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Source: *The Journal of Finance*, Vol. 43, No. 2 (Jun., 1988), pp. 431-450
Published by: Blackwell Publishing for the American Finance Association
Stable URL: http://www.jstor.org/stable/2328469
Accessed: 26/11/2009 07:36

THE JOURNAL OF FINANCE • VOL. XLIII, NO. 2 • JUNE 1988

From T-Bills to Common Stocks: Investigating the Generality of Intra-Week Return Seasonality

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ABSTRACT

The authors investigate the extent to which intra-week seasonality still exists and whether its pattern is uniform across three stock indices and Treasury bonds with seven different maturities. They find that intra-week seasonality continues to be significant and that its pattern is not uniform, either between the stock indices and the Treasury bonds or even among the bonds alone. A pattern shared by stocks and bonds is that Monday returns become increasingly negative with maturity. These findings suggest that neither institutional nor general-equilibrium explanations by themselves can explain the pattern of intra-week seasonality in securities markets.

BEGINNING WITH A PAPER by French [6], a number of researchers have documented a puzzling "weekend effect" in U.S. common stock prices. They found that stock positions held over the weekend (or sometimes over other non-trading periods as well) earn a small, negative, but statistically significant return on average. This effect has been documented widely over long and varied time periods for daily stock price relatives, for dividend-adjusted returns, and for individual stocks. (See Cornell [4], Fama [5], Gibbons and Hess [8], French and Roll [7], Harris [9], Keim and Stambaugh [11], McInish and Wood [14], Rogalski [16], and Smirlock and Starks [19].) That these negative returns are economically small does not make them any less puzzling. As the investigations on intra-week seasonality widened, researchers documented seasonal behavior in one-month Treasury bills (Gibbons and Hess [8]), gold (Ball, Torous, and Tschoegl [3]), foreign exchange rates (McFarland, Pettit, and Sung [13]), and federal funds (Saunders and Urich [17]). Internationally, Jaffe and Westerfield [10] have demonstrated that stocks also exhibit intra-week seasonality in Australia, Canada, Japan, and the U.K.[1]

Lakonishok and Levi [12] tried to account for intra-week seasonality by adjusting raw stock returns for market clearing and payment arrangements but found that these institutional factors failed to explain entirely the observed day-

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[1] Ariel [1, 2] reports other types of stock return seasonality: a marked intra-monthly pattern to stock returns and exceptionally high returns preceding major holidays. For Treasury bills, Park and Reinganum [15] have shown that there is a "turn-of-the-month" effect tied to various bills' maturity dates (not, as in the other literature cited here, to the trading dates).

to-day variations in returns. Keim and Stambaugh [11] assessed the possibility that the weekend effect occurred because Friday closing stock price quotes were systematically biased for less actively traded stocks but concluded that this factor could not explain the empirical results. In short, the available literature indicates that stock returns are not homogeneously distributed over the days of the week.

Prior researchers have evaluated individual securities without determining how seasonality is related across assets. However, the pattern of return seasonals *across different securities* can provide important insights into the causes of intra-week seasonality. If seasonality is generated by broad-based economic factors that influence all asset returns, securities should exhibit similar seasonal patterns regardless of the particular markets in which they are traded. On the other hand, if seasonality reflects specific payment, clearing, or other institutional arrangements in individual markets, seasonal patterns should be similar for securities traded in the same market but should be different across markets. This paper addresses the following question: how uniform are intra-week and other seasonal patterns across common stocks and Treasury securities with a wide range of maturities (one month through thirty years)?

We describe our data in Section I. In Section II, we document intra-week seasonality in the raw-return series for each of eleven assets (an overnight RP rate, seven Treasury securities of different maturities, and three stock market indices) between 1976 and 1984. We find substantial intra-week seasonality in all the assets we study even though our time period contains more recent data than earlier papers.[2] Furthermore, the negative Monday stock returns persist. We were also intrigued to discover that Monday's mean Treasury returns are smaller than any other day's for all maturities and that Monday returns become more negative as the security's maturity increases.

Having established seasonality in the raw-return series, in Section III we proceed to account for the clearing and payment conventions governing different markets. Because (most) security trades are forward contracts, the opportunity cost of an overnight position is not determined until several business days later. To control for intertemporal and intermarket differences in clearing schedules, we subtract the actual (that is, ex post) cost of borrowing in the RP market to finance each overnight position in a stock or bond. This adjustment makes it possible to compare returns (and their seasonality) across different types of assets. In effect, we study the seasonality of the risk premia (excess returns) of zero-wealth portfolios that are long in a Treasury or stock security and short in RPs.

In Section IV, we show that many, but not all, intra-week seasonal patterns dissappear when returns are adjusted for clearing conventions. For instance, high observed Treasury returns on Thursday and high stock returns on Friday seem

[2] Some earlier work indicated that the weekend effect seemed to diminish over time. Lakonishok and Levi [12] contend that "the effects of the day of the week have disappeared by 1974" (page 887). Gibbons and Hess [8] also note the absence of significant seasonality in the S&P 500 and CRSP value-weighted returns in their latest subperiod (November 1974 through December 1978). Smirlock and Starks [19] report an insignificantly negative Monday close-to-close DJIA return for the period 1974 through 1983, and they find that there is no significant intra-weekly seasonality during this period.

to be due entirely to clearing conventions in these markets. However, the negative weekend return pattern persists, and Monday Treasury returns continue to be progressively more negative as the maturity of the Treasury securities increases. The thirty-year bond's (negative) Monday return is comparable to the stock indices' returns.

We then proceed to test hypotheses about the similarity of return seasonality across different assets. We reject the hypothesis that intra-week seasonality is the same across all securities for each day of the week. Even within similar securities, seasonals differ significantly. Our seven Treasury securities' seasonals differ significantly from one another, and the three stock indices' seasonals also exhibit different patterns. Finally, we show that there is a linear negative relation between Monday Treasury returns and the underlying securities' duration (and maturity). We conclude by discussing some theoretical implications of this observation.

I. Data

For a seven-year period (mid-1977 through mid-1984), we collected daily return data on eleven securities: three stock indices, overnight repurchase (RP) agreements, and seven maturities of Treasury securities. The latter included Treasury bills with approximately one-, three-, six-, and twelve-month maturities (TB1, TB3, TB6, TB12), and Treasury bonds maturing in approximately three, seven, and thirty years (TB36, TB84, TB360). The RP rates and stock index returns are straightforward to compute, but the infrequent issuance of new Treasury securities forced us to construct a set of returns to bonds of approximately constant "nominal" maturity. Here were present only the aspects of our return calculations that are essential to interpreting the results; remaining data-construction details are relegated to the Appendix.

The three indices of common stock returns are the equally weighted and value-weighted CRSP returns (EW, VW) and the Standard and Poor 500 (S&P500). All three stock indices are adjusted for splits. The two CRSP returns reflect dividends, while the S&P500 does not.

Unlike stocks, the characteristics of bonds and bills change through time as their maturity date approaches. If a bond's term-structure premium varies with its maturity, the return series for a particular bond or bill will contain systematic changes corresponding to the shortening of its maturity. To control for the effect of changing maturity, it is necessary to construct a return series for constant-maturity bonds. However, a strictly constant-maturity series cannot be constructed because the Treasury auctions new securities weekly or even less frequently. For example, new Treasury bills with three and six months to maturity are delivered only once per week (on Thursday, unless it is a holiday), and one-year bills are auctioned every fourth week. Treasury *bond* auctions are less regular, occurring approximately quarterly in recent years. The availability of Treasury securities close to our desired "nominal" maturity thus depends on idiosyncratic financing decisions at the Treasury.

Given these issuance patterns, "nominal-maturity" return series can be constructed in either of two ways. First, the price of the bill (bond) with actual maturity closest to the one desired can be adjusted to estimate the price of a bill with the desired nominal maturity by assuming a locally flat term structure. Gibbons and Hess [8] employ this method (see especially their footnote 9) for their thirty-day bill series. Alternatively, an "approximately constant-maturity" series can be constructed in which daily returns are the percent price change in a bill (bond) with maturity closest to the one desired. We use the latter method.[3] Our approximately constant-maturity series of daily returns uses actual market prices, with each return corresponding to a trade that actually could have occurred. For example, a (nonholiday) Monday return to the "one-month" bill is calculated as the *actual* return of the thirty-four-day bill from Friday to Monday, while the Tuesday return is calculated as the *actual* return of the thirty-one-day bill from Monday to Tuesday. Return series for the other maturities are constructed in the same way. (See the Appendix.) The last column of Table I reports how closely our actual bills' average maturities correspond to their nominal maturities.

One limitation of our data is that they contain only one observation per day, making it impossible to distinguish overnight returns from intra-day returns. While earlier studies of the stock market (e.g., Rogalski [16], Harris [9], and Smirlock and Starks [19]) have documented that the Monday effect largely occurs between Friday's close and Monday's open, we are unable to investigate this type of issue for Treasury returns.

II. Properties of the Raw, Unadjusted Returns

In order to establish comparability with earlier studies, we begin by evaluating unadjusted daily returns by day of the week for each of our eleven securities. We distinguish "holiday" returns, which are earned over a non-trading holiday period, from "regular" returns, which accrue when there is no intervening holiday period. For example, a regular Monday follows a two-day weekend, while a holiday Monday follows a Friday holiday. Mean returns for each type of day are calculated by regressing the daily return series on ten (zero–one) dummy variables: one for each regular day of the week plus five more dummies for the holiday days of the week. That is, for each asset i we compute the regression:

$$\begin{aligned}\tilde{R}_{i\tau} = {} & \alpha_m^i DM_\tau + \alpha_t^i DT_\tau + \alpha_w^i DW_\tau + \alpha_h^i DH_\tau + \alpha_f^i DF_\tau + \alpha_{hm}^i DHM_\tau \\ & + \alpha_{ht}^i DHT_\tau + \alpha_{hw}^i DHW_\tau + \alpha_{hh}^i DHH_\tau + \alpha_{hf}^i DHF_\tau + \tilde{\xi}_{i\tau},\end{aligned} \tag{1}$$

[3] The Gibbons and Hess method suffers from two disadvantages. First, their calculated returns are notional in that no transaction would have produced exactly those returns. It is therefore difficult to compare these returns directly with returns on other types of securities. Second, and much more importantly for studies of seasonality, when a new physical security becomes the one closest to the desired maturity, the return apparently has been calculated across two different securities. If there is a term-structure premium in bill prices that varies with maturity, this procedure introduces a weekly bias to the calculated returns. Upon unscrambling the first-differenced coefficients in Gibbons and Hess' Table 5, by far the most striking element of their weekly seasonality is a very low Tuesday return. We speculate that this results from their procedure of calculating Tuesday returns across different bills.

