186]	[.0000]	[.0000]
Thursday	0.0493	−0.1740*	0.2120**	−0.0805*	0.00774
	(0.0342)	(0.0824)	(0.0735)	(0.0369)	(0.0460)
	[.1492]	[.0352]	[.0039]	[.0291]	[.8663]
Friday	0.2720**	0.1240	0.0334	0.0905**	−0.0499
	(0.0328)	(0.0688)	(0.0607)	(0.0298)	(0.0359)
	[.000]	[.0726]	[.5826]	[.0024]	[.165]
Log likelihood	13206.88	11414.11	11153.03	12620.98	12350.57

Table 3 (*continued*)

Lags	Canada	Germany	Japan	United States	United Kingdom
Panel B: Autocorrelation Q statistics					
5	15.513**	5.703	4.393	5.876	6.296
	[.008]	[.336]	[.494]	[.318]	[.278]
10	26.003**	11.649	18.065	16.703	14.584
	[.004]	[.309]	[.054]	[.081]	[.148]
15	31.034**	19.694	20.420	31.654**	19.089
	[.009]	[.184]	[.156]	[.007]	[.21]
20	33.850*	22.041	29.145	34.977*	30.535
	[.027]	[.338]	[.085]	[.02]	[.062]
25	35.756	24.611	37.423	38.413*	37.786*
	[.075]	[.484]	[.053]	[.042]	[.049]
Panel C: ARCH-LM tests					
5	4.277	3.056	25.774**	12.215*	19.508**
	[.510]	[.691]	[.0001]	[.031]	[.002]
10	30.109**	3.728	25.889**	43.137**	77.010**
	[.001]	[.958]	[.004]	[.000]	[.000]
15	59.184**	4.129	26.087*	54.283**	116.463**
	[.000]	[.997]	[.037]	[.000]	[.000]
20	80.492**	5.178	28.633	67.800**	138.405**
	[.000]	[.999]	[.095]	[.000]	[.000]
25	96.704**	5.615	29.908	79.386**	154.096**
	[.000]	[.999]	[.227]	[.000]	[.000]

Standard errors are reported in parentheses and p values are reported in brackets.

* Statistically significant at the 5% level.

** Statistically significant at the 1% level.

The highest volatility seems to be split among countries, where Germany and Japan have significantly higher volatility on Mondays while Canada and the United States experience the same on Fridays. The statistical evidence clearly suggests the presence of the day of the week effect on stock market return volatility in developed markets. By using the likelihood ratio tests, we reject the null hypothesis that there is no day of the week effect in the conditional variance equation. Hence, we confirm that the day of the week effect is present in both the mean (return) and variance (volatility or risk) equations.

Panels B and C of Table 3 report the autocorrelation Q statistics and ARCH-LM tests. Both tests indicate that there is no autocorrelation. The ARCH-LM test on the standardized residuals suggests the presence of heteroskedasticity. In Panel B, we report the Ljung–Box Q statistics for different order lags. We consider lags of 5, 10, 15, 20, and 25 days. Engle's ARCH-LM test statistics can reject the null hypothesis of no ARCH effect for all countries except Germany in the standardized residuals.[10]

[10] By construction, the variances are positive but some variables with corresponding negative coefficients may force the conditional variance to take on negative values.

The results of the day of the week effect in volume are reported in Table 4. We model the logarithm of the volume as an autoregressive process with trend and model the conditional variance as the GARCH (1,1) process. The empirical results show that the lowest volume of trading occurs on Mondays for all markets. The estimated coefficients for volume are lowest on Mondays compared to Wednesdays and are −0.2341 for Canada, −0.1661 for the United States, and −0.2931 for the United Kingdom. The second lowest volumes are on Fridays and the estimated coefficients are −0.1124, −0.0971, and −0.0845 for Canada, the United States,

