The Impact of Weekly Time Period Choice on Volume and Size Cross-Autocorrelations

Eric Higgins*
Kansas State University

Amir Tavakkol
Kansas State University

This study determines if the U-shaped pattern that Boudoukh, Richardson, and Whitelaw (1994) find in weekly return autocorrelations exists for weekly return cross-autocorrelations. Using size-sorted and volume-sorted portfolios of equity returns from 1963-2000, we find that the U-shaped pattern observed for autocorrelations does not exist for cross-autocorrelations in size or volume sorted return portfolios, consistent with the findings of Boudoukh, Richardson, and Whitelaw. Our results are shown to be robust after controlling for the Fama and French (1993) factors and for prior market condition.

Introduction

Several studies show that significant cross-autocorrelations exist in weekly security returns. Lo and MacKinlay (1990) find that significant size-based cross-autocorrelations exist in weekly returns, specifically showing that large firm returns lead small firm returns. Chordia and Swaminathan (2000) show that significant volume-based cross-autocorrelations exist in security returns, where high volume stocks lead low volume stocks, after controlling for size. They control for size by sorting returns on size and then, within each size portfolio, sorting on volume. Both studies use weekly returns formed from Wednesday close to the following Wednesday close.[1]

Boudoukh, Richardson, and Whitelaw (1994) find that autocorrelations calculated from weekly returns are significantly larger when calculated using a Monday to Friday week as compared to other weekly periods. For example, for the 1984-1990

[1] Chordia and Swaminathan (2000) also use Friday to Friday and Tuesday to Tuesday periods to form returns and note that results are similar.

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time period, Boudoukh, Richardson, and Whitelaw find first-order autocorrelations for the weeks ending with Monday, Tuesday, Wednesday, Thursday, and Friday of 0.325, 0.273, 0.268, 0.281, and 0.352, respectively. They find that this U-shaped pattern in autocorrelations is consistent across other time periods and across different sampling methods. Boudoukh, Richardson, and Whitelaw explore many possible explanations for this phenomenon and attribute this phenomenon to the importance of weekend return patterns.

The weekly autocorrelation pattern found by Boudoukh, Richardson, and Whitelaw (1994) is consistent with results found in daily return studies. Keim and Stambaugh (1984), Bessembinder and Hertzel (1993), and Abraham and Ikenberry (1994) all find that daily autocorrelations are significantly larger around the weekend than at other times during the week. Higgins and Peterson (1999) examine size-based cross-autocorrelation patterns around the weekend and find that the autocorrelation pattern found by Bessembinder and Hertzel subsumes any significant cross-autocorrelation patterns in returns around the weekend.

Brock and Kleidon (1992) provide a model to explain the U-shaped intra-day patterns observed in most financial markets. They suggest that information arrives during trading stoppages, making end-of-the-day positions different from the optimal position. This deviation from the optimal position necessitates trading at the open. If some of the new information that arrives during a trading stoppage is based on trading prior to the stoppage, some traders (notably individuals) will trade based on the price movements prior to the pause in trading. This generates higher autocorrelations around a trading stoppage. This model, if applied to weekend-related trading stoppages, provides further support for the assertion of Boudoukh, Richardson, and Whitelaw (1994) that the U-shaped pattern observed in autocorrelations is associated with the weekend.

The literature has not, however, simultaneously examined the significance of weekly autocorrelations and cross-autocorrelations using different week-ending definitions. If the U-shaped pattern observed in weekly autocorrelations is also observed in cross-autocorrelations, one can conclude that cross-autocorrelations and autocorrelations are independent sources of return predictability. If cross-autocorrelations are an explanation for portfolio return autocorrelation, as suggested by Lo and MacKinlay (1990), cross-autocorrelation patterns in weekly returns should subsume any autocorrelation patterns found in returns. If a pattern in weekly cross-autocorrelations does not exist while a pattern does exist in autocorrelations, this would provide further evidence supporting the argument of Boudoukh, Richardson, and Whitelaw (1994) that cross-autocorrelations are simply a manifestation of portfolio return autocorrelation and contemporaneous cross-correlation in security returns. Thus, examining the weekly pattern that exists in return cross-autocorrelations provides further evidence regarding the validity of cross-autocorrelations as a significant source of predictability in security returns.

In this paper, we examine the patterns of weekly autocorrelations and cross-autocorrelations with alternate week-ending definitions. We use both size-sorted portfolios and volume-sorted portfolios of weekly returns to study these patterns in order to separate the findings of Chordia and Swaminathan (2000) (volume-based cross-autocorrelations) with those of Lo and MacKinlay (1990) (size-based cross-autocorrelations). Our results extend the existing literature in several ways. First, we examine the significance of, and patterns in, weekly size and volume cross-autocorrelations. Second, following Higgins and Peterson (2001), we examine the robustness of any weekly cross-autocorrelation patterns by controlling for autocorrelations and the Fama and French (1993) factors. Third, we detail the significance of weekly cross-autocorrelations in volume-sorted and size-sorted portfolios by examining different sub-periods of the data and by examining both good and bad market conditions, as suggested by McQueen, Thorley, and Pinegar (1996).

We find in examining autocorrelations and cross-autocorrelations independently that a U-shaped pattern exists in both. After controlling for autocorrelations and the Fama and French (1993) factors, however, weekly cross-autocorrelations are largely insignificant and do not have any discernable patterns. The U-shaped pattern in autocorrelations that is associated with the weekend, originally documented by Boudoukh, Richardson, and Whitelaw (1994), remains significant after controlling for cross-autocorrelations and the Fama and French factors. The U-shaped pattern in autocorrelations does vary, however, over time and with market condition (good news versus bad news).