Table I

OLS Regressions for Raw Asset Returns[a]

August 29, 1977 through July 9, 1984 ($N = 1710$)

$$\tilde{R}_{i\tau} = \alpha^i_m DM_\tau + \alpha^i_t DT_\tau + \alpha^i_w DW_\tau + \alpha^i_h DH_\tau + \alpha^i_f DF_\tau + \alpha^i_{hm} DHM_\tau + \alpha^i_{ht} DHT_\tau + \alpha^i_{hw} DHW_\tau + \alpha^i_{hh} DHH_\tau + \alpha^i_{hf} DHF_\tau + \tilde{\xi}_{i\tau}$$

	Regular Trading Days					Days following a Holiday							
Security	*M*	*T*	*W*	*H*	*F*	*M*	*T*	*W*	*H*	*F*	R^2	Overall Mean	Average Maturity[b]
RP	2.97**	2.95**	2.91**	3.00**	8.92**	6.03**	5.93**	6.60**	12.40**	10.93**	0.915	4.32	1.00
	(0.088)	(0.083)	(0.083)	(0.084)	(0.088)	(0.444)	(0.769)	(0.464)	(0.427)	(0.250)		(0.073)	
TB1	2.37**	2.77**	3.74**	8.57**	2.42**	2.37**	2.21**	3.37**	8.90**	3.30**	0.747	3.99	0.88
	(0.154)	(0.154)	(0.147)	(0.147)	(0.149)	(0.782)	(0.445)	(0.782)	(1.355)	(0.782)		(0.087)	
TB3	2.15**	2.80**	4.14**	9.04**	3.01**	3.41*	2.32**	5.05**	11.08**	2.52	0.462	4.27	0.96
	(0.305)	(0.304)	(0.290)	(0.290)	(0.294)	(1.487)	(0.893)	(1.547)	(2.680)	(1.616)		(0.143)	
TB6	1.01	3.24**	4.02**	8.90**	3.61**	2.88	2.00	5.93*	13.13**	2.21	0.227	4.20	0.98
	(0.523)	(0.522)	(0.496)	(0.496)	(0.503)	(2.544)	(1.508)	(2.647)	(4.585)	(2.765)		(0.230)	
TB12	0.68	3.36**	3.13**	8.43**	4.23**	6.80	−0.16	15.68**	18.87*	2.31	0.079	4.08	0.96
	(0.973)	(0.972)	(0.924)	(0.924)	(0.937)	(4.737)	(2.808)	(4.931)	(8.540)	(5.150)		(0.418)	
TB36	−2.03	4.64*	1.69	8.07**	5.11**	18.91*	−3.08	17.63	19.97	0.76	0.025	3.67	0.99
	(1.948)	(1.945)	(1.849)	(1.849)	(1.877)	(9.483)	(5.621)	(9.870)	(17.096)	(10.309)		(0.830)	
TB84	−5.42	3.11	−0.87	7.03*	8.82**	18.65	−9.41	23.05	44.09	6.51	0.014	2.77	0.99
	(3.238)	(3.233)	(3.073)	(3.073)	(3.119)	(15.762)	(9.343)	(16.405)	(28.415)	(17.135)		(1.379)	
TB360	−13.83**	5.82	−2.31	7.60	7.75	34.30	−16.31	44.33	56.17	7.20	0.015	1.52	0.98
	(4.723)	(4.715)	(4.482)	(4.482)	(4.549)	(22.987)	(13.626)	(23.926)	(41.441)	(25.000)		(2.013)	
STKEW	−13.33**	1.80	18.89**	14.48**	24.76**	−19.13	−16.32	−14.45	5.16	66.79**	0.049	9.45	—
	(4.356)	(4.301)	(4.093)	(4.128)	(4.190)	(22.104)	(14.219)	(38.285)	(54.144)	(25.520)		(1.880)	
STKVW	−10.28*	3.46	15.20**	4.14	12.20**	−16.41	−14.48	−23.41	−7.75	54.12	0.017	4.97	—
	(4.815)	(4.754)	(4.524)	(4.563)	(4.631)	(24.432)	(15.716)	(42.318)	(59.846)	(28.212)		(2.055)	
S&P500	−11.16*	2.44	13.05**	0.546	8.03	−19.00	−14.311	−24.90	−13.93	46.49	0.012	2.58	—
	(4.998)	(4.935)	(4.696)	(4.737)	(4.808)	(25.364)	(16.316)	(43.932)	(62.129)	(29.288)		(2.140)	

[a] Standard errors are in parentheses.

[b] Average maturity as a proportion of nominal maturity.

* Significantly different from zero, five percent confidence level.

** Significantly different from zero, one percent confidence level.

where $\tilde{R}_{i\tau}$ is the ith asset's raw return on day τ, DM, DT, DW, DH, and DF are dummies for normal trading days, and DHM, DHT, DHW, DHH, and DHF are dummies for return days preceded by a holiday.[4] This procedure closely resembles the method of French [6], Gibbons and Hess [8], and others, except that we include holiday returns rather than omitting them from the analysis.[5]

Table I displays the pattern of returns by day of the week for the eleven assets we study.[6] These results confirm the received wisdom about weekly seasonality across normal return days in the stock market for a more recent period than is available elsewhere in the literature. All three market indices reflect the much-publicized weekend effect, with negative Monday returns varying from minus ten to minus thirteen basis points. (These daily returns annualize to a very substantial range of minus twenty-eight percent to minus thirty-eight percent, assuming 250 trading days per year.) Holiday Monday and Tuesday returns are also substantially negative. In addition to these anomalous weekend returns, stock returns appear unusually large (relative to the overall mean) on normal Wednesdays and Fridays. Earlier studies reveal this same pattern, though generally it has not been emphasized.

The more novel information in Table I concerns the weekly pattern of Treasury returns for maturities ranging from one month to thirty years. Gibbons and Hess [8] conclude that thirty-day bills during the mid-1960's "reveal a pattern of T-bill returns similar to stock returns.... Apparently, T-bills, like stocks, have strong day of the week effects, and the effects for bills and stocks are qualitatively the same" (page 588). We find two pronounced tendencies: Thursday returns are uniformly high (for both normal and holiday Thursdays), and normal Monday returns are lower than the mean return on any other normal day of the week. Though the Monday Treasury returns are not always statistically lower than the other days, there is an intriguing pattern—the longer the maturity, the lower the mean Monday return. The mean returns on three-, seven-, and thirty-year bonds are actually negative over the weekend. Also, the thirty-year bond's mean Monday return is lower than the Monday return on any of the stock indices.

Looking across these securities (that is, reading down Table I), it appears that weekly seasonal patterns differ between the Treasuries and the stocks. Stock returns are relatively high on Wednesday and Friday, while Treasury returns are highest on Thursday. Monday returns also seem to vary across assets.

[4] That is, DM is unity for all normal Mondays and zero otherwise. Because holidays in the Treasury market do not always correspond to those in the stock market (banks dominate the Treasury dealer market, and banking holidays sometimes differ from stock exchange holidays), we constructed a separate set of dummies for each type of security.

[5] Holidays influence the length of calendar time a stock position must be held. For example, a Tuesday return following a Monday holiday exposes the investor to information-arrival risk for four calendar days, instead of the single day's exposure that attaches to a regular Tuesday return. We therefore employ two different sets of dummy variables in Table I (and subsequently) because investors might demand different returns across holiday and nonholiday holding periods that terminate on the same day of the week.

[6] For technical reasons, we attached the RP-rate holiday dummies to the day the transaction was initiated (as opposed to the day it was terminated, as for the other ten securities). This fact means that the dummy-variable coefficient on RP's cannot be directly compared with those on the other securities in Table I.

The raw-return data in Table I are provided only to indicate the basic characteristics of daily security returns. Proper return calculations must account for clearing and payment conventions, which may explain some of the indicated "seasonality". In addition, the raw returns described in Table I are heteroscedastic by day of the week and exhibit serial correlation, making the reported standard errors suspect. Therefore, in the following section, we correct for these factors to provide better estimates of intra-week seasonality in individual asset returns.

III. Statistical and Institutional Adjustments to the Raw Returns

We apply two types of adjustments to the raw-return data underlying Table I: adjustments that control for opportunity-cost differences due to institutional variations in clearing and payment schedules, and purely statistical corrections to transform the regression error terms into white noise.

A. *Institutional Adjustments*

Gibbons and Hess [8] briefly discuss the potential influence of Treasury bill clearing conventions on intra-week return seasonality. For stocks, Lakonishok and Levi [12] investigate whether correcting raw stock returns for clearing arrangements would eliminate the raw returns' pronouned weekly seasonality. They find that net stock returns remain negative on Monday, though returns become more uniform for the remaining days of the week. Our clearing adjustments follow Lakonishok and Levi quite closely in spirit, with two important differences. First, they use the prime rate to measure the opportunity cost associated with a given stock return, while we use the overnight RP rate. Because the RP rate is market determined (as opposed to administered), it should capture true opportunity costs better than the prime.[7] All major market participants may lend in the overnight RP market, and securities dealers will also recognize the RP rate as a relevant liability cost.[8] Second, we also apply an opportunity-cost correction to Treasury securities, which clear according to a schedule different

[7] The prime rate is generally much more stable than market-determined rates. For example, during Lakonishok and Levi's sample period (February 1968 through December 1979), the prime changed only 138 times (or an average of about once per month). This stickiness means that Lakonishok and Levi's correction is most effective at capturing variations in the period of time for which an overnight stock must be financed and much less effective at measuring changes in the opportunity cost of holding stocks.

[8] The RP rate is not the only reasonable proxy for overnight financing costs that one could employ. Other candidates include the overnight federal-funds rate and the broker-loan (call-loan) rate. We prefer the RP rate to the federal-funds rate because some major market participants cannot own or trade federal funds. We are suspicious of the call-loan rate because it is quite sticky. Since bank securities financing is generally one facet of a more inclusive "customer relationship," we expect that compensating variations in the terms of other product pricing will adjust the *effective* call-money rate to current market conditions even if the *stated* rate does not move very quickly. We therefore view the RP rate as the best single indicator of overnight opportunity costs for all traders. Note also that the tests we conduct below cannot be undertaken if we use a different opportunity-cost measure for stocks versus bonds; in that case, any measured differences in return seasonality could be due *either* to differences in raw-return seasonality or to differences in the seasonality of the various opportunity cost measures.

from that of stocks. By expressing both Treasury and stock returns net of ex post opportunity (financing) costs, we can compare directly the intra-week return seasonality of the various securities.

We now describe the opportunity-cost corrections for Treasuries and stocks. In the stock market, a purchaser must pay for newly acquired securities on the fifth business day following the trade date. At that time, stock certificates are exchanged for a bank check. Allowing one additional day for the check to clear, a purchaser loses good funds on the sixth business day following his or her stock purchase. The most important implication of this payment convention is that an overnight stock return does not always correspond to a single day's financing cost. For instance, if an investor purchases stock at Wednesday close and sells it at Thursday close (generating a Thursday return), the investor will lose good funds the following Thursday to pay for the Wednesday purchase. Since the investor will receive good funds from Thursday's sale on the following Friday, the financing cost of the Thursday return is the following Thursday's overnight cost of funds. By contrast, a Friday stock return requires three days' financing. In this transaction, the investor loses funds on the following Friday to pay for the Thursday purchase and receives good funds on Monday (ten days later) from the Friday sale. The Friday return's financing cost is thus the following Friday's cost of funds, a three-day rate.[9] In an efficient market, this payments feature will cause high Friday stock returns. Indeed, Table I indicates that Friday stock returns are substantially higher than any other day's.

Intervening holidays alter this payment pattern because the payment schedule is based on *business* days. For instance, if the *first* Monday following a Friday return is a holiday, the financing cost for that Friday's stock return is the second subsequent *Monday's* cost of funds—a one-day rate.[10] If, instead, the *second* Monday following a Friday return is a holiday, then the financing cost remains the following Friday's cost of funds, which is now a four-day rate because it extends over the Monday holiday. Similar effects can occur for other days' returns as well. As a result, all returns for the same day of the week are not alike in their financing costs, which means that the raw returns would tend to differ according to the applicable payment schedule for that particular day. If holidays influence different weekdays' returns differently, this could partly explain seasonal return patterns.

For Treasury securities, the standard clearing convention is that purchased

[9] The question arises whether weekend calendar days earn interest to the same extent that trading days do. This issue partially motivated French's [6] inquiry into stock seasonality. At least in the interbank (RP and federal funds) markets, however, calendar time is the relevant determinant of value. Because reserve requirements give Friday's closing reserve position a weight of three in the seven-day reserve-holding period, banks willingly pay three times the one-day interest rate for funds borrowed on Friday. (An analogous convention applies over holidays.) We have reflected this convention in the RP rates underlying Table I. Furthermore, bank competition should cause depositors with collected balances over the weekend to earn three days' interest. With this sort of opportunity cost associated with positions financed over a weekend or holiday, raw security returns in an efficient market will manifest seasonal fluctuations.

[10] That is, the Thursday purchase now requires payment on the second following Monday (eleven calendar days hence), while the Friday sale produces cash on the second following Tuesday (also eleven days after the trade date).

bills or bonds exchange for good (that is, federal) funds the following business day. However, the standard source for daily Treasury price data reports prices for bills and bonds deliverable (against good funds) *two* business days later.[11] This clearing convention should induce intra-week seasonality in raw Treasury returns, though the pattern should differ from that of the stock market. In the absence of intervening holidays, Treasury returns for Monday, Tuesday, Wednesday, and Friday all require a single calendar day's financing. By contrast, Thursday Treasury returns require three days' financing; Wednesday purchases require payment on Friday, while the Thursday sale generates cash on Monday, leaving the billholder short of cash for three calendar days. Note that Thursday bill and bond returns in Table I exceed those for other days of the week, as would be expected under this clearing arrangement.

We adjusted all bill, bond, and stock returns by subtracting their actual, ex post financing costs (as measured by the overnight RP rate) from the raw security returns. These adjustments take into account the holiday schedules in each market. In effect, our adjusted returns represent the ex post return to ten zero-wealth portfolios, each long in a Treasury or stock security and short in overnight RPs. These excess returns (denoted $E\tilde{R}_{i\tau}$) are the focus of our remaining analysis for two reasons. First, they take proper account of payment schedules. Second, adjusted stock and bond returns can be compared directly, despite their different payment schedules. This allows us to assess the uniformity of any remaining intra-week seasonality across different types of assets.

B. Statistical Adjustments

We also undertook two purely statistical corrections to ensure that our test statistics are based on white-noise error terms. However, neither adjustment had any material effect on the test statistics.

B.1. Heteroscedasticity

Gibbons and Hess [8] reject the hypothesis that stock return variances are equal across days of the week. The regression residuals in Table I also exhibit significant heteroscedasticity by weekday, which may bias the reported standard errors. We followed Gibbons and Hess by deflating each adjusted return by the sample standard error for the day of the week on which it occurred.

B.2. Autocorrelation

The adjusted returns also exhibit serial correlation that must be eliminated to produce unbiased confidence intervals and test statistics. Therefore, we estimated

[11] The New York Federal Reserve Bank releases a daily report entitled "Composite Closing Quotations for U.S. Government Securities," which contains representative yields for Treasury securities on trades deliverable two business days hence. These data are reported the following business day in *The Wall Street Journal*. The fact that these data are not transaction prices may introduce errors to our return calculations, but we can think of no reason why the errors should vary systematically across days of the week. Moreover, since our returns are used only as dependent variables, any measurement errors become impounded in the regression error term. No estimated coefficient will be affected, though statistical tests will be biased against rejecting any null hypothesis. For this reason, our methodology may be biased *against* finding significant return seasonality for Treasuries.

each regression for the adjusted asset return with an ARMA process for the residuals. We adjusted the ARMA specification until the Box-Pierce statistic (reported in Table II) failed to reject the hypothesis of zero autocorrelations through lag 42 (using a one percent confidence level). We retained the same ARMA specifications in the subsequent joint estimations.

IV. Seasonality in Adjusted Asset Returns

For each asset's excess return ($E\tilde{R}_{i\tau}$), we estimated a regression similar to equation (1) corrected for heteroscedasticity and autocorrelation in the residuals. The estimated coefficients measure mean adjusted returns, by day of the week, for the ten assets we study. Table II reports these results, along with a Q-statistic for each regression.[12] Our adjustments for market-clearing conventions eliminate a good portion of intra-week seasonality in the raw returns. In particular, neither Thursday Treasury returns nor Friday stock returns (with the exception of the EW index) seem unusually high anymore. Contrasting the estimated returns in Table I with those in Table II indicates the potential pitfall associated with comparing asset returns whose payment schedules differ substantially. Remaining intra-week seasonality in Table II includes most prominently the negative Monday return to stocks and to Treasury securities.[13] In addition, note that the Monday adjusted Treasury returns decline monotonically with the security's maturity. Finally, Wednesday stock returns seem rather high compared with other days of the week and with the Treasury returns.

In the remainder of this section, we investigate further the statistical properties of the apparent intra-week seasonality in adjusted returns. We test three types of hypotheses: that significant seasonality is present in each asset return individually (see Tables III and IV), that seasonal patterns are similar across assets (see Table V), and that Monday Treasury returns are related to the maturities or durations of the securities.

A. Intra-Week Seasonality for Individual Assets

Before we test for the uniformity of intra-week seasonality across assets, we must determine the extent and nature of this seasonality for each asset separately. Table III presents the most basic tests of return homogeneity for each security. The hypothesis that all days' mean returns are equal (column 1) is rejected for seven of ten securities at the five percent level or better, and we fail to reject this hypothesis at the ten percent level only for six-month bills. Clearly, weekly return seasonality is not limited to the stock market. To determine which days of the

[12] We compared our results with the ARMA correction to OLS regressions on the same adjusted returns and found that in no case did the ARMA correction substantially change either an estimated coefficient or its standard error.

[13] The estimated coefficients and standard errors for Monday returns in Table II are not driven by a small number of extreme values. Inspecting histograms for the ten securities' Monday returns indicates no substantial outliers for any of the securities, and nonparametric (Wilcoxon sign-rank) tests failed to reject the hypothesis of negative regular Monday mean adjusted returns for only two of the ten securities studied.

Table II
OLS Regressions for Adjusted Asset Returns[a]
August 29, 1977 through July 9, 1984 ($N = 1710$)

$$\tilde{ER}_{i\tau} = \alpha^i_m DM_\tau + \alpha^i_t DT_\tau + \alpha^i_w DW_\tau + \alpha^i_h DH_\tau + \alpha^i_f DF_\tau + \alpha^i_{hm} DHM_\tau + \alpha^i_{ht} DHT_\tau + \alpha^i_{hw} DHW_\tau + \alpha^i_{hh} DHH_\tau + \alpha^i_{hf} DHF_\tau + \tilde{\xi}_{i\tau}$$

	Regular Trading Days					Days following a Holiday						
Security	M	T	W	H	F	M	T	W	H	F	R^2	Q-Statistic[b]
TB1-RP	−0.61**	−0.28*	0.17	−0.29**	−0.63**	−1.26*	−0.59	−0.88	−0.12	0.12	0.067	52.58
	(0.137)	(0.113)	(0.114)	(0.109)	(0.105)	(0.640)	(0.316)	(0.581)	(0.965)	(0.555)		(0.88)
TB3-RP	−0.79*	−0.27	0.63**	0.18	−0.06	−0.30	−0.64	0.94	2.28	−0.80	0.036	49.46
	(0.395)	(0.256)	(0.216)	(0.255)	(0.282)	(1.875)	(0.722)	(1.122)	(2.301)	(1.509)		(0.145)
TB6-RP	−2.06**	0.17	0.48	0.06	0.61	−0.51	−0.98	1.93	4.68	−1.01	0.023	45.64
	(0.769)	(0.451)	(0.384)	(0.397)	(0.546)	(3.578)	(1.247)	(1.957)	(3.501)	(2.864)		(0.249)
TB12-RP	−2.21	0.33	−0.44	−0.42	1.16	3.35	−3.41	11.77**	9.05	−0.44	0.019	57.90
	(1.259)	(0.872)	(0.725)	(0.803)	(1.025)	(6.078)	(2.503)	(3.835)	(7.362)	(5.581)		(0.033)
TB36-RP	−4.50	1.56	−2.14	−0.64	2.03	11.51	−6.74	16.07*	11.11	−3.64	0.036	54.26
	(2.553)	(2.058)	(1.551)	(1.501)	(1.955)	(11.820)	(5.672)	(7.835)	(13.103)	(10.168)		(0.042)
TB84-RP	−8.38*	0.10	−4.44	−1.91	5.90	13.28	−12.18	18.87	36.55	3.47	0.014	44.37
	(3.966)	(3.163)	(2.510)	(2.775)	(3.287)	(19.228)	(9.107)	(13.343)	(25.55)	(17.983)		(0.331)
TB360-RP	−16.57**	2.82	−5.87	−1.23	4.77	30.09	−19.98	39.92	42.06	2.58	0.018	60.09
	(5.786)	(4.521)	(3.905)	(4.255)	(4.483)	(28.003)	(12.999)	(20.718)	(39.094)	(24.481)		(0.021)
STKEW-RP	−16.45**	−0.78	15.58**	10.15*	17.67**	−26.28	−26.40*	−4.88	−3.73	42.59	0.025	50.78
	(5.151)	(4.379)	(4.406)	(4.147)	(4.205)	(22.726)	(12.660)	(35.204)	(46.687)	(22.09)		(0.166)
STKVW-RP	−13.65*	1.06	11.00**	−0.13	4.43	−17.09	−22.93	−21.66	−17.53	39.76	0.126	41.18
	(5.517)	(4.814)	(4.583)	(4.176)	(4.214)	(27.397)	(15.587)	(41.847)	(53.465)	(25.091)		(0.507)
S&P500-RP	−14.56**	−0.05	9.93*	−3.75	0.15	−20.45	−21.14	−24.66	−22.35	34.07	0.038	39.70
	(5.732)	(5.097)	(4.753)	(4.289)	(4.322)	(28.752)	(16.666)	(43.892)	(55.523)	(26.009)		(0.594)

[a] Standard errors are in parentheses.
[b] Confidence level of Q-statistic in parentheses (for the hypothesis of zero residual autocorrelation through lag 42).
* Significantly different from zero, five percent confidence level.
** Significantly different from zero, one percent confidence level.

Table III

Intra-Week Seasonality Tests for Individual Assets
August 20, 1977 through July 9, 1984 ($N = 1710$)
(Adjusted Returns)

	χ^2 Statistics	
	All Days Alike (9 DF)	Holiday and Regular Mean Returns Equal (5 DF)
TB1-RP	39.67**	6.78
TB3-RP	17.76**	1.37
TB6-RP	14.40	3.61
TB12-RP	18.47*	14.26*
TB36-RP	15.86†	9.99†
TB84-RP	17.16*	8.07
TB360-RP	20.26*	11.34*
EW-RP	60.29**	5.61
VW-RP	21.08*	4.84
S&P500-RP	16.55†	3.88

† Exceeds ten percent significance level.
* Exceeds five percent significance level.
** Exceeds one percent significance level.

Table IV

More Intra-Week Seasonality Tests for Individual Assets[a]
August 29, 1977 through July 9, 1984 ($N = 1710$)
(Adjusted Returns)

	All Returns Equal	All Returns Equal Except:				
		Monday	Tuesday	Wednesday	Thursday	Friday
				"Regular" Returns		
TB1-RP	35.17**	30.88**	35.15**	10.71*	35.17**	24.10**
TB3-RP	14.39**	9.60*	11.65**	4.97	14.39**	14.22**
TB6-RP	10.83*	1.31	10.67*	9.75*	10.53*	9.20*
TB12-RP	5.27	2.22	4.72	5.11	5.17	2.95
TB36-RP	8.03†	4.43	5.91	6.40†	8.04*	5.09
TB84-RP	10.44*	6.61†	9.80	8.72*	10.42*	3.54
TB360-RP	11.59*	4.08	9.75*	10.31*	11.51**	8.21*
EW-RP	45.97**	16.12**	44.02**	39.45**	45.89**	28.47**
VW-RP	14.98**	5.51	14.98**	8.50*	13.96**	13.54**
S&P500-RP	12.22*	5.47	12.18**	5.65	11.05*	11.84**
				"Holiday" Returns		
TB1-RP	3.21	1.96	3.21	2.86	2.95	1.25
TB3-RP	2.74	2.74	1.71	1.54	1.54	2.57
TB6-RP	3.61	3.61	1.97	2.46	1.72	3.45
TB12-EP	12.27*	12.19**	3.75	3.31	11.18*	12.12**
TB36-RP	7.05	6.40†	2.30	2.95	6.56†	6.56†
TB84-RP	6.22	5.87	1.20	4.27	4.30	6.22
TB360-RP	8.22†	7.24†	1.54	4.46	7.20†	8.22*
EW-RP	7.89†	7.40†	4.89	7.86*	7.86*	0.53
VW-RP	4.78	4.68	3.15	4.69	4.76	0.04
S&P500-RP	3.61	3.45	2.69	3.49	3.56	0.01

[a] χ^2 test statistics in column 1 have four degrees of freedom; the other test statistics have three.

† Exceeds ten percent significance level.
* Exceeds five percent significance level.
** Exceeds one percent significance level.

Table V

Seasonality Patterns across Securities
August 29, 1977 through July 9, 1984 ($N = 1710$)
(Adjusted Returns)

	χ^2-statistic[a]		
Type of Seasonality[b]	All Ten Assets	Treasury Securities Only	Stock Indices Only
H1: No Seasonality	174.40** (40)	85.83** (28)	90.71** (12)
H2: All Seasonality Identical	123.73** (36)	34.46† (24)	43.24** (8)
H3: Monday Seasonality Identical	18.56* (9)	14.21* (6)	0.35 (2)
H4: Wednesday Seasonality Identical	30.63** (9)	11.63† (6)	3.62 (2)
H5: Thursday Seasonality Identical	32.78** (9)	9.22 (6)	15.58** (2)
H6: Friday Seasonality Identical	45.16** (9)	7.59 (6)	22.00** (2)

[a] The degrees of freedom for each test are noted in parentheses.
[b] Tested hypotheses refer to regular days of the week.
† Significant at ten percent level.
* Significant at five percent level.
** Significant at one percent level.

week are responsible for these seasonal factors, we conducted a series of further tests. First, we checked whether holiday returns differ significantly from regular returns accruing on the same day of the week. Column 2 in Table III tests the joint hypothesis (for all five weekdays) that a day's mean return is unaffected by the presence of a preceding holiday. At the ten percent level or better, we reject the hypothesis that there is no difference between holiday and regular day returns for three of our ten securities. Because the equivalence of holiday and regular day returns is rejected for three securities, we test the remaining hypotheses for regular day and holiday returns separately.

Table IV contains additional statistics that characterize the extent of intra-week seasonality for each asset. We test for equal mean returns across various combinations of "regular" weekdays (in the top half of the table) or "holiday" weekdays (in the bottom half).

A.1. Regular Return Seasonality

In the top half of Table IV, column 1 contains tests of whether returns are equal across all five weekdays. Equality of daily means is rejected for all securities except the twelve-month bill. To determine whether particular days are responsible for these homogeneity rejections, we investigate whether other combinations of weekday returns are equal. The test statistics are reported in columns 2 through 6. The results in column 2 indicate that returns vary significantly across Tuesday through Friday for four securities. The last four columns then demonstrate that other days besides Monday also contribute to the significant seasonal pattern exhibited (in column 1) by most securities. In sum, the upper half of Table IV clearly indicates that return seasonality is not limited to stocks alone or to Mondays. These findings are generally comparable to those reported previously in the literature for stocks alone.

A.2. Holiday Return Seasonality

The lower half of Table IV reports results for the same seasonality tests applied to holiday returns. Here, statistically significant seasonality is less prevalent, though the twelve-month bill return seems to vary significantly across holiday days of the week. Inspection of Table II suggests that this arises largely from the very large return to holiday Wednesdays. We suspect that the relatively small number of returns for holidays falling on any given day of the week at least partially accounts for our failure to reject other types of seasonality across holiday returns.[14]

B. Is Seasonality Uniform across Assets?

Tables III and IV establish that statistically significant intra-week seasonality exists in most assets' returns even after making the necessary institutional and statistical adjustments. Moreover, this seasonality is not limited to Mondays. The primary question we set out to evaluate, however, is whether intra-week seasonality in adjusted returns is *uniform* across securities. This issue is important to investigate because it can shed light on the sources of intra-week seasonal patterns. As noted in the introduction, if intra-week seasonality is uniform across different types of securities, the cause is likely to be fluctuations in broad-based economic factors. By contrast, if different types of securities exhibit differing, idiosyncratic seasonal patterns, return seasonality likely reflects primarily institutional clearing or other characteristics.

We test whether seasonal patterns are similar across assets by imposing cross-equation constraints on a system of ten simultaneously estimated equations (one for each security) of the form:

$$\begin{aligned} E\tilde{R}_{i\tau} = C_i &+ \beta^i_m DM_\tau + \beta^i_w DW_\tau + \beta^i_h DH_\tau + \beta^i_f DF_\tau + \beta^i_{hm} DHM_\tau \\ &+ \beta^i_{ht} DHT_\tau + \beta^i_{hw} DHW_\tau + \beta^i_{hh} DHH_\tau + \beta^i_{hf} DHF_\tau + \tilde{\xi}_{i\tau}, \end{aligned} \tag{2}$$

where $E\tilde{R}_{i\tau}$ is the adjusted return to asset i ($i = 1, \cdots, 10$) at time τ and the dummy variables are defined following equation (1). We include a constant term in equation (2) because we want to measure each day's mean return *deviation* from a fixed point, which we take to be a regular Tuesday. Without constraints, equations (2) and (1) have the same explanatory power. Cross-equation constraints on the coefficients test for the equality of different securities' daily deviations from their mean Tuesday returns. In other words, having allowed each security to have its own mean return (measured by C_i), we can test whether the

[14] In our sample of 1710 total observations, seventy-seven (fifty-six) Treasury (stock) returns were preceded by a holiday as follows: thirteen (twelve) Monday returns, thirty-seven (twenty-nine) Tuesday returns, twelve (four) Wednesday returns, four (two) Thursday returns, and eleven (nine) Friday returns.

other days' *deviations* from that overall mean return are the same across securities. Table V reports the resulting test statistics for three sets of securities (with returns that have been adjusted as in Table II): all ten securities, the seven Treasury securities alone, and the three stock indices alone. We identify six relevant hypotheses (involving only the regular weekdays) for each set of securities:

H1: "No Seasonality": Each security's overall mean return is separately estimated, but no intra-weekly variation in regular-day returns is allowed. Specifically, we impose on the equation system (2) the constraