J Econ Finan (2012) 36:282–302
DOI 10.1007/s12197-009-9118-y

# Stock market return and volatility: day-of-the-week effect

**M. Hakan Berument · Nukhet Dogan**

Published online: 9 January 2010


**Abstract** This paper examines the stock market returns and volatility relationship using US daily returns from May 26, 1952 to September 29, 2006. The empirical evidence reported here does not support the proposition that the return-volatility relationship is present and the same for each day of the week.

**Keywords** Day-of-the-Week Effect · Return-Volatility Relation · Time Varying Risk Premia · EGARCH

**JEL Classification** G10 · G12 · C22

## 1 Introduction

Finding any systematic pattern in the behavior of stock market returns is an important research topic in financial economics. Two of the most commonly investigated patterns are (1) the relationship between stock market returns and stock market volatility (or variance), and (2) the difference in expected returns across the days of the week. While there does not seem to be universal agreement on the issue, the positive relationship between stock market returns and volatility is often taken as the positive risk premium; risk-averse investors need to be compensated for holding risky assets. The purpose of this paper is to determine whether the relationships

We would like to thank anonymous referee, Anita Akkas and Rana Nelson for their helpful comments.

M. H. Berument
Department of Economics, Bilkent University, 06800 Ankara, Turkey
e-mail: berument@bilkent.edu.tr
URL: http://www.bilkent.edu.tr/~berument

N. Dogan (✉)
Department of Econometrics, Gazi University, 06420 Ankara, Turkey
e-mail: nukhed@gazi.edu.tr
URL: http://nukhetdog.googlepages.com/home

between stock market returns and volatility are the same or different for each day of the week using a popular Autoregressive Conditional Heteroscedastic (ARCH) specification known as the Exponential Generalized Autoregressive Conditional Heteroscedastic (EGARCH) specification. The EGARCH specification has several advantages over other ARCH specifications. First, since the levels of variances are not modeled, there is no need to artificially impose non-negativity constraints on the model parameters. Second, EGARCH models allow this asymmetry; adverse stock market shocks have a more profound effect on volatility than positive shocks (leverage effect). Third, the EGARCH model uses the level of standardized value of $\varepsilon_{t-1}$, which allows for more natural interpretation of the size and persistence of shocks. On the other hand, allowing the relation between stock returns and stock volatility to change over time is important for assessing whether the degree of risk aversion changes across the days of the week, and if the agents of the degree of risk aversion change on a particular day of the week. This paper contributes to the literature on habit formation in the markets that suggests the presence of time varying risk aversion,[1] as the degree of risk aversion changes with each day of the week.

Regarding the relationship between stock market returns and volatility, most asset pricing models suggest that the relationship is positive (see for example: Sharpe 1964; Linter 1965; Merton 1973). However, a negative relationship between stock returns and volatility has also been proposed (see Black 1976; Cox and Ross 1976; Bekaert and Wu 2000). Similarly, empirical studies have drawn conflicting conclusions regarding the sign of the relationship. In general, despite differing specifications and estimation techniques, most of the empirical studies have found a positive relationship between stock market returns and volatility: Bollerslev et al. (1988), Harvey (1989), Campbell and Hentschel (1992), Scruggs (1998), Bali and Peng (2006) and Ghysels et al. (2005). A number of studies reported negative relationships: Black (1976), Cox and Ross (1976), Bekaert and Wu (2000), and Whitelaw (2000). Thus, the relationship between return and volatility as documented in the literature is mixed.

Concerning the expected return across the days of the week, day-of-the-week literature claims that investors behave differently on different days of the week. Osborne (1962) and Lakonishok and Maberly (1990) argue that since individual investors have more time to make financial decisions over weekends, they are more active in the financial markets on Mondays. However, institutional investors are less active in financial markets on Mondays because it tends to be a day of strategic planning. Lakonishok and Maberly (1990) also argue that as well as a decrease in the total volume of transactions on Mondays, there is an increase in *sell* transactions on Mondays relative to *buy* transactions by individuals. There is another set of arguments that Mondays have lower returns. First, the trade dates and the settlement dates do not necessarily coincide. If transactions are settled after three business days, buyers on Mondays and Tuesdays must pay during the same week (on Thursday or Friday), but buyers on Wednesday through Friday need not pay for 5 days because a weekend occurs before the settlement day; buyers get an extra 3 days of interest-free

[1] One may visit Campbell and Cochrane (1999) and the references cited therein for the literature on habit formation.

credit from brokers before settlement. Thus, Monday prices must be lower than Friday prices to compensate those investors who delay purchases until Monday. Second, according to the information release hypothesis, a firm with good news will release it quickly so investors can bid the stock price up, but bad news is an orphan, hidden from investor scrutiny by being released after the Friday close. This may cause lower demands for assets on Mondays (see, for example, Gibbons and Hess 1981; Lakonishok and Levi 1982; Ederington and Lee 1993)

The day-of-the-week effect is often documented on stock market returns and on stock market volatility. Regarding stock market returns, the literature suggests that on Mondays the market has statistically significant negative returns but on Fridays statistically significant positive returns (see for example: Osborne 1962; Cross 1973; French 1980; Gibbons and Hess 1981; Jaffe et al. 1989; Chang et al. 1993; Agrawal and Tandon 1994; Dubois and Louvet 1996). However, in a smaller subset of markets such as Japan, Australia and Turkey, a "Tuesday" effect has also been documented, in which it is the mean Tuesday return that is found to be significantly negative and less than the average returns combined of Wednesdays, Thursdays and Fridays. As for stock market volatility, there is evidence suggesting that the day-of-the-week effect actually appears in the volatility of stock returns (French and Roll 1996; Foster and Viswanathan 1990, 1993; Mookerjee and Yu 1999; Franses and Paap 2000; Berument and Kiymaz 2001; Kiymaz and Berument 2003; Savva et al. 2006; French and Roll 1986) find that the variance of returns from Friday close to Monday close is higher than the variance of returns from Monday close to Tuesday close. They explain the variance pattern with the different patterns of private and public information releases. Moreover, Foster and Viswanathan (1990) argue that informed traders have more information on Mondays than on other days and thus Mondays are when the variance of price changes are highest.

Agrawal and Tandon (1994), Mookerjee and Yu (1999), Franses and Paap (2000) and Savva et al. (2006) assess the day-of-the-week effect in stock returns as well as volatilities. When they examine whether volatility is different for each day of week, they use different measurements for volatility. While Agrawal and Tandon (1994) and Mookerjee and Yu (1999) use the return's unconditional standard errors as volatility, the other two papers use Periodic-GARCH models for the conditional variance in order to explain periodicity in both conditional mean and variance. They found that the day-of-the-week effect exists not only in the mean but also in variance. Moreover, they examine whether the volatility each day of the week's return is the same. These studies do not account for the volatility changes after accounting for the return changes across days, or vice versa.

As documented above, the expected returns and volatility of returns are different for each day of the week if (1) bad news was revealed over weekend so that it was available to traders on Monday; (2) most informed trading occurs on Monday relative to other days; and (3) more individual trading relative to institutional trading occurs on Monday and individual traders have different preferences from institutional traders. Thus, pricing the risk across the days of the week will not be the same. Even the sets of studies that report 1) a relationship between return and volatility 2) the day-of-the-week effect on returns and 3) day-of-the-week effect on volatility, they all assume that the relationship between return and volatility is time invarying. As can be seen, our model is different on testing return-volatility relationship; the other model either assumes this relationship is unchanging (Sharpe 1964; Black 1976; French and Roll 1986; Kim and Kon 1994) or non-existing (Agrawal and Tandon 1994). The contribution of this paper is to explicitly model the time varying return-volatility relationship. The empirical evidence provided here cannot support the proposition that the return-volatility relationship is present and the same for each day of the week. The remainder of this paper is organized as follows: Section 2 describes the data and methodology; Section 3 reports the empirical results; Section 4 concludes the paper.

## 2 Data and methodology

This study is conducted using the daily NYSE (New York Stock Exchange), S&P500 (Standard & Poor's 500), NASDAQ (National Association of Securities Dealers Automated Quotations) and AMEX (the American Stock Exchange) equal- and value-weighted and the DOW Dow Jones Industrial Average equal-weighted indexes from May 26, 1952 to September 29, 2006[2]. The daily return, $R_t$, is calculated as the growth of the above markets' index levels, $P_t$ at time $t$.

$$R_t = \left(\frac{P_t}{P_{t-1}} - 1\right) * 100 \tag{1}$$

In most studies, such as in French (1980) and Smirlock and Starks (1986), the standard Ordinary Least Square method is used for assessing the day-of-the-week effect in the returns by regressing the daily returns on the five daily dummies. However, this method has two drawbacks. One drawback is that if the errors are autocorrelated, then the inferences will be misleading. The other drawback is that error variances may be time dependent. In order to account for the autocorrelated errors, we included the $n$ lag values of the return.[3] Thus, the daily returns of the stock markets are modeled as:

$$R_t = \alpha_M M_t + \alpha_U U_t + \alpha_W W_t + \alpha_H H_t + \alpha_F F_t + \sum_{i=1}^{n} \alpha_i R_{t-i} + \varepsilon_t, \tag{2}$$

where $M_t$, $U_t$, $W_t$, $H_t$ and $F_t$ are the dummy variables for Monday, Tuesday, Wednesday Thursday and Friday. They each take the value of one on the respective day of the week and zero otherwise. Note that the constant term is excluded in order to avoid the dummy variable trap. To consider the time varying variances, following

[2] During the period prior to May 1952, the number of trading days in a week was six: Monday through Saturday. Thus, in order to incorporate the same pattern for the day-of-the-week effect, we start our sample from May of 1952.

[3] The final prediction error criteria (FPEC) are used to determine the optimum lag order $n$. FPEC determines the lag length such that it eliminates autocorrelation in the residual term. If we have autocorrelated residuals, ARCH-LM tests would suggest the presence of the residual term with heteroscedasticity even if the residuals were homoscedastic (see Cosimano and Dennis 1988).

Nelson (1991), we modeled the conditional variance as the EGARCH model. To be more specific, the conditional variance, $h_t^2$, is defined as:

$$\log h_t^2 = \kappa + \sum_{i=1}^{v} \delta_i \log h_{t-i}^2 + \gamma_1 \left( \left| \frac{\varepsilon_{t-1}}{h_{t-1}} \right| - E\left| \frac{\varepsilon_{t-1}}{h_{t-1}} \right| + \chi \frac{\varepsilon_{t-1}}{h_{t-1}} \right) \tag{3}$$

To consider the excess kurtosis, we assume that errors have a General Error Distribution.

Therefore, $E\left|\frac{\varepsilon_t}{h_t}\right| = \Lambda 2^{\frac{1}{D}} \frac{\Gamma\left(\frac{2}{D}\right)}{\Gamma\left(\frac{1}{D}\right)}$where $\Gamma(.)$ is the gamma function, $\Lambda = \sqrt{2^{\frac{-2}{D}} \frac{\Gamma\left(\frac{1}{D}\right)}{\Gamma\left(\frac{3}{D}\right)}}$ and D is the parameter for the General Error Distribution. To account for the thickness of the tails D is a positive parameter. If $D=2$, then the distribution is normal; if $D<2$, then the density has thicker tails than the normal distribution and if $D>2$, then the density has thinner tails.

The EGARCH specification has certain advantages. One of them, since the logarithm of the conditional variance is modeled, is that $h_t^2$can never be negative. Furthermore, this specification allows the leverage effect: if $\chi=0$, then a positive shock ($\varepsilon_{t-1}>0$) has the same magnitude effect as a negative surprise; if $-1<\chi< 0$, a negative surprise increases volatility more than a positive surprise does; if $\chi<-1$, then a positive surprise reduces volatility while a negative surprise increases volatility.

When we use the conditional variance as a measure of volatility, we are able to assess the impact of volatility on return by considering the following model:

$$R_t = \alpha_M M_t + \alpha_U U_t + \alpha_W W_t + \alpha_H H_t + \alpha_F F_t + \sum_{i=1}^{n} \alpha_i R_{t-i} + \lambda h_t^2 + \varepsilon_t. \tag{4}$$

In the model, Eq. 4 assumes that return-volatility is the same for each day of the week. In order to allow a changing return-volatility relationship for each day of the week, the interactive dummy variables (obtained by multiplying the daily dummy variables with the conditional variance) are incorporated into the specification:

$$\begin{aligned} R_t = {} & \alpha_M M_t + \alpha_U U_t + \alpha_w W_t + \alpha_H H_t + \alpha_F F_t \\ & + \sum_{i=1}^{n} \alpha_i R_{t-i} + \lambda_M M_t h_t^2 + \lambda_U U_t h_t^2 + \lambda_W W_t h_t^2 + \lambda_H H_t h_t^2 + \lambda_F F_t h_t^2 + \varepsilon_t. \end{aligned} \tag{5}$$

In order to estimate the model, the Quasi-Maximum Likelihood Estimation (QMLE) method, introduced by Bollerslev and Wooldridge (1992), is used to estimate parameters,[4] Similar to Berument and Kiymaz (2001), Kiymaz and Berument (2003) and Savva et al. (2006), one could also suggest including the day-of-the-week effect dummies in the variance specification. If intercept dummies

[4] Pagan (1984) argues that using stochastic regressors gives biased estimates. In order to avoid this, queryPagan and Ulah (1988) suggest using the Full Information Maximum Likelihood Estimation (MLE) technique to estimate the system of equations. queryBollerslev and Wooldridge (1992), however, argue that the normality of the standardized conditional errors $\varepsilon_t/h_t$ assumption may cause misspecification of the likelihood function and they suggest using the QMLE method to avoid the misspecification problem. Bollerslev and Wooldrige formally show that the QMLE is generally consistent and has a limited distribution.

are introduced in the mean and the variance equations as well as in the return-volatility specification, the two-equation model is not estimatable jointly due to the perfect multicollinearity. The source of the perfect multicollinearity is due to the presence of a return-volatility relationship in the mean equation. This presence will allow the day-of-the-week dummies to be accounted for twice in the mean equation; one for the dummies in the mean itself and the other in the variance equation.

Our specification indebted various hypotheses already tested in the literature. First, within the econometric specification that we employ, the positive relationship between return and volatility that Sharpe (1964) and Black (1976) suggest can be tested by estimating the model

$$R_t = \alpha_0 + \lambda h_t^2 + \varepsilon_t, \tag{6}$$

and testing the null hypothesis $H_0 : \lambda=0$ against $H_A$: not $H_0$. Second, in order to assess the day-of-the-week effect in mean as in Agrawal and Tandon (1994), one may estimate

$$R_t = \alpha_M M_t + \alpha_U U_t + \alpha_W W_t + \alpha_H H_t + \alpha_F F_t + \varepsilon_t. \tag{7}$$

The null hypothesis to be tested is $H_0 : \alpha_M=\alpha_U=\alpha_w=\alpha_H=\alpha_F$ against $H_A$: not $H_0$. Third, in order to assess if the volatility of each day of the week's return is the same, the null hypothesis can be tested for the above specification $H_0 : \sigma_M=\sigma_U=\sigma_W=\sigma_H=\sigma_F$ against $H_A$ : *not* $H_0$ where $\sigma_i$ is either the unconditional variances (or unconditional standard deviations) of return for each day or the conditional variances that come from a class of ARCH models.

Fourth, similar to Kim and Kon (1994), we can assess the volatility within our specification, and they also account for autocorrelation of the returns:

$$R_t = \alpha_0 + \sum_{i=1}^{n} \alpha_i R_{t-i} + \lambda h_t^2 + \varepsilon_t. \tag{8}$$

Here the null hypothesis is $H_0 : \lambda = 0$ and the alternative is $H_A$: not $H_0$.

However in our model to assess if λ changes across each day of the week as specied in Eq. 5 and test the null hypothesis $H_0 : \lambda_M=\lambda_U=\lambda_W=\lambda_H=\lambda_F$ against $H_A$ : not $H_0$. As can be seen, our specification is different on testing return-volatility relationship; the other models either assume this relationship is unchanging (Sharpe 1964; Black 1976; French and Roll 1986; Kim and Kon 1994) or non-existing (Agrawal and Tandon 1994).

## 3 Empirical results

Table 1 reports the expected returns of the nine series of the NYSE, S&P500 NASDAQ and AMEX for their equal- and value-weighted indexes and of the DOW for its equal-weighted index for all days and each day of the week. A set of patterns appears from the table. First, the expected returns of Mondays are always the lowest of the week and negative. Second, the Friday returns are higher than the Monday returns. Last, the highest returns are observed on either Wednesdays or Fridays. Table 2 reports the variances of the daily returns for the indexes. Note that the

**Table 1** Mean of daily raw return data over the May 26, 1952 to September 29, 2006 period

| | Weighting | All | Monday | Tuesday | Wednesday | Thursday | Friday |
|---|---|---|---|---|---|---|---|
| NYSE | Equal | 0.068 (13679) | −0.085 (2834) | 0.016 (2787) | 0.125 (2782) | 0.101 (2747) | 0.188 (2729) |
| NYSE | Value | 0.046 (13679) | −0.059(2834) | 0.044 (2787) | 0.101 (2782) | 0.050 (2747) | 0.096 (2729) |
| S&P500 | Equal | 0.055 (13679) | −0.061 (2834) | 0.038 (2787) | 0.117 (2782) | 0.070 (2747) | 0.116 (2729) |
| S&P500 | Value | 0.046 (13679) | −0.048 (2834) | 0.053 (2787) | 0.101 (2782) | 0.045 (2747) | 0.084 (2729) |
| NASDAQ | Equal | 0.098 (8529) | −0.090 (1763) | −0.001 (1745) | 0.132 (1746) | 0.176 (1711) | 0.270 (1705) |
| NASDAQ | Value | 0.046 (8529) | −0.117 (1763) | −0.021 (1745) | 0.128 (1746) | 0.115 (1711) | 0.111 (1705) |
| AMEX | Equal | 0.094 (11138) | −0.077 (2308) | 0.002 (2276) | 0.136 (2263) | 0.140 (2238) | 0.276 (2225) |
| AMEX | Value | 0.041 (11138) | −0.123 (2308) | −0.015 (2276) | 0.108 (2263) | 0.081 (2238) | 0.156 (2225) |
| DOW | Equal | 0.032 (14100) | −0.040 (2919) | 0.041 (2869) | 0.072 (2867) | 0.028 (2831) | 0.063 (2813) |

Parentheses under the returns denote the number of observations used to compute the mean

**Table 2** Variance of daily raw return data over the May 26, 1952 to September 29, 2006 period

| Index | Weighting | All | Monday | Tuesday | Wednesday | Thursday | Friday |
|---|---|---|---|---|---|---|---|
| NYSE | Equal | 0.512 | 0.719 | 0.437 | 0.479 | 0.456 | 0.421 |
| NYSE | Value | 0.676 | 0.943 | 0.635 | 0.621 | 0.597 | 0.585 |
| S&P500 | Equal | 0.736 | 1.023 | 0.660 | 0.674 | 0.672 | 0.646 |
| S&P500 | Value | 0.793 | 1.078 | 0.773 | 0.734 | 0.698 | 0.699 |
| NASDAQ | Equal | 0.569 | 0.691 | 0.548 | 0.531 | 0.517 | 0.486 |
| NASDAQ | Value | 1.476 | 1.715 | 1.543 | 1.466 | 1.396 | 1.304 |
| AMEX | Equal | 0.553 | 0.728 | 0.492 | 0.524 | 0.485 | 0.460 |
| AMEX | Value | 0.727 | 0.922 | 0.686 | 0.718 | 0.668 | 0.611 |
| DOW | Equal | 0.818 | 1.133 | 0.775 | 0.749 | 0.725 | 0.723 |

highest volatilities are observed on Mondays but for DOW (where it is Tuesdays) and the lowest volatilities are observed on Fridays.

Table 3 reports the estimates of Eqs. 3 and 4 for the five US markets that we consider. In Panel A, we report the estimates of the return equation as specified in Eq. 4. Panel B reports the parameters of the conditional variance specification of the returns, Eq. 3, and Panel C reports the *p*-values of two sets of (parametric) robustness test statistics. Panel D is for a set of non-parametric robustness tests. $M_t$, $U_t$,$W_t$,$H_t$ and $F_t$ are the dummy variables for Monday, Tuesday, Wednesday, Thursday and Friday at time *t*. Furthermore, $R_{t-i}$ , $h_t^2$ and $\chi$ denote the parameters for the lagged returns, the conditional variance of the returns and the leverage effect, respectively.

After accounting for the conditional variance of the returns as well as for the dynamics of the return with the lag values of the returns, the evidence reported in Table 3 indicates that for all the indexes that we consider (1) the lowest returns are observed on Mondays; (2) Friday returns are higher than Monday returns and (3) the highest returns are observed on Fridays for all the indexes. Thus, the evidence gathered in Table 1 is robust. This result is also consistent with previous studies such as Osborne (1962), Cross (1973), French (1980), Gibbons and Hess (1981), Jaffe et al. (1989), Chang et al. (1993), Mookerjee and Yu (1999) and Dubois and Louvet (1996), who find that the market has statistically significant negative returns on Mondays but statistically significant positive returns on Fridays. Meanwhile, the estimated coefficients for $h_t^2$ are always positive. This suggests that high (low) volatility is associated with high (low) returns: there is a positive risk premium. Similar results are observed by Scruggs (1998), Bali and Peng (2006) and Ghysels et al. (2005). The evidence reported here is statistically significant at the 10% level for the equal-weighted indexes of the NYSE and at the 5% level for the equal-weighted NASDAQ and AMEX indexes. In Panel B, we report the estimated coefficients for the conditional variances. In order to gather non-autocorrelated and homoscedastic standardized residuals, we included various lag values of the logarithm of the conditional variance. All estimated models give characteristic roots inside of the unit circle in the conditional variance specifications and this satisfies the non-explosiveness of the conditional variance (see Nelson 1991). The estimated coefficients for the leverage effect ($\chi$) are always negative, less than one in absolute value and statistically significant for all market indexes; this is consistent with the leverage hypothesis: negative surprises increase volatility more than positive surprises.[5] This result is parallel to various previous works, including Cheung and Ng (1992) and Kim and Kon (1994). Panel C reports the *p*-values of two sets of robustness test statistics. The first set reports the Ljung-Box Q-statistics for the standardized residuals for the 5, 10, 20 and 60 lags. Here, we cannot reject the null hypothesis that the residuals are not autocorrelated for any of the indexes except AMEX's equal-weighted index. The second set reported in Panel C performs the ARCH-LM test for the standardized residuals for the 5, 10, 20 and 60 lags. There is no statistically significant ARCH effect in the standardized residuals except for the value-weighted S&P500 and the equal-weighted NASDAQ for lag 60, the value-weighted NASDAQ for lags 5, 10 and 60 and the equal-weighted AMEX for lag 5 and DOW for lag 5 and 10. Panel D reports a set of non-parametric sign and size-biased tests. We can reject the null hypothesis that the squared standardized residuals are constant only for the Positive- and Joint-biased tests for NASDAQ, DOW and the Joint test of the value-weighted AMEX. Thus, overall most of the *p*-values for these two sets are not statistically significant; this further supports our specification.

Table 4 reports the estimates of the specification in Eqs. 3 and 5, which allow the return-volatility relationship to vary across the days of the week for the nine market indexes. Similar to the estimates reported in Table 3 and the existing literature cited above, the expected value of the conditional returns are highest on Fridays and lowest on Mondays. Moreover, parallel to the estimates reported in Table 3 and the relevant literature, the estimated coefficients for the leverage effect ($\chi$) are negative and statistically significant. When we allow the conditional variance to vary across the days of the week, a set of conclusions can be drawn: (1) the return-volatility relationships for Tuesdays are always positive, and generally statistically significant (only the value-weighted NASDAQ is not statistically significant); (2) for each of the indexes that we consider, the return-volatility relationship is positive and statistically significant for at least one of the days; (3) the return-volatility relationships are always positive for Wednesdays; (4) for the Monday return-volatility relationship, when they are statistically significant, then the estimated coefficients are negative; and (5) if the Friday return-volatility relationships are statistically significant, then the estimated coefficients are positive. If there is a positive relationship between risk and return, this suggests that risk is positively priced. This is what is expected if the investors are assumed risk averse; they want to be compensated for bearing higher risk. Not finding positive and statistically significant coefficients on Mondays for the risk coefficient ($\lambda_m$ in Eq. 5) suggests that risk is not priced on Mondays. This supports French and Roll (1986) and Foster and Viswanathan's (1990, 1993) argument that informed trading, which may not be risk bearing, is more likely to occur on Mondays and liquidity trading (which explores the intra-day differences in stock prices) is also lower on Mondays; this might be the reason why risk is not priced.

[5] The level of significance is 5% unless otherwise specified

**Table 3** Return-volatility relationships over the May 26, 1952 to September 29, 2006 period[a]

| | NYSE | | S&P500 | | NASDAQ | | AMEX | | DOW |
|---|---|---|---|---|---|---|---|---|---|
| | Equal | Value | Equal | Value | Equal | Value | Equal | Value | Equal |
| Panel A: return specification | | | | | | | | | |
| $M_t$ | −0.099** (−9.991) | −0.058** (−4.952) | −0.073** (−6.353) | −0.058** (−4.600) | −0.179** (−17.01) | −0.125** (−7.639) | −0.154** (−14.50) | −0.106** (−8.323) | −0.050** (−3.668) |
| $U_t$ | −0.0003 (−0.038) | 0.033** (2.778) | 0.026** (2.263) | 0.037** (2.859) | −0.026** (−2.332) | 0.007 (0.388) | −0.036** (−3.305) | −0.004 (−0.333) | 0.024* (1.758) |
| $W_t$ | 0.063** (6.183) | 0.065** (5.125) | 0.075** (6.172) | 0.064** (4.687) | 0.077** (7.316) | 0.108** (6.584) | 0.042** (3.976) | 0.075** (5.830) | 0.052** (3.644) |
| $H_t$ | 0.053** (5.180) | 0.035** (2.782) | 0.039** (3.194) | 0.029** (2.145) | 0.095** (8.893) | 0.096** (5.661) | 0.052** (4.798) | 0.055** (4.184) | 0.024 (1.673) |
| $F_t$ | 0.142** (13.44) | 0.105** (8.071) | 0.120** (9.434) | 0.098** (6.941) | 0.167** (15.06) | 0.132** (7.389) | 0.171** (15.75) | 0.122** (9.176) | 0.086** (5.786) |
| $R_{t-1}$ | 0.314** (35.79) | 0.177** (20.38) | 0.211** (24.65) | 0.134** (15.214) | 0.354** (30.52) | 0.230** (19.77) | 0.332** (33.62) | 0.264** (26.13) | 0.111** (13.15) |
| $R_{t-2}$ | −0.039** (−4.336) | −0.039** (−4.463) | −0.030** (−3.398) | −0.033** (−3.854) | 0.010 (0.880) | −0.021* (−1.914) | 0.024** (2.368) | −0.020** (−2.058) | −0.035** (−4.095) |
| $R_{t-3}$ | 0.074** (8.331) | 0.020** (2.314) | 0.040** (4.592) | 0.009 (1.102) | 0.089** (8.271) | 0.045** (4.174) | 0.085** (8.455) | 0.062** (6.514) | |
| $R_{t-4}$ | 0.040** (4.561) | 0.018** (2.120) | 0.035** (4.063) | 0.014 (1.591) | 0.050** (4.682) | 0.026** (2.386) | 0.055** (5.627) | 0.023** (2.424) | |
| $R_{t-5}$ | 0.030** (3.485) | 0.008 (0.925) | 0.022** (2.592) | 0.004 (0.508) | 0.035** (3.185) | 0.021* (1.900) | 0.033** (3.443) | 0.029** (3.021) | |
| $R_{t-6}$ | −0.004 (−0.485) | | | | 0.022** (2.075) | −0.0002 (−0.026) | 0.002 (0.175) | −0.004 (−0.472) | |
| $R_{t-7}$ | 0.012 (1.402) | | | | 0.002 (0.181) | −0.006 (−0.528) | 0.010 (1.074) | 0.007 (0.693) | |
| $R_{t-8}$ | 0.016* (1.856) | | | | 0.020* (1.926) | 0.004 (0.399) | 0.016* (1.782) | 0.011 (1.143) | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $R_{t-9}$ | 0.013 (1.523) | | | | 0.027** (2.570) | 0.011 (1.069) | 0.012 (1.310) | 0.001 (0.140) | |
| $R_{t-10}$ | 0.013 (1.616) | | | | 0.030** (2.940) | 0.023** (2.088) | 0.016* (1.758) | 0.015 (1.593) | |
| $R_{t-11}$ | 0.0003 (0.049) | | | | 0.021** (2.079) | 0.010 (0.912) | 0.001 (0.065) | −0.004 (−0.473) | |
| $R_{t-12}$ | 0.030** (3.943) | | | | 0.044** (4.542) | 0.054** (5.210) | 0.012 (1.443) | 0.025** (2.775) | |
| $R_{t-13}$ | | | | | | | 0.010 (1.147) | | |
| $R_{t-14}$ | | | | | | | 0.006 (0.711) | | |
| $R_{t-15}$ | | | | | | | 0.030** (3.925) | | |
| $h_t^2$ | 0.032* (1.808) | 0.022 (1.426) | 0.021 (1.489) | 0.019 (1.386) | 0.074** (4.370) | 0.015 (1.529) | 0.082** (4.432) | 0.020 (1.291) | 0.011 (0.778) |
| Panel B: variance specification | | | | | | | | | |
| *Constant* | −0.038** (−8.327) | −0.009** (−4.867) | −0.007** (−3.839) | −0.005** (−2.753) | −0.026** (−3.954) | 0.0002 (0.121) | −0.048** (−7.840) | −0.013** (−3.644) | −0.003** (−2.622) |
| $\log h_{t-1}^2$ | 0.961** (294.0) | 0.984** (545.6) | 0.985** (583.4) | 0.718** (7.261) | 0.769** (11.88) | 0.742** (9.279) | 0.953** (228.5) | 0.804** (11.97) | 0.989** (668.98) |
| $\log h_{t-2}^2$ | | | | 0.267** (2.721) | −0.120 (−1.251) | −0.122 (−1.067) | | −0.180* (−1.812) | |
| $\log h_{t-3}^2$ | | | | | 0.324** (5.467) | 0.369** (5.018) | | 0.353** (5.655) | |
| $\left(\left\|\frac{\varepsilon_{t-1}}{h_{t-1}}\right\| - E\left\|\frac{\varepsilon_{t-1}}{h_{t-1}}\right\| + \chi\frac{\varepsilon_{t-1}}{h_{t-1}}\right)$ | 0.220** (20.78) | 0.135** (17.01) | 0.148** (18.33) | 0.156** (11.31) | 0.329** (15.20) | 0.235** (12.91) | 0.280** (20.90) | 0.262** (15.03) | 0.115** (16.494) |
| $\chi$ | −0.481** (12.42) | −0.599** (11.30) | −0.567** (11.96) | −0.575** (11.34) | −0.368** (8.392) | −0.422** (8.179) | −0.336** (10.19) | −0.397** (9.583) | 0.487** (10.01) |
| *Function Value* | −3095.9 | −6190.36 | −6407.31 | −7345.57 | −1267.9 | −5733.78 | −2043.6 | −4667.84 | −8048.44 |

**Table 3** (continued)

| | NYSE | | S&P500 | | NASDAQ | | AMEX | | DOW |
|---|---|---|---|---|---|---|---|---|---|
| | Equal | Value | Equal | Value | Equal | Value | Equal | Value | Equal |
| Panel C: robustness statistics | | | | | | | | | |
| Lag(s) | Ljung-Box Q-Stat | | | | | | | | |
| 5 | [0.145] | [0.900] | [0.873] | [0.831] | [0.222] | [0.549] | [0.000]** | [0.332] | [0.570] |
| 10 | [0.352] | [0.893] | [0.817] | [0.867] | [0.480] | [0.823] | [0.004]** | [0.763] | [0.590] |
| 20 | [0.134] | [0.744] | [0.497] | [0.598] | [0.341] | [0.566] | [0.004]** | [0.509] | [0.513] |
| 60 | [0.051]* | [0.386] | [0.227] | [0.413] | [0.086]* | [0.178] | [0.005]** | [0.064]* | [0.266] |
| Lag(s) | ARCH- LM tests | | | | | | | | |
| 5 | [0.992] | [0.918] | [0.853] | [0.342] | [0.338] | [0.013]** | [0.023]** | [0.166] | [0.023]** |
| 10 | [0.998] | [0.994] | [0.979] | [0.577] | [0.584] | [0.039]** | [0.056]* | [0.132] | [0.074]* |
| 20 | [0.999] | [0.999] | [0.999] | [0.963] | [0.686] | [0.126] | [0.202] | [0.294] | [0.514] |
| 60 | [0.999] | [0.997] | [0.999] | [0.000]** | [0.044]** | [0.023]** | [0.206] | [0.646] | [0.256] |
| Panel D: non-parametric tests | | | | | | | | | |
| Sign Bias | [0.742] | [0.947] | [0.501] | [0.923] | [0.144] | [0.564] | [0.141] | [0.452] | [0.242] |
| Negative Size | [0.665] | [0.568] | [0.851] | [0.958] | [0.671] | [0.996] | [0.849] | [0.886] | [0.169] |
| Positive Size | [0.303] | [0.274] | [0.649] | [0.250] | [0.005]** | [0.083]* | [0.931] | [0.146] | [0.013]** |
| Joint Test | [0.633] | [0.367] | [0.445] | [0.439] | [0.042]** | [0.030]** | [0.260] | [0.035]** | [0.018]** |

[a] $t$-statistics are reported in parentheses and $p$-values are reported in brackets

* Indicates the level of significance at the 10% level. ** Indicates the level of significance at the 5% level

**Table 4** Day-of-the-week effect on return-volatility relationships over the May 26, 1952 to September 29, 2006 period[a]

| | NYSE | | S&P500 | | NASDAQ | | AMEX | | DOW |
|---|---|---|---|---|---|---|---|---|---|
| | Equal | Value | Equal | Value | Equal | Value | Equal | Value | Equal |
| Panel A: return specification | | | | | | | | | |
| $M_t$ | −0.045** | −0.038** | −0.054** | −0.057** | −0.165** | −0.131** | −0.100** | −0.061** | −0.062** |
| | (−3.232) | (−2.398) | (−3.630) | (−3.354) | (−13.80) | (−7.048) | (−7.273) | (−3.822) | (−3.242) |
| $U_t$ | −0.022 | 0.002 | 0.006 | 0.013 | −0.032** | −0.001 | −0.050** | −0.024 | −0.003 |
| | (−1.620) | (0.119) | (0.408) | (0.743) | (−2.609) | (−0.025) | (−3.675) | (−1.413) | (−0.155) |
| $W_t$ | 0.047** | 0.051** | 0.064** | 0.059** | 0.077** | 0.097** | 0.018 (1.303) | 0.066** | 0.050** |
| | (3.449) | (2.987) | (4.092) | (3.195) | (6.319) | (5.205) | | (4.100) | (2.463) |
| $H_t$ | 0.061** | 0.048** | 0.044** | 0.043** | 0.096** | 0.102** | 0.051** | 0.051** | 0.041** |
| | (4.470) | (2.877) | (2.859) | (2.394) | (7.801) | (5.300) | (3.755) | (3.186) | (2.032) |
| $F_t$ | 0.129** | 0.119** | 0.131** | 0.116** | 0.157** | 0.147** | 0.142** | 0.098** | 0.104** |
| | (8.947) | (6.629) | (7.847) | (6.037) | (12.323) | (7.199) | (10.229) | (5.810) | (4.803) |
| $R_{t-1}$ | 0.312** | 0.177** | 0.212** | 0.134** | 0.356** | 0.230** | 0.333** | 0.265** | 0.111** |
| | (36.239) | (20.338) | (24.672) | (15.175) | (30.609) | (19.724) | (33.915) | (26.209) | (13.143) |
| $R_{t-2}$ | −0.038** | −0.038** | −0.029** | −0.032** | 0.009 | −0.020* | 0.024** | −0.020** | −0.034** |
| | (−4.323) | (−4.319) | (−3.304) | (−3.728) | (0.817) | (−1.839) | (2.446) | (−2.014) | (−3.952) |
| $R_{t-3}$ | 0.074** | 0.020** | 0.041** | 0.009 | 0.089** | 0.044** | 0.088** | 0.062** | |
| | (8.367) | (2.308) | (4.679) | (1.096) | (8.288) | (4.120) | (8.774) | (6.520) | |
| $R_{t-4}$ | 0.041** | 0.017** | 0.034** | 0.013 | 0.052** | 0.026** | 0.054* | 0.023** | |
| | (4.763) | (2.029) | (3.978) | (1.573) | (4.791) | (2.393) | (5.587) | (2.422) | |
| $R_{t-5}$ | 0.026** | 0.008 | 0.022** | 0.004 | 0.034** | 0.020* | 0.030** | 0.029** | |
| | (3.054) | (0.994) | (2.577) | (0.449) | (3.092) | (1.852) | (3.141) | (2.971) | |
| $R_{t-6}$ | −0.001 | | | | 0.024** | 0.001 | 0.003 | −0.003 | |
| | (−0.138) | | | | (2.236) | (0.050) | (0.363) | (−0.333) | |
| $R_{t-7}$ | 0.013 | | | | 0.001 | −0.006 | 0.011 | 0.006 | |
| | (1.538) | | | | (0.116) | (−0.532) | (1.186) | (0.655) | |
| $R_{t-8}$ | 0.017** | | | | 0.020* | 0.005 | 0.018* | 0.011 | |
| | (2.005) | | | | (1.921) | (0.432) | (1.952) | (1.199) | |

**Table 4** (continued)

| | NYSE | | S&P500 | | NASDAQ | | AMEX | | DOW |
|---|---|---|---|---|---|---|---|---|---|
| | Equal | Value | Equal | Value | Equal | Value | Equal | Value | Equal |
| $R_{t-9}$ | 0.011 (1.388) | | | | 0.026** (2.525) | 0.011 (1.026) | 0.012 (1.323) | 0.002 (0.208) | |
| $R_{t-10}$ | 0.013 (1.548) | | | | 0.030** (2.887) | 0.022** (2.072) | 0.014 (1.562) | 0.015 (1.628) | |
| $R_{t-11}$ | 0.002 (0.213) | | | | 0.022** (2.165) | 0.010 (0.969) | 0.003 (0.362) | −0.003 (−0.295) | |
| $R_{t-12}$ | 0.031** (4.095) | | | | 0.044** (4.496) | 0.054** (5.186) | 0.011 (1.306) | 0.025** (2.831) | |
| $R_{t-13}$ | | | | | | | 0.012 (1.426) | | |
| $R_{t-14}$ | | | | | | | 0.005 (0.562) | | |
| $R_{t-15}$ | | | | | | | 0.030** (3.931) | | |
| $M_t$ | −0.199** (−4.862) | −0.033 (−1.020) | −0.032 (−1.106) | 0.014 (0.486) | −0.006 (−0.157) | 0.028* (1.310) | −0.172** (−3.937) | −0.123** (−3.665) | 0.035 (1.117) |
| $U_t$ | 0.112** (2.775) | 0.100** (2.950) | 0.074** (2.399) | 0.072** (2.361) | 0.112** (2.987) | 0.027 (1.232) | 0.132** (3.112) | 0.081** (2.313) | 0.064** (1.979) |
| $W_t$ | 0.096** (2.401) | 0.060* (1.729) | 0.051* (1.657) | 0.031 (0.987) | 0.078** (2.077) | 0.039* (1.783) | 0.184** (4.263) | 0.046 (1.349) | 0.015 (0.470) |
| $H_t$ | 0.005 (0.114) | −0.015 (−0.441) | 0.007 (0.243) | −0.011 (−0.377) | 0.068* (1.730) | 0.004 (0.162) | 0.085** (2.005) | 0.028 (0.830) | −0.023 (−0.731) |
| $F_t$ | 0.086** (2.000) | −0.016 (−0.449) | −0.010 (−0.325) | −0.023 (−0.716) | 0.137** (3.555) | −0.020 (−0.871) | 0.204** (4.567) | 0.086** (2.373) | −0.027 (−0.771) |
| Panel B: variance specification | | | | | | | | | |
| *Constant* | −0.037** (−8.615) | −0.010** (−4.988) | −0.007** (−3.951) | −0.005** (−2.763) | −0.027** (−4.163) | 0.0002 (0.117) | −0.051** (−8.313) | −0.014** (−3.937) | −0.003** (−2.704) |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $\log h_{t-1}^2$ | 0.963$^{**}$ (309.1) | 0.983$^{**}$ (535.4) | 0.985$^{**}$ (570.18) | 0.713$^{**}$ (7.318) | 0.766$^{**}$ (11.991) | 0.742$^{**}$ (9.317) | 0.952$^{**}$ (229.15) | 0.798$^{**}$ (11.935) | 0.989$^{**}$ (662.48) |
| $\log h_{t-2}^2$ | | | | 0.272$^{**}$ (2.811) | −0.117 (−1.232) | −0.127 (−1.109) | | −0.164$^{*}$ (−1.665) | |
| $\log h_{t-3}^2$ | | | | | 0.323$^{**}$ (5.508) | 0.372$^{**}$ (5.070) | | 0.341$^{**}$ (5.515) | |
| $\left(\left\|\frac{\varepsilon_{t-1}}{h_{t-1}}\right\| - E\left\|\frac{\varepsilon_{t-1}}{h_{t-1}}\right\| + \chi\frac{\varepsilon_{t-1}}{h_{t-1}}\right)$ | 0.200$^{**}$ (21.55) | 0.136$^{**}$ (17.08) | 0.150$^{**}$ (18.403) | 0.157$^{**}$ (11.464) | 0.329$^{**}$ (15.321) | 0.234$^{**}$ (12.875) | 0.272$^{**}$ (21.060) | 0.262$^{**}$ (15.058) | 0.115$^{**}$ (16.503) |
| $\chi$ | −0.528$^{**}$ (12.81) | −0.613$^{**}$ (11.57) | −0.578$^{**}$ (12.25) | −0.581$^{**}$ (11.486) | −0.380$^{**}$ (8.622) | −0.423$^{**}$ (8.166) | −0.381$^{**}$ (11.310) | −0.417$^{**}$ (10.00) | −0.491$^{**}$ (10.097) |
| *Function Value* | −3076.3 | −6185.16 | −6403.69 | −7342.79 | −1264.62 | −5731.77 | −2022.76 | −4656.49 | −8045.41 |
| *Test Statistics* | 39.120$^{**}$ | 10.408$^{**}$ | 7.252 | 5.552 | 6.700 | 4.024 | 41.784$^{**}$ | 22.708$^{**}$ | 6.06 |
| Panel C: robustness statistics | | | | | | | | | |
| Lag(s) | Ljung-Box Q-Stat | | | | | | | | |
| 5 | [0.105] | [0.879] | [0.874] | [0.835] | [0.222] | [0.520] | [0.000]$^{**}$ | [0.329] | [0.579] |
| 10 | [0.262] | [0.892] | [0.829] | [0.878] | [0.493] | [0.798] | [0.002]$^{**}$ | [0.744] | [0.614] |
| 20 | [0.104] | [0.732] | [0.511] | [0.589] | [0.325] | [0.556] | [0.003]$^{**}$ | [0.456] | [0.523] |
| 60 | [0.058]$^{*}$ | [0.435] | [0.262] | [0.438] | [0.083]$^{*}$ | [0.199] | [0.004]$^{**}$ | [0.065]$^{*}$ | [0.302] |
| Lag(s) | ARCH- LM tests | | | | | | | | |
| 5 | [0.967] | [0.963] | [0.899] | [0.453] | [0.407] | [0.011]$^{**}$ | [0.004]$^{**}$ | [0.261] | [0.041]$^{**}$ |
| 10 | [0.995] | [0.997] | [0.985] | [0.653] | [0.622] | [0.035]$^{**}$ | [0.019]$^{**}$ | [0.164] | [0.105] |
| 20 | [0.999] | [0.999] | [0.999] | [0.977] | [0.712] | [0.126] | [0.107] | [0.338] | [0.601] |
| 60 | [0.999] | [0.997] | [0.999] | [0.000]$^{**}$ | [0.044]$^{**}$ | [0.026]$^{**}$ | [0.128] | [0.720] | [0.273] |
| Panel D: non-parametric tests | | | | | | | | | |
| Sign Bias | [0.798] | [0.859] | [0.637] | [0.990] | [0.478] | [0.590] | [0.180] | [0.417] | [0.230] |
| Negative Size | [0.662] | [0.684] | [0.800] | [0.941] | [0.983] | [0.979] | [0.888] | [0.993] | [0.168] |
| Positive Size | [0.332] | [0.371] | [0.612] | [0.246] | [0.023]$^{**}$ | [0.074]$^{*}$ | [0.927] | [0.211] | [0.013]$^{**}$ |
| Joint Test | [0.640] | [0.424] | [0.545] | [0.491] | [0.119] | [0.027]$^{**}$ | [0.334] | [0.071]$^{*}$ | [0.019]$^{**}$ |

[a] *t*-statistics are reported in parentheses and *p*-values are reported in brackets

* Indicates the level of significance at the 10% level. ** Indicates the level of significance at the 5% level

**Table 5** Day-of-the-week effect on return-volatility relationships for the January 02, 1997 to September 29, 2006 period[a]

| | NYSE | | S&P500 | | NASDAQ | | AMEX | | DOW |
|---|---|---|---|---|---|---|---|---|---|
| | Equal | Value | Equal | Value | Equal | Value | Equal | Value | Equal |
| Panel A: return specification | | | | | | | | | |
| $M_t$ | −0.027 (−0.594) | −0.042 (−0.682) | −0.064 (−0.962) | −0.025 (−0.384) | −0.014 (−0.281) | 0.081 (1.092) | −0.035 (−0.96) | 0.01 (0.171) | 44.72** (4.932) |
| $U_t$ | −0.092* (−1.865) | −0.053 (−0.901) | −0.024 (−0.376) | −0.081 (−1.362) | −0.15** (−3.21) | 0.008 (0.11) | −0.1** (−2.69) | −0.097 (−1.564) | −20.84** (−2.353) |
| $W_t$ | −0.009 (−0.192) | 0.018 (0.298) | 0.088 (1.295) | 0.046 (0.713) | 0.083 (1.536) | 0.116 (1.491) | −0.018 (−0.476) | 0.06 (0.953) | −20.28** (−2.396) |
| $H_t$ | 0.016 (0.344) | 0.012 (0.196) | −0.01 (−0.155) | −0.008 (−0.131) | 0.036 (0.72) | −0.085 (−1.099) | 0.019 (0.491) | 0.014 (0.23) | 9.809 (1.188) |
| $F_t$ | −0.024 (−0.5) | 0.006 (0.09) | −0.035 (−0.502) | −0.029 (−0.440) | 0.098* (1.882) | −0.063 (−0.769) | 0.123** (3.075) | 0.075 (1.18) | 5.776 (0.641) |
| $R_{t-1}$ | 0.196** (8.876) | 0.038 (1.681) | 0.041* (1.905) | −0.012 (−0.522) | 0.228** (9.975) | 0.026 (1.187) | 0.268** (11.91) | 0.117** (5.306) | 0.221** (10.02) |
| $R_{t-2}$ | 0.017 (0.803) | −0.019 (−0.906) | −0.016 (−0.764) | −0.017 (−0.825) | 0.038* (1.682) | −0.026 (−1.206) | 0.064** (3) | −0.014 (−0.608) | −0.113** (−5.162) |
| $R_{t-3}$ | 0.085** (4.056) | 0.001 (0.06) | 0.01 (0.463) | −0.003 (−0.148) | 0.107** (4.984) | 0.024 (1.188) | 0.093** (4.245) | 0.046** (2.192) | 0.055** (2.626) |
| $R_{t-4}$ | 0.028 (1.37) | −0.001 (−0.045) | 0.007 (0.321) | 0.002 (0.090) | 0.037* (1.823) | 0.01 (0.499) | 0.063** (2.995) | 0.001 (0.056) | 0.042** (1.996) |
| $R_{t-5}$ | 0.013 (0.649) | −0.019 (−0.969) | −0.007 (−0.336) | −0.011 (−0.530) | 0.043** (2.07) | 0.003 (0.147) | 0.024 (1.166) | 0.015 (0.762) | |
| $R_{t-6}$ | 0.008 (0.38) | | | | 0.02 (0.977) | −0.006 (−0.302) | 0.02 (0.967) | 0.007 (0.338) | |
| $R_{t-7}$ | −0.026 (−1.251) | | | | −0.024 (−1.132) | −0.005 (−0.238) | −0.026 (−1.288) | −0.013 (−0.652) | |
| $R_{t-8}$ | 0.064** (3.198) | | | | 0.0505** (2.489) | 0.0226 (1.122) | 0.043** (2.196) | 0.0575** (2.907) | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $R_{t-9}$ | 0.014 | | | | 0.012 | 0.009 | 0.006 | −0.001 | |
| | (0.692) | | | | (0.598) | (0.441) | (0.296) | (−0.053) | |
| $R_{t-10}$ | 0.019 | | | | 0.008 | 0.019 | 0.023 | 0.007 | |
| | (0.97) | | | | (0.387) | (0.924) | (1.263) | (0.346) | |
| $R_{t-11}$ | 0.039** | | | | 0.0375* | 0.0178 | 0.014 | 0.027 | |
| | (2.033) | | | | (1.924) | (0.892) | (0.758) | (1.413) | |
| $R_{t-12}$ | 0.042** | | | | 0.051** | 0.074** | 0.014 | 0.025 | |
| | (2.303) | | | | (2.657) | (3.686) | (0.784) | (1.307) | |
| $R_{t-13}$ | | | | | | | 0.025 | | |
| | | | | | | | (1.317) | | |
| $R_{t-14}$ | | | | | | | −0.017 | | |
| | | | | | | | (−0.884) | | |
| $R_{t-15}$ | | | | | | | −0.0004 | | |
| | | | | | | | (−0.025) | | |
| $M_t$ | −0.005 | 0.13* | 0.126** | 0.084 | −0.06 | −0.017 | −0.249** | −0.046 | −0.017** |
| | (−.051) | (1.795) | (1.995) | (1.415) | (−0.927) | (−0.533) | (−1.945) | (−0.576) | (−6.205) |
| $U_t$ | 0.274** | 0.106 | 0.046 | 0.100* | 0.216** | 0.01 | 0.349** | 0.144* | 0.008** |
| | (2.29) | (1.458) | (0.698) | (1.715) | (3.29) | (0.304) | (2.659) | (1.746) | (2.959) |
| $W_t$ | 0.095 | 0.029 | −0.017 | 0.006 | −0.01 | −0.003 | 0.138 | −0.012 | 0.007** |
| | (0.817) | (0.397) | (−0.262) | (0.095) | (−0.15) | (−0.086) | (1.004) | (−0.141) | (2.673) |
| $H_t$ | 0.011 | 0.01 | 0.049 | 0.035 | 0.065 | 0.04 | 0.101 | 0.045 | −0.0004 |
| | (0.097) | (0.142) | (0.754) | (0.581) | (0.945) | (1.229) | (0.775) | (0.561) | (−0.177) |
| $F_t$ | 0.353** | 0.06 | 0.081 | 0.034 | 0.141** | 0.022 | 0.406** | 0.087 | 0.003 |
| | (2.94) | (0.78) | (1.159) | (0.547) | (2.141) | (0.651) | (2.948) | (0.998) | (1.251) |
| Panel B: variance specification | | | | | | | | | |
| *Constant* | −0.053** | −0.007* | −0.0002 | 0.002 (0.469) | −0.016** | 0.01** | −0.107** | −0.015** | 0.962** |
| | (−5.052) | (−1.823) | (−0.08) | | (−2.46) | (2.265) | (−5.600) | (−2.664) | (6.233) |
| $\log h^2_{t-1}$ | 0.944** | 0.971** | 0.983** | 0.913** | 1.209** | 1.13** | 0.917** | 1.208** | 0.881** |
| | (99.232) | (164.60) | (233.35) | (4.942) | (8.571) | (7.667) | (68.606) | (7.709) | (46.29) |
| $\log h^2_{t-2}$ | | | | 0.063 | −0.63** | −0.65** | | −0.666** | |
| | | | | (0.344) | (−3.157) | (−3.056) | | (−2.917) | |
| $\log h^2_{t-3}$ | | | | | 0.377** | 0.508** | | 0.416 ** | |
| | | | | | (4.145) | (4.432) | | (3.816) | |

**Table 5** (continued)

| | NYSE | | S&P500 | | NASDAQ | | AMEX | | DOW |
|---|---|---|---|---|---|---|---|---|---|
| | Equal | Value | Equal | Value | Equal | Value | Equal | Value | Equal |
| $\left(\left\lvert\frac{\varepsilon_{t-1}}{h_{t-1}}\right\rvert - E\left\lvert\frac{\varepsilon_{t-1}}{h_{t-1}}\right\rvert + \chi\frac{\varepsilon_{t-1}}{h_{t-1}}\right)$ | 0.149** (5.851) | 0.108** (5.513) | 0.08** (5.202) | 0.126** (4.814) | 0.243** (6.765) | 0.165** (6.241) | 0.274** (8.801) | 0.161** (6.166) | 0.076** (4.067) |
| $\chi$ | −1.018** (5.164) | −1.094** (4.932) | −1.223** (4.524) | −0.985** (5.387) | −0.56** (5.749) | −0.624** (5.424) | −0.495** (6.135) | −0.838** (5.619) | −1.844** (3.952) |
| *Function Value* | −891.88 | −1764.7 | −2004.2 | −2072.1 | −1578.0 | −3031.2 | −401.1 | −1607.5 | −12101 |
| *Test Statistics* | 7.30 | 1.78 | 2.08 | 1.06 | 10.74** | 14.78** | 11.74 | 2.9 | 70.42** |
| Panel C: robustness statistics | | | | | | | | | |
| Lag(s) | Ljung-Box Q-Stat | | | | | | | | |
| 5 | [0.968] | [0.983] | [0.984] | [0.406] | [0.773] | [0.939] | [0.191] | [0.947] | [0.301] |
| 10 | [0.999] | [0.572] | [0.823] | [0.209] | [0.981] | [0.992] | [0.572] | [0.994] | [0.416] |
| 20 | [0.999] | [0.514] | [0.549] | [0.486] | [0.997] | [0.931] | [0.870] | [0.984] | [0.205] |
| 60 | [0.423] | [0.080] * | [0.031] ** | [0.281] | [0.662] | [0.858] | [0.645] | [0.819] | [0.038] ** |
| Lag(s) | ARCH- LM tests | | | | | | | | |
| 5 | [0.449] | [0.819] | [0.682] | [0.000] ** | [0.002] ** | [0.006] ** | [0.117] | [0.102] | [0.994] |
| 10 | [0.723] | [0.870] | [0.934] | [0.000] ** | [0.014] ** | [0.089] * | [0.372] | [0.378] | [0.999] |
| 20 | [0.967] | [0.988] | [0.988] | [0.000] ** | [0.109] | [0.378] | [0.821] | [0.709] | [0.999] |
| 60 | [0.196] | [0.565] | [0.481] | [0.084] * | [0.231] | [0.681] | [0.840] | [0.766] | [0.911] |
| Panel D: non-parametric tests | | | | | | | | | |
| Sign Bias | [0.085] | [0.271] | [0.113] | [0.704] | [0.040] ** | [0.999] | [0.654] | [0.165] | [0.589] |
| Negative Size | [0.252] | [0.650] | [0.694] | [0.963] | [0.004] ** | [0.327] | [0.609] | [0.159] | [0.608] |
| Positive Size | [0.728] | [0.054] * | [0.244] | [0.097] * | [0.203] | [0.075] | [0.726] | [0.538] | [0.051] * |
| Joint Test | [0.133] | [0.004] ** | [0.009]v | [0.080] * | [0.003] ** | [0.202] | [0.872] | [0.195] | [0.004] ** |

[a] *t*-statistics are reported in parentheses and *p*-values are reported in brackets

* Indicates the level of significance at the 10% level. ** Indicates the level of significance at the 5% level

Damodaran (1985), Admati and Pfleiderer (1988), Ross (1989) and Foster and Viswanathan (1990) provide theoretical justification for the different equity premiums on Mondays. These papers conclude that return volatility changes because of trades related to private information. Foster and Viswanathan (1990) note that informed traders receive information each weekday and argue that the informed trader has a greater advantage on Mondays. Therefore, due to adverse selection, liquidity trading decreases on Mondays. This also decreases trading volume. Finally, higher volatility due to lower volume is associated with lower returns. As a second explanation, Dyl and Maberly (1988), Patell and Wolfson (1982) and Fishe et al. (1993) claim that good news is released during the week while bad news is released over the weekend and that negative Monday returns are more indicative of bad news releases. Since bad news increases volatility more than good news (see Koutmos 1998) higher volatility and lower returns suggest a negative return-volatility relation on Mondays.

The *Test Statistics* in Table 4 is for the null of the estimated coefficient of the return-volatility relationship is the same across each day of the week. To be specific, we tested $H_0$: $\lambda_M=\lambda_U=\lambda_W=\lambda_H=\lambda_F$ versus $H_A$: Not $H_0$ as specified in Eq. 3. We can reject the null hypothesis for the equal- and value-weighted indexes of the NYSE and the AMEX. For the other three indexes, (1) at least 1 day has a positive and statistically significant coefficient at the 10% level and (2) at least one coefficient is not statistically significant. Thus, we cannot support the proposition that the return-volatility relationship is present and the same for each day of the week. The estimates on the conditional variance specification reported in Panel B and the specification test statistics reported in Panel C and D are all parallel to the ones reported in our estimate of the benchmark specification in Table 3. Thus, these also support our specification.

The Electronic Brokers System (EBS) started to be implemented in equity markets in the mid-1990s. After 1996 this transformation was complete (see for example: McAndrews and Stefanadis 2000). EBS provides faster trade execution, lower transaction costs and more complete price information, which makes the financial markets more integrated. Thus, in order to assess the role of EBS on our specification we also estimate the model for post-1996 era; Table 5 reports these estimates. The supporting evidence for two of the five conclusion are now weaker; first, the return-volatility relationships are no longer positive on Wednesdays (statement iii), but this relationship is now positive when the relation is statistically significant. Second, regarding statement iv on Mondays' return-volatility relationship, when the estimated coefficients are statistically significant then they are negative is not true for the value-weighted NYSE. On the other hand, the evidence for the remaining three conclusions is robust: the results on the return-volatility relationship for Tuesdays are always positive and generally significant (statement i) are true; the statement for each of the indexes that we consider (statement iii) is true for all the indexes but for the NASDAQ value-weighted index. Statement v, that if the Friday return-volatility relationships are statistically significant, then the estimated coefficients are positive, is also true. Thus we can claim that even if some of the general patterns on the return-volatility relationship across days changed with EBS, others persist for the sub-period that we consider here. Thus our claim that return-volatility relationship changes across each day of the week persists.

## 4 Conclusions

This paper examines the presence and the constancy of the return-volatility relationship across the days of the week for the equal- and value-weighted NYSE, S&P500, NASDAQ, AMEX and equal-weighted DOW index covering the period from May 26, 1952 to September 29, 2006. When the EGARCH specification is used for estimating the volatility under the assumption that the return-volatility relationship of each market is constant throughout each day of the week, we obtain results that are similar to previous findings. However, when conditional risk is allowed to vary across the days of the week, the empirical findings do not support the proposition that a return-volatility relationship is present and the same for each day of the week.

## References

Admati AR, Pfleiderer P (1988) A theory of intraday trading patterns: volume and price variability. Rev Financ Stud 1:3–40

Agrawal A, Tandon K (1994) Anomalies or illusions? Evidence from stock markets in eighteen countries. J Int Money Financ 13:83–106

Bali TG, Peng L (2006) Is there a risk-return tradeoff? Evidence from high- frequency data. J Appl Econ 21(8):1169–1198

Bekaert G, Wu G (2000) Asymmetric volatility and risk in equity returns. Rev Financ Stud 13:1–42

Berument H, Kiymaz H (2001) The day of the week effect on stock market volatility. J Econ Finance 25 (2):181–193

Black F (1976) Studies of stock market volatility changes, Proceedings of the American Statistical Association, Business and Economics Statistics Section, 177–181

Bollerslev T, Engle RF, Wooldridge JM (1988) A capital asset pricing model with time varying covariances. J Polit Econ 96:116–131

Bollerslev T, Wooldridge JM (1992) Quasi-maximum likelihood estimation and inference in dynamic models with time-varying covariances. Econom Rev 11:143–172

Campbell JY, Cochrane JH (1999) By force of habit: a consumption- based explanation of aggregate stock market behavior. J Polit Econ 107(2):205–251

Campbell JY, Hentschel L (1992) No news is good news: an asymmetric model of changing volatility in stock returns. J Financ Econ 31:281–318

Chang E, Pinegar MJ, Ravichandran R (1993) International evidence on the robustness of the day of the-week effect. J Financ Quant Anal 28:497–513

Cheung Y, Ng LK (1992) Stock price dynamics and firm size: an empirical investigation. J Finance 47 (5):1985–1997

Cosimano T, Dennis J (1988) Estimation of the variance of US inflation based upon the ARCH model. J Money, Credit Bank 20(3):409–423

Cox JC, Ross S (1976) A survey of some new results in financial option pricing theory. J Finance 31:382–402

Cross F (1973) The behaviour of stock prices on fridays and mondays. Financ Anal J 31(6):67–69

Damodaran A (1985) Economic events, information structure and the return-generating process. J Financ Quant Anal 20:423–434

Dubois M, Louvet P (1996) The day-of-the-week effect: international evidence. J Bank Financ 20:1463–1484

Dyl EA, Maberly ED (1988) The anomaly that isn't there: a comment on friday the thirteenth. J Finance 43(5):1285–1286, American Finance Association

Ederington LH, Lee JH (1993) How markets process information: news releases and volatility. J Finance 48:1161–1191

Fishe RPH, Gosnell TF, Lasser DJ (1993) Good news, bad news, volume, and the Monday effect. J Bus Finance Account 20(6):881–892

Foster FD, Viswanathan S (1990) A theory of interday variations in volumes, variances and trading costs in security markets. Rev Financ Stud 3:593–624

Foster FD, Viswanathan S (1993) Variations in trading volume, return volatility, and trading costs: evidence on recent price formation models. J Finance 48:187–211

Franses PH, Paap R (2000) Modelling day-of-the-week seasonality in the S&P 500 index. Appl Financ Econ 10:483–488

French K (1980) Stock seturns and the weekend effect. J Financ Econ 8(1):55–69

French, Kenneth R and Roll Richard, 1986, "Stock Return Variances: The Arrival of Information and the Reaction of Traders" in *Advances in Behavioral Finance*, Thaler, R.H. (ed.), 1993, pp. 219–45, New York: Russell Sage Foundation.

Ghysels E, Clara PS, Valkanov R (2005) There is a risk-return tradeoff after all. J Financ Econ 76(3):509–548

Gibbons M, Hess P (1981) Day of the week effect and asset returns. J Bus 54:579–596

Harvey CR (1989) Time-varying conditional covariances in tests of asset pricing models. J Financ Econ 24:289–317

Jaffe J, Westerfield R, Ma C (1989) A twist on the monday effect in stock prices: evidence from the U.S. and foreign stock markets. J Bank Financ 13:641–650

Kim D, Kon SJ (1994) Alternative models for the conditional heteroscedasticity of stock returns. J Bus 67 (4):563–598

Kiymaz H, Berument H (2003) The day of the week effect on stock market volatility and volume: international evidence. Rev Financ Econ 12:363–380

Koutmos G (1998) Asymmetries in the conditional mean and the conditional variance: evidence from nine stock markets. J Econ Bus 50:277–290

Linter J (1965) The valuation of risky assets and the selection of risky investments in stock portfolios and capital budgets. Rev Econ Stat 47:13–37

Lakonishok J, Levi M (1982) Weekend effects on stock returns: a note. J Finance 37:883–889

Lakonishok J, Maberly ED (1990) The weekend effect: trading patterns of ındividual and ınstitutional ınvestors. J Finance 45:231–243

McAndrews J, Stefanadis C (2000) The emergence of electronic communications networks in the U.S. equity markets. Federal reserve bank of New York. Current Issues in Economics and Finance 6(12):1–6

Merton RC (1973) An intertemporal capital asset pricing model. Econometrica 41:867–887

Mookerjee R, Yu Q (1999) An empirical analysis of the equity markets in China. Rev Financ Econ 8:41–60

Nelson DB (1991) Conditional heteroskedaticity in asset returns: a new approach. Econometrica 59 (2):347–370

Osborne MFM (1962) Periodic structure in the Brownian motion of the stock markets. Oper Res 10:345–379

Pagan A (1984) Econometric ıssues in the analysis of regressions with generated regressors. Int Econ Rev 25:221–247

Pagan AR, Ulah A (1988) The econometric analysis models with risk terms. J Appl Econ 3:87–105

Patell JM, Wolfson MA (1982) Good news, bad news and the ıntraday timing of corporate disclosures. The Accounting Review 509–527

Ross SA (1989) Information and volatility: the no-arbitrage martingale approach to trading and resolution irrelevancy. J Finance 44:1–18

Savva CS, Osborn DR, Gill L (2006) The day of the week effect in fifteen European Stock Markets. University of Manchester

Scruggs JT (1998) Resolving the puzzling intertemporal relation between the market risk premium and conditional market variance: A two-factor approach. J Finance 53:575–603

Sharpe WF (1964) Capital asset prices: a theory of market equilibrium under conditions of market risk. J Finance 19:425–442

Smirlock M, Starks L (1986) Day of the week and intraday effects in stock returns. J Financ Econ 17:197–210

Whitelaw R (2000) Stock market risk and return: an empirical equilibrium approach. Rev Financ Stud 13:521–547