Table 4
Day of the week effect in volume

	Canada	United States	United Kingdom
Return equation			
Constant	5.9162**	3.0827**	3.4036**
	(0.2105)	(0.1019)	(0.1197)
	[.0000]	[.0000]	[.0000]
Monday	−0.2341**	−0.1661**	−0.2931**
	(0.0128)	(0.0070)	(0.0109)
	[.0000]	[.0000]	[.0000]
Tuesday	0.0854**	0.0322**	0.0738**
	(0.0135)	(0.0081)	(0.0120)
	[.0000]	[.0001]	[.0000]
Thursday	−0.0476**	−0.0541**	−0.0144
	(0.0131)	(0.0081)	(0.0120)
	[.0003]	[.000]	[.2306]
Friday	−0.1124**	−0.0971**	−0.0845**
	(0.0132)	(0.0065)	(0.0110)
	[.0000]	[.0000]	[.0000]
Trend	0.00024**	0.00018**	0.00019**
	(0.000009)	(0.000006)	(0.000007)
	[.0000]	[.0000]	[.0000]
Volume_{t-1}	0.6364**	0.7373**	0.7089**
	(0.0130)	(0.0087)	(0.0103)
	[.0000]	[.0000]	[.0000]
Volatility equation			
V_c	0.0442**	0.0045**	0.0179**
	(0.0043)	(0.0003)	(0.0013)
	[.0000]	[.0000]	[.0000]
V_{1a}	0.12073**	0.2275**	0.1735**
	(0.0142)	(0.0147)	(0.0122)
	[.0000]	[.0000]	[.0000]
V_{1b}	0.1514*	0.6642**	0.5239**
	(0.0766)	(0.0154)	(0.0300)
	[.0479]	[.0000]	[.0000]
Log likelihood	−11.446	1491.853	106.823

Standard errors are reported in parentheses and p values are reported in brackets.

* Statistically significant at the 5% level.

** Statistically significant at the 1% level.

and the United Kingdom, respectively. The highest volumes occur on Tuesdays. The estimated coefficients are 0.0854 for Canada, 0.0322 for the United States, and 0.0738 for the United Kingdom. The estimated coefficients are all statistically significant at the 1% level.

In summary, the volatility of returns and trading volume findings for each country is as follows: The highest volatility of returns for the United States is observed on Fridays while the lowest volatility of returns occurs on Tuesdays. The highest volume occurs on Tuesdays and the lower volumes occur on Mondays and Fridays. High volatility appears to coincide with low trading volume. These findings are in line with the predictions of the Foster and Viswanathan (1990) model that the high volatility would be accompanied with low trading volume because of the unwillingness of liquidity traders to trade in periods where the prices are more volatile. Foster and Viswanathan (1993) report similar findings that show low volumes on Mondays along with Chang et al. (1997) that partially supports the Foster and Viswanathan (1990) model by finding that the return variance is highest while volume is lowest on Monday. Wei and Zee (1998) also find higher volatility on Fridays and lower volume on both Mondays and Fridays in their study of the currency futures markets, providing partial support to the Foster and Viswanathan (1990) argument.

The findings of volatility patterns in this paper do not rule out the public information release hypothesis. Finding of the second lowest volatility on Fridays also partially supports the macroeconomic news release hypothesis. Harvey and Huang (1991) report higher volatility in the interest rate and foreign exchange futures markets on Fridays, which they interpret as evidence of more public information arriving on Fridays. Ederington and Lee (1993) further support these results.

The findings for Canada are similar to those of the United States. The highest volatility of returns is observed on Fridays and the lowest volatility of return on Mondays, while the lower volumes occur on Mondays and Fridays and the highest volume occurs on Tuesdays. These findings also partially support the Foster and Viswanathan (1990) argument. The findings for the United Kingdom, on the other hand, do not exhibit a consistent pattern. While both the lowest volatility of return and lowest volume are on Mondays, the highest volatility is on Thursdays and the highest volume is on Tuesdays.

5. Summary and conclusion

The day of the week effect anomaly is documented extensively in both equity and nonequity markets. The day of the week effect patterns in return and volatility might enable investors to take advantage of relatively regular shifts in the market by designing trading strategies, which account for such predictable patterns. This study investigates the day of the week effect on stock market volatility for major stock markets using a conditional variance methodology. The data include the daily major market indexes from Canada, Germany, Japan, the United Kingdom, and the United States for the period of January 1, 1988, through June 28, 2002. Findings indicate that the day of the week effect is present in both return and volatility equations. We observe the highest volatility of returns on Mondays for Germany and Japan, on Fridays for Canada and the United States, and on Thursday for the United

Kingdom. The lowest volatility of returns occurs on Mondays for Canada and Tuesdays for Germany, Japan, the United Kingdom, and the United States. The lowest trading volumes occur on Mondays and Fridays for Japan, the United Kingdom, and the United States, and the highest trading volume occurs on Tuesdays for each market.

The findings of this paper support the Foster and Viswanathan (1990) argument that the high volatility would be accompanied with low trading volume due to liquidity traders being unwilling to trade in periods where the prices are more volatile. Chang et al. (1997), Foster and Viswanathan (1993), and Wei and Zee (1998) also support the Foster and Viswanathan (1990) argument.

The volatility patterns found in this paper, however, do not refute the public information release hypothesis. Findings of the highest volatility on Fridays in Canada and the United States support the macroeconomic news release hypothesis. Harvey and Huang (1991) report higher volatility in the interest rate and foreign exchange futures markets on Fridays and interpret this as evidence of more public information arriving on Fridays.

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