Literature Review

Lo and MacKinlay (1990) and Mech (1993) argue that cross-autocorrelations in portfolio returns are an explanation for portfolio return autocorrelation. Thus, it follows that autocorrelation patterns found in security returns should be explained by cross-autocorrelation patterns in returns. This suggestion is contrary to Boudoukh, Richardson, and Whitelaw (1994) who show that cross-autocorrelations could be a manifestation of portfolio return autocorrelation and contemporaneous cross-security correlation.

Boudoukh, Richardson, and Whitelaw (1994) use a simple model to show that the observed cross-correlation between large and small size-sorted portfolio returns is a spurious correlation. Based on the assumption that lagged portfolio returns completely describe the conditional expected return for that portfolio, they derive the first-order cross-correlation of returns for two portfolios (R_{it} and $R_{j,t}$) as:

$$\text{Corr}\,(R_{it}, R_{jt-1}) = \text{Corr}\,(R_{it}, R_{jt}) * \text{Corr}\,(R_{it}, R_{it-1}) \tag{1}$$

In this equation, the observed cross-autocorrelations are spuriously caused by the contemporaneous correlation across equity returns and portfolio return autocorrelation. If some asset prices are slow in responding to the news, or, as argued by many momentum theorists, some investors purchase stocks after the prices have already gone up, asset returns would be autocorrelated. Therefore, the essence of Boudoukh, Richardson, and Whitelaw's argument is that the observed cross-autocorrelation of portfolio returns is generated by the contemporaneous spread of information throughout the return measurement period and the inherent momentum of returns.

Early empirical research by Lo and MacKinlay (1990) and Chan (1993), supported the existence of significant cross-autocorrelations in security returns based upon theories of differential information across market participants. Recent research has been mixed in its support for the existence of significant cross-autocorrelations in security returns. Higgins and Peterson (1999) cast some doubt on the significance of cross-autocorrelations in daily security returns. McQueen, Thorley, and Pinegar (1996) show that size-based cross-autocorrelations exist only following good news in the market. Hameed (1997) shows that cross-autocorrelations are not significant after controlling for time-varying risk factors. Higgins and Peterson (2001) combine the work of McQueen, Thorley, and Pinegar and Hameed by examining the significance of daily cross-autocorrelations after controlling for good and bad news and for the Fama and French (1993) factors. Higgins and Peterson find that cross-autocorrelations in size-sorted daily returns are significant after controlling for the Fama and French (1993) factors and for portfolio return autocorrelation. They also find that cross-autocorrelations are only significant in daily returns following bad news. Thus, the issue of whether cross-autocorrelations represent a significant source of predictability in returns remains an open question.

Recently, Chordia and Swaminathan (2000) make a case that cross-autocorrelations should exist based on volume as opposed to size. They show that the delayed stock price reaction to market-wide information is a function of trading volume, turnover, and size. Size and trading volume of an equity represent the availability of information about the firm. Furthermore, the production and distribution of information among investors also plays a role in the speed of adjustment to new information. The availability and flow of information among investors improves over time as trading occurs. If a delayed reaction to new information is the cause for significant autocorrelations and cross-autocorrelations, improvement in the amount and availability of information should reduce the significance of autocorrelations and cross-autocorrelations. Fargher and Weigand (1998) support this assertion by showing that the significance of cross-autocorrelations has declined over time. Thus, it is important to examine the significance of autocorrelations and cross-autocorrelations over time in a variety of models using different weekly time periods to calculate returns. These tests would indicate whether the increase in the availability of information has caused any changes in the significance of autocorrelations, the significance of cross-autocorrelations, the size-volume controversy, and finally the U-shaped patterns observed in weekly autocorrelations.

Data and Methodology

Data

Five size-sorted and five volume-sorted portfolios of weekly security returns are created from the CRSP data base for NYSE/AMEX securities from July 1, 1963, to December 29, 2000.[2] Return portfolios for each data set are formed yearly based on prior year values for size and volume. Size is defined as the market value of equity on the last trading day of the prior year and volume is defined as the average daily trading volume over the prior year.

To be included in the portfolio formation process for size or volume, a firm must not have more than two consecutive non-trading days during the year. This screen eliminates firms with excessive non-trading, which may induce spurious predictability in returns. This criterion eliminates firms that have been delisted and those firms that switch markets.

To be included in the size-sorted portfolios, a firm must have a closing price and number of shares outstanding available on the last trading day of the year. To be included in the volume-sorted portfolios, a firm's volume record on the CRSP database must not begin or end during the prior year. This ensures that a firm has a complete volume record over the previous year. After identifying the securities to be included in the portfolio formation process for a given year, the securities are sorted into five portfolios, for both size and volume. Portfolios are reformed yearly. After identifying the securities eligible for inclusion in the size and volume portfolios, average weekly returns for the portfolios are calculated using each possible week-ending day. Thus, there are five different weekly return portfolios for size and for volume creating ten total data sets that are used in this study.

Methodology

To examine if the U-shaped pattern in autocorrelations exists in cross-autocorrelations, size-based and volume-based cross-autocorrelations of one lag are generated for all possible week-ending day choices.[3] Pearson product-moment correlations are used to calculate the cross-autocorrelation matrices.

We spilt our sample based upon the previous week's market return, as measured by the Fama and French (1993) market risk premium (MRP). If the previous week's MRP is positive, the observation is categorized as good-news and if the previous week's MRP is negative, it is categorized as bad-news. This allows us to examine if the good-news effect in cross-autocorrelations identified by McQueen, Thorley, and

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[2] We use July 1, 1963 as our starting date for calculating returns to match starting date of available data for the Fama and French (1993) factors.

[3] While other lags may be significant, for this study it is only necessary to show that a significant U-shaped pattern exists in first-order cross-autocorrelations that is consistent with the pattern in first-order autocorrelations identified by Boudoukh, Richardson, and Whitelaw (1994).

Pinegar (1996) affects the weekly pattern of autocorrelations and cross-autocorrelations.

While the calculation of cross-autocorrelation matrices allows us to determine if a U-shaped pattern exists in cross-autocorrelations, it does not allow us to determine if this pattern is significant after controlling for other factors. Thus, we conduct a series of multiple regressions that account for autocorrelation and for time-varying risk factors, as proxied by the Fama and French (1993) three-factor model. If cross-autocorrelations are a significant source of predictability in weekly returns, they should remain significant after controlling for autocorrelation and the Fama and French factors. Also, we should observe a U-shaped pattern in cross-autocorrelations that is consistent with the pattern in autocorrelations identified by Boudoukh, Richardson, and Whitelaw (1994).

In our regressions, the smallest size (volume) portfolio return is the dependent variable. We examine two regression equations.

$$R_{1,t} = \alpha + \beta_1 R_{1,t-1} + \beta_2 R_{5,t-1} \quad (2)$$

$$R_{1,t} = \alpha + \beta_1 R_{1,t-1} + \beta_2 R_{5,t-1}\ \beta_3 MRP_t + \beta_4 SMB_t + \beta_5 HML_t \quad (3)$$

In the two equations, $R_{1,t}$ is the return for the smallest size (volume) portfolio in week t. $R_{1,t-1}$ and $R_{5,t-1}$ are the returns for the smallest and largest size (volume) portfolio in week t-1, respectively. MRP_t, SMB_t, and HML_t are the Fama and French (1993) factors, representing market risk premium, size, and book-to-market equity factors in week t, respectively.[4] Thus, in these equations, β_1 measures the autocorrelation in the smallest size (volume) portfolio and β_2 measures the cross-autocorrelation in the smallest size (volume) portfolio.

We estimate these two equations for different subsets of our data. We sort our data jointly on time period and on good news/bad news. Fargher and Weigand (1998) hypothesize that the speed at which information is impounded into stock prices has increased over time, which should decrease the significance of cross-autocorrelations in security returns. Fargher and Weigand split their sample into two time periods, with 1976 serving as the breakpoint, to investigate their hypothesis.[5] We use a similar breakpoint to determine if cross-autocorrelations have become less significant over time. Again, following the methodology of McQueen, Thorley, and Pinegar (1996), we identify good news and bad news periods based upon the MRP in the previous week. Thus, we estimate our regression models for five different subsets

[4] Data for the Fama and French (1993) was obtained from Kenneth French's (2003) website. Daily Fama and French factors are available staring July 1, 1963. The daily factors are compounded to form weekly factors using all possible beginning days of the week.
[5] The advent of negotiated commissions and the introduction of the DOT order-routing system occurred around 1976, which motivated their choice of breakpoint.

of our data: all weeks, 1963-1975 and good news, 1963-1975 and bad news, 1976-2000 and good news, and 1976-2000 and bad news.

Results

Cross-Autocorrelation Matrices

Table 1 contains cross-autocorrelations of one lag for size and volume sorted weekly returns for all possible beginning days of the week.[6] For size-based portfolios, correlations are calculated over all weeks, for good news weeks and bad news weeks. These results are reported in the left panel of Table 1. The right panel of Table 1 contains the autocorrelations for volume-based portfolios. In this table, R_1 refers to the smallest size (volume)-sorted portfolio, and R_5 refers to the largest size (volume)-sorted portfolio. Given this definition, autocorrelations appear on the first row of each week definition.

We observe the same weekend pattern in autocorrelations for size-based portfolios that Boudoukh, Richardson, and Whitelaw (1994) report. We find similar patterns in portfolios sorted by volume. Also, our data confirm the findings of Lo and MacKinlay (1990) and Chordia and Swaminathan (2000) that returns of small firms and low volume firms are correlated with lagged values of large firm returns and those of high volume firm returns. This is true for the full sample and the all sub-samples. While we cannot directly test the difference between cross-autocorrelations in the good news environment and in the bad news environment, both autocorrelations and cross-autocorrelations in the good-news environment are generally larger than those in the bad news environment.

For the full-sample, the U-shaped pattern observed in the autocorrelations of weekly returns is also apparent in cross-autocorrelations. Cross-autocorrelations are largest for Monday to Friday weekly returns, decline to a minimum for Wednesday to Tuesday weekly returns, and then increase for the weeks beginning with Thursday and Friday. This can be observed for size-based and volume-based return cross-autocorrelations. Thus, it is possible that the observed U-shaped pattern in autocorrelations identified by Boudoukh, Richardson, and Whitelaw (1994) could be related to cross-autocorrelations in returns.

When examining autocorrelations and cross-autocorrelations for the good news period, the emerging results are similar to those found in the full sample. For the sub-sample of data with negative prior week's MRP, however, a different pattern emerges. The cross-autocorrelations in this case are high for the Monday to Friday week, drop for Tuesday and Wednesday week beginnings, rise to a high level for the week that begins on Thursday, and then fall again for the week beginning on Friday. Boudoukh, Richardson, and Whitelaw (1994) suggest that the U-shaped pattern that

[6] Full cross-autocorrelation matrices were calculated. Results are reported only for the smallest size(volume) portfolio.

they found is related to the weekend effect found in returns. By comparing good news and bad news periods, it can be seen that this result may only apply after good news. Thus, the impact of the weekend on autocorrelations and cross-autocorrelations in weekly returns is dependent upon the prior week's market condition which supports the findings of McQueen, Thorley, and Pinegar (1996).

Table 1—Weekly NYSE/AMEX Size and Volume Autocorrelations and Cross-Autocorrelations

This table presents weekly autocorrelations and cross-autocorrelations for the smallest size and volume sorted portfolios of returns. Autocorrelation and cross-autocorrelation matrices are calculated for all possible accumulation periods for weekly returns. For example, the Wednesday-Tuesday rows contain weekly cross-autocorrelations calculated from returns accumulated over the Wednesday to Tuesday weekly period. The smallest size (volume) portfolio is designated as portfolio 1 and the largest size (volume) portfolio is designated as portfolio 5. $R_{j,t-1}$represents the return for portfolio j, j = 1,...,5, in week t-1. The autocorrelations and cross-autocorrelations are Pearson product-moment correlations. The sample sizes are: Mon.-Fri = 1956, Tues.-Mon = 1955, Weds.-Tues.: 1955, Thurs.-Weds. = 1954, Fri.-Thurs. = 1954

		Size-Sorted Returns			Volume-Sorted Returns		
Accumulation Period		All Days	Good News	Bad News	All Days	Good News	Bad News
Mon.-Fri	$R_{1,t-1}$	0.4205	0.4110	0.3024	0.4536	0.4266	0.3368
	$R_{2,t-1}$	0.4003	0.3960	0.2697	0.4571	0.4364	0.3304
	$R_{3,t-1}$	0.3915	0.3759	0.2730	0.4511	0.4109	0.3416
	$R_{4,t-1}$	0.3626	0.3225	0.2507	0.4307	0.3762	0.3248
	$R_{5,t-1}$	0.2997	0.1943	0.1947	0.3950	0.2966	0.3040
Tues.-Mon.	$R_{1,t-1}$	0.3203	0.3142	0.2168	0.3708	0.3427	0.2778
	$R_{2,t-1}$	0.3403	0.3094	0.1859	0.3683	0.3492	0.2648
	$R_{3,t-1}$	0.2975	0.2911	0.1924	0.3516	0.3215	0.2624
	$R_{4,t-1}$	0.2805	0.2562	0.1832	0.3466	0.3059	0.2545
	$R_{5,t-1}$	0.2406	0.1591	0.1655	0.3189	0.2435	0.2391
Weds.-Tues.	$R_{1,t-1}$	0.3312	0.3345	0.2218	0.3635	0.3549	0.2528
	$R_{2,t-1}$	0.3093	0.3228	0.1823	0.3613	0.3584	0.2405
	$R_{3,t-1}$	0.3019	0.2960	0.1867	0.3467	0.3193	0.2368
	$R_{4,t-1}$	0.2832	0.2546	0.1746	0.3392	0.2994	0.2332
	$R_{5,t-1}$	0.2399	0.1606	0.1367	0.3070	0.2260	0.2103
Thurs.-Weds.	$R_{1,t-1}$	0.3800	0.3303	0.3034	0.4207	0.3500	0.3050
	$R_{2,t-1}$	0.3608	0.2979	0.2834	0.4110	0.3502	0.3162
	$R_{3,t-1}$	0.3565	0.2810	0.2894	0.3960	0.3143	0.3096
	$R_{4,t-1}$	0.3318	0.2403	0.2632	0.3871	0.2891	0.3098
	$R_{5,t-1}$	0.2793	0.1449	0.2040	0.3593	0.2236	0.2942
Fri.-Thurs	$R_{1,t-1}$	0.3987	0.3826	0.2765	0.4211	0.4015	0.2933
	$R_{2,t-1}$	0.3787	0.3657	0.2453	0.4271	0.4087	0.2966
	$R_{3,t-1}$	0.3736	0.3451	0.2546	0.4182	0.3881	0.2938
	$R_{4,t-1}$	0.3485	0.2908	0.2397	0.4039	0.3458	0.2962
.	$R_{5,t-1}$	0.2910	0.1669	0.1931	0.3715	0.2647	0.2819

When we compare the volume-based return portfolios with size-based return portfolios, some other differences appear. For example, volume autocorrelations and cross-autocorrelations are largest when using the Monday to Friday week following both good news and bad news. This indicates a stronger presence of the weekend effect in volume-sorted returns relative to size-sorted returns. Another interesting result is that autocorrelations and cross-autocorrelations are larger for volume portfolios than for those of the size portfolios. This provides some support for the results of Chordia and Swaminathan (2000), which show that volume-based cross-autocorrelations subsume the predictive ability of size-based cross-autocorrelations.

Regression Results

While the cross-autocorrelation matrices show that a U-shaped pattern exists in weekly returns for both autocorrelations and cross-autocorrelations, it cannot be determined if either autocorrelations or cross-autocorrelations are significant after controlling for the other. To examine the joint effect of autocorrelations, cross-autocorrelations, and other effects, we estimate two regression models. Model 1 contains autocorrelation and cross-autocorrelation terms, and Model 2 adds the Fama and French (1993) factors to control for market-wide risk factors. We run both models for all weekly portfolios (with different beginnings of the week) for both the size and volume sorted return portfolios. This allows us to determine if the predictability of returns changes when using different beginning days of the week to calculate weekly returns. Also, we sort our returns jointly on prior market return (good news and bad news) and on time period (1963-1975 and 1976-2000). This allows us to compare our results to those of McQueen, Thorley, and Pinegar (1996), who show that cross-autocorrelations are only significant following good news, and to those of Fargher and Weigand (1998), who show that the significance of cross-autocorrelations declines over time.

Table 2 contains results for size-sorted weekly returns, and Table 3 contains results for volume-sorted returns. In both tables, Panel A contains results for all weeks, Panel B contains results for the 1963-1975 time period and good news, Panel C contains results for the 1963-1975 time period and bad news, Panel D contains results for the 1976-2000 time period and good news, and Panel E contains results for the 1976-2000 time period and bad news.

When examining results for the whole sample of size-sorted returns in Panel A of Table 2, it can be seen that cross-autocorrelations are not significant after controlling for autocorrelation in returns. There is still a U-shaped pattern in autocorrelations, with the largest autocorrelation occurring for the Monday to Friday weekly return. When the Fama and French (1993) factors are included, the autocorrelation terms remain significant and cross-autocorrelations become negative and significant. Again, the autocorrelation terms display the U-shaped pattern documented by Boudoukh, Richardson, and Whitelaw (1994). The negative cross-

Table 2—Autocorrelations, Cross-Autocorrelations, and Fama and French (1993) Factors in Small Size-Sorted Weekly Returns Conditioned on Market Information and Time Period

The following table contains the results of regression models estimating autocorrelations, cross-autocorrelations, and Fama and French (1993) factor betas using the smallest size-sorted portfolio weekly return ($R_{1,t}$) as the dependent variable. $R_{1,t-1}$ and $R_{5,t-1}$ are the returns in week t-1 for the smallest and largest size-sorted portfolios, respectively. MRP, SMB, and HML are the Fama and French (1993) market, size, and book-to-market equity factors in week t, respectively. Regression models are estimated for all possible accumulation periods for weekly returns. In this table, results are conditioned on the prior week's market return and the time period. Panel A contains results for the entire time period, panels B and C contain results for the 1963-1975 sub-period when the prior week's market return is positive and negative. Panels D and E contains results for the 1976-2000 sub-period when the prior week's market return is positive and negative. An asterisk indicates that the regression coefficient is significant at the 5 percent level and a double asterisk indicates significance at the 1 percent level

	Weekly Return Accumulation Period									
	Monday-Friday		Tuesday-Monday		Wednesday-Tuesday		Thursday-Wednesday		Friday-Thursday	
Variable	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Panel A: All Weeks										
$R_{1,t-1}$	0.4074**	0.2633**	0.2977**	0.2178**	0.3216**	0.2055**	0.3559**	0.2078**	0.3788**	0.2432**
$R_{5,t-1}$	0.0326	-0.1407**	0.0446	-0.1333**	0.0196	-0.1465**	0.0505	-0.1194**	0.0404	-0.1339**
MRP		1.1031**		1.1684**		1.1502**		1.1176**		1.1157**
SMB		0.6668**		0.7597**		0.7511		0.7460**		0.6682**
HML		1.0359**		1.1187**		1.2001**		1.1552**		1.0853**
R-squared	0.1771	0.7689	0.1031	0.7775	0.1098	0.7814	0.1451	0.7667	0.1594	0.7813
Panel B: 1963-1975 Sub-Period and Prior Week's Market Return is Positive										
$R_{1,t-1}$	0.3727**	0.1832**	0.2625**	0.1601**	0.3420**	0.1959**	0.2807**	0.1457**	0.3345**	0.1796**
$R_{5,t-1}$	0.0622	-0.1227	0.1585	-0.1041	0.0372	-0.1787*	0.0809	-0.1630*	0.1441	-0.0831
MRP		1.2773**		1.3508**		1.2694**		1.2586**		1.2184**
SMB		1.8585**		1.9396**		1.9568**		2.0241**		1.8549**
HML		0.9200**		1.0577		1.0739**		1.0444**		0.8706**
R-squared	0.1256	0.7891	0.0747	0.8206	0.0965	0.7964	0.0767	0.7712	0.1201	0.7878

Table 2 (continued)—Autocorrelations, Cross-Autocorrelations, and Fama and French (1993) Factors in Small Size-Sorted Weekly Returns Conditioned on Market Information and Time Period

	Weekly Return Accumulation Period								
	Monday-Friday		Tuesday-Monday		Wednesday-Tuesday		Thursday-Wednesday		Friday-Thursday
Variable	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1
Panel C: 1963-1975 Sub-Period and Prior Week's Market Return is Negative									
$R_{1,t-1}$	0.4263**	0.2116**	0.2067	0.1851**	0.1106	0.1713**	0.2592**	0.1682**	0.4706**
$R_{5,t-1}$	-0.3265*	-0.2616**	-0.1637	-0.2913**	0.0183	-0.3012**	0.3727*	-0.1993**	-0.1344
MRP		1.1156**		1.0737**		1.1014**		1.0955**	
SMB		1.3482**		1.4817**		1.5203**		1.4566**	
HML		0.4028**		0.4116**		0.3497**		0.3436**	
R-squared	0.0759	0.9097	0.0134	0.9238	0.0095	0.9322	0.1053	0.9202	0.1098
Panel D: 1976-2000 Sub-Period and Prior Week's Market Return is Positive									
$R_{1,t-1}$	0.5200**	0.3690**	0.3809**	0.02721**	0.3498**	0.2361**	0.4594**	0.2766**	0.4900**
$R_{5,t-1}$	0.0151	-0.1384**	-0.0155	-0.1341**	-0.0148	-0.0880*	-0.0871	-0.1226**	-0.0799
MRP		1.0144**		1.0044**		0.9978**		1.0789**	
SMB		0.8432**		0.8465**		0.8785**		0.9522**	
HML		0.5327**		0.6064**		0.6113**		0.6982**	
R-squared	0.2097	0.7304	0.1235	0.6593	0.1172	0.6756	0.1467	0.7053	0.1731
Panel E: 1976-2000 Sub-Period and Prior Week's Market Return is Negative									
$R_{1,t-1}$	0.2672**	0.1949**	0.2474**	0.1916**	0.4215**	0.2448**	0.3573**	0.2550**	0.1891**
$R_{5,t-1}$	0.1682	-0.0982	0.1599	-0.1095**	-0.1241	-0.1890**	-0.1038	-0.2125**	0.1374
MRP		0.9589**		1.0551**		1.0375**		0.9773**	
SMB		0.7846**		0.8673**		0.9142**		0.7804**	
HML		0.5440**		0.5711**		0.5467**		0.5195**	
R-squared	0.1009	0.7370	0.0830	0.7947	0.1041	0.7834	0.0855	0.7800	0.0522

autocorrelation is difficult to interpret. It is likely that the cross-autocorrelation term becomes significant due to the addition of the Fama and French factors. The factors account for a significant amount of variation in the returns of the smallest size portfolio. Thus, the root mean squared error of Model 2 is significantly less than Model 1. This most likely causes the cross-autocorrelation term to become significant in Model 2. The sign, however, is not consistent with any of the existing theories that explain the existence of cross-autocorrelations in security returns.

When examining the results for the various subsets of the data, appearing in Panels B through E of Table 2, the cross-autocorrelation terms are again insignificant when accounting for autocorrelations and become negative when we account for the Fama and French (1993) factors. Autocorrelations follow the U-shaped pattern identified by Boudoukh, Richardson, and Whitelaw (1994) only in the 1976-2000 subperiod when the prior MRP is positive. Thus, similar to the results found for the cross-autocorrelation matrices, the weekly pattern identified in autocorrelations is not consistent across time.

We do not find that cross-autocorrelations are significant following good news. This is most likely due to the fact that we account for the Fama and French factors. We find that the Fama and French (1993) factors seem to explain more variation in returns in the 1963-1975 time period and autocorrelations are larger in the 1976-2000 time period. The decline in the predictive ability of the Fama and French factors is consistent with the suggestion of Fargher and Weigand (1998) that markets have become more efficient at processing information making returns less predictable. The increase in the size of the autocorrelation coefficient is consistent with the increasing importance of momentum in returns in the more recent time periods.

The results for volume-sorted cross-autocorrelations, found in Panels A through E of Table 3, are different from those found for size-sorted cross-autocorrelations. For all data, volume sorted cross-autocorrelations are significant after controlling for autocorrelations for all weekly return portfolios except the Wednesday to Tuesday return portfolio. The volume cross-autocorrelations are most significant in the 1976-2000 time period when the prior week's MRP is negative. When accounting for the Fama and French (1993) factors, the volume cross-autocorrelations largely become insignificant. In the 1976-2000 time period when the prior week's MRP is negative, volume cross-autocorrelations remain significant after accounting for the Fama and French (1993) factors for Monday to Friday and Friday to Thursday weekly returns. These results suggest that volume cross-autocorrelations are a more significant source of predictability than are size cross-autocorrelations. This result is consistent with the findings of Chordia and Swaminathan (2000). We find that, similar to the results for size-sorted returns, the amount of predictability in returns declines in the 1976-2000 time period, which is again consistent with the results of Fargher and Weigand (1998).

Table 3—Autocorrelations, Cross-Autocorrelations, and Fama and French (1993) Factors in Small Volume-Sorted Weekly Returns Conditioned on Market Information and Time Period

The following table contains the results of regression models estimating autocorrelations, cross-autocorrelations, and Fama and French (1993) factor betas using the smallest volume-sorted portfolio weekly return ($R_{1,t}$) as the dependent variable. $R_{1,t-1}$ and $R_{5,t-1}$ are the returns in week t-1 for the smallest and largest volume-sorted portfolios, respectively. MRP, SMB, and HML are the Fama and French (1993) market, volume, and book-to-market equity factors in week t, respectively. Regression models are estimated for all possible accumulation periods for weekly returns. In this table, results are conditioned on the prior week's market return and the time period. Panel A contains results for the entire time period, panels B and C contain results for the 1963-1975 sub-period when the prior week's market return is positive and negative. Panels D and E contains results for the 1976-2000 sub-period when the prior week's market return is positive and negative. An asterisk indicates that the regression coefficient is significant at the 5 percent level and a double asterisk indicates significance at the 1 percent level

	Weekly Return Accumulation Period									
Variable	Monday-Friday		Tuesday-Monday		Wednesday-Tuesday		Thursday-Wednesday		Friday-Thursday	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Panel A: All Days										
$R_{1,t-1}$	0.3636**	0.2513**	0.3060**	0.2337**	0.3185**	0.2112**	0.3087**	0.1913**	0.3310**	0.2216**
$R_{5,t-1}$	0.1034**	-0.0128	0.0691**	-0.0244	0.0493	-0.0412**	0.1078**	-0.0119	0.1022**	-0.0143
MRP		0.8428**		0.8496**		0.8607**		0.8446**		0.8488**
SMB		0.5347**		0.5777**		0.5751**		0.5868**		0.5597**
HML		0.6748**		0.7010**		0.7690**		0.7719**		0.7221**
R-squared	0.2118	0.8077	0.1404	0.8082	0.1334	0.8157	0.1684	0.8095	0.1830	0.8183
Panel B: 1963-1975 Sub-Period and Prior Week's Market Return is Positive										
$R_{1,t-1}$	0.4100**	0.2797**	0.3070**	0.2661**	0.3761**	0.2834**	0.3464**	0.2357**	0.3572**	0.2478**
$R_{5,t-1}$	0.0916	-0.0606	0.1191	-0.0545	0.0287	-0.1003**	0.0403	-0.0798*	0.1156	-0.0464
MRP		0.9148**		0.9639**		0.9431**		0.8975**		0.8957**
SMB		1.0959**		1.0900**		1.1542**		1.1813**		1.1092**
HML		0.5627**		0.6477**		0.6617**		0.6639**		0.5881**
R-squared	0.1774	0.8414	0.1113	0.8585	0.1169	0.8388	0.1115	0.8209	0.1531	0.8334

Table 3 (continued)—Autocorrelations, Cross-Autocorrelations, and Fama and French (1993) Factors in Small Volume-Sorted Weekly Returns Conditioned on Market Information and Time Period

Variable	Weekly Return Accumulation Period									
	Monday-Friday		Tuesday-Monday		Wednesday-Tuesday		Thursday-Wednesday		Friday-Thursday	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Panel C: 1963-1975 Sub-Period and Prior Week's Market Return is Negative										
$R_{1,t-1}$	0.3392**	0.1776**	0.3182**	0.1640**	0.1803	0.1033**	0.1707	0.1094**	0.4237**	0.2075**
$R_{5,t-1}$	-0.0141	0.0251	-0.1007	-0.0163	0.0141	0.0426	0.3479**	0.0675*	0.0437	0.0128
MRP		0.8837**		0.8432**		0.8693**		0.8746**		0.9128**
SMB		0.7570**		0.8453**		0.9063**		0.8705**		0.8124**
HML		0.4208**		0.4090**		0.3628**		0.3513**		0.4694**
R-squared	0.0824	0.9087	0.0378	0.9197	0.0256	0.9187	0.1393	0.9205	0.1342	0.9209
Panel D: 1976-2000 Sub-Period and Prior Week's Market Return is Positive										
$R_{1,t-1}$	0.4297*	0.3235**	0.3384**	0.2737**	0.3564**	0.2542**	0.3831**	0.2587**	0.4495**	0.3164**
$R_{5,t-1}$	0.0962*	-0.0401	0.0505	-0.0493	0.0096	-0.0485	0.0186	-0.0491	0.0127	-0.0805**
MRP		0.7623**		0.7414**		0.7396**		0.7884**		0.7966**
SMB		0.5850**		0.5248**		0.5689**		0.6474**		0.6090**
HML		0.4610**		0.4764**		0.4649**		0.5299**		0.5492**
R-squared	0.1758	0.7259	0.1150	0.6823	0.1169	0.6950	0.1191	0.7113	0.1618	0.7088
Panel E: 1976-2000 Sub-Period and Prior Week's Market Return is Negative										
$R_{1,t-1}$	0.1982**	0.1217**	0.2186**	0.1404**	0.3214**	0.1757**	0.2505**	0.1473**	0.0869	0.0587*
$R_{5,t-1}$	0.2505**	0.0812*	0.1954**	0.0403	0.0384	-0.0326	0.0635	-0.0290	0.2378**	0.0841**
MRP		0.7508**		0.7963**		0.8185**		0.7998**		0.7935**
SMB		0.5667**		0.6194**		0.6566**		0.6214**		0.6172**
HML		0.5113**		0.5364**		0.5303**		0.5446**		0.4823**
R-squared	0.1382	0.7855	0.1177	0.7996	0.0958	0.8184	0.0741	0.8109	0.0684	0.8325

The volume-sorted returns display the U-shaped pattern in autocorrelations for the full time period, even after controlling for the Fama and French (1993) factors. Similar to the results for the size-sorted portfolios, the U-shaped pattern is not consistent across all of the different time-periods examined. Thus, the impact of the weekend on weekly autocorrelations is not consistent

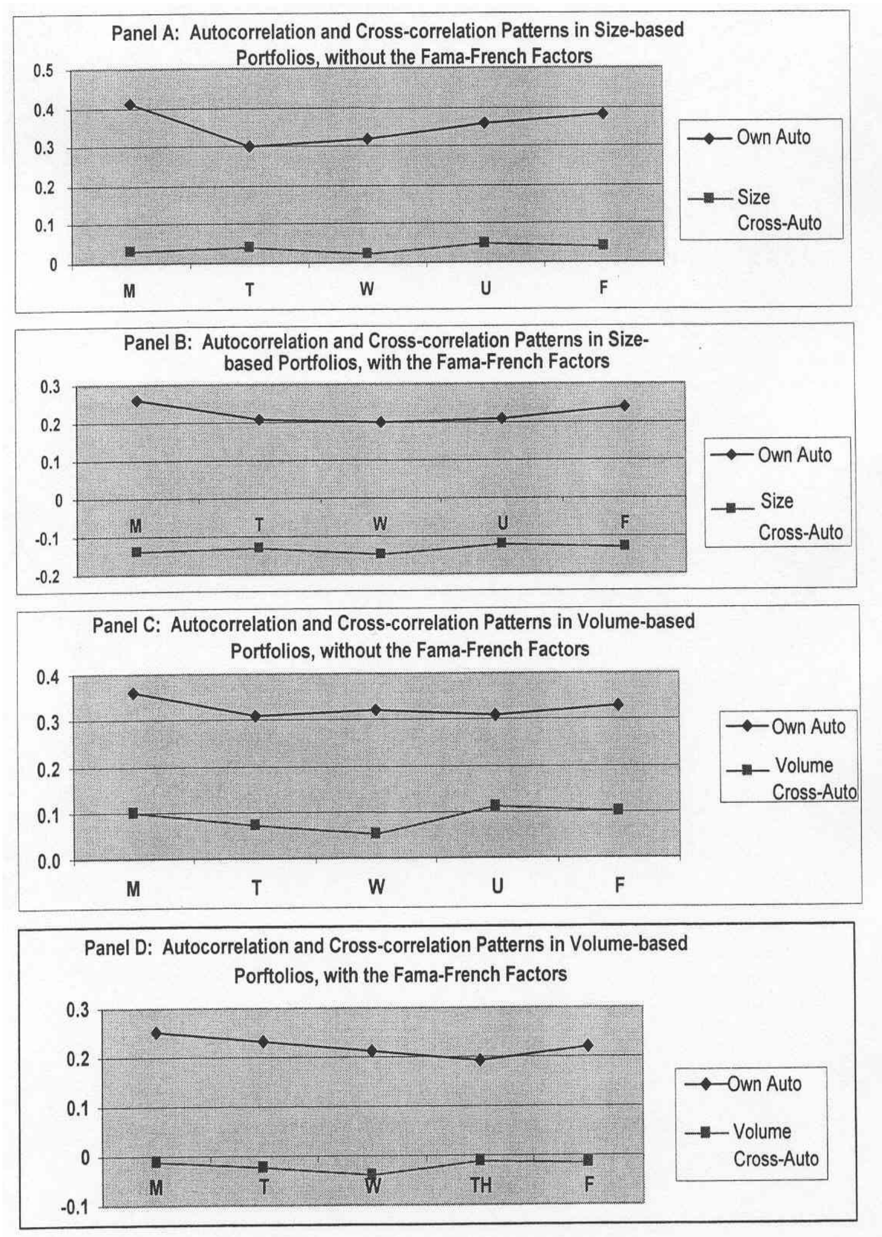
Figure 1 summarizes the patterns of autocorrelations and cross-autocorrelations estimated from equations (2) and (3). Panels A and B present the full sample patterns for size-based return autocorrelations and cross-autocorrelations without and with the Fama and French (1993) factors, respectively. Panels C and D present these patterns for volume-based return autocorrelations and cross-autocorrelations. While the autocorrelations for size-sorted return portfolios have the U-shaped patterns with or without the Fama and French factors, the cross-autocorrelations do not have any obvious patterns. For the volume-sorted return portfolios, the autocorrelations show a U-shaped pattern. The cross-autocorrelations, once again, do not show any clear patterns. Thus, the observed U-shaped patterns in autocorrelations do not exist for cross-autocorrelations after controlling for autocorrelations and the Fama and French factors, indicating that market-wide factors and return autocorrelation subsume the predictive power of size-based cross-autocorrelations.

Conclusions

Boudoukh, Richardson, and Whitelaw (1994) show that autocorrelations calculated using weekly returns vary depending upon the beginning day of the week used to form the weekly returns. Specifically, they show that autocorrelations are largest when using a Monday to Friday week and they document a U-shaped pattern in weekly return autocorrelations. They attribute this result to the dynamics of returns around the weekend. This paper examines if a U-shaped pattern exists in cross-autocorrelations calculated for size and volume sorted returns. If cross-autocorrelations represent a significant source of predictability in returns, it would be expected that a similar U-shaped pattern should exist in cross-autocorrelations and should explain the U-shaped pattern that exists in autocorrelations. Thus, this paper provides further evidence regarding the significance of cross-autocorrelations in returns relative to autocorrelations.

When examining size and volume cross-autocorrelation matrices, we find that a U-shaped pattern does exist in both autocorrelations and cross-autocorrelations when examining all data. When the data are conditioned upon the prior market return (good news versus bad news), no consistent U-shaped pattern emerges in autocorrelations or cross-autocorrelations. Regression methodology indicates, however, that the predictability of cross-autocorrelations in size-sorted returns is subsumed by that of autocorrelations and the Fama and French (1993) factors. For volume-sorted returns, significant cross-autocorrelations exist even when accounting for the Fama and French factors. Thus, our results are consistent with those of Chordia and Swa-

Figure 1—Patterns of Autocorrelations and Cross-Autocorrelations for all Possible Week Definitions for Size and Volume Sorted Return Portfolios



minathan (2000), showing that volume cross-autocorrelations are more significant than size cross-autocorrelations. Our results also support the findings of Boudoukh, Richardson, and Whitelaw (1994) that portfolio return autocorrelation explains portfolio return cross-autocorrelation. This is also supported by the fact that the U-shaped patterns observed in weekly autocorrelations does not hold for cross-autocorrelations. We find, however, that the U-shaped pattern identified in autocorrelations by Boudoukh, Richardson, and Whitelaw is dependent on time period and on prior market condition.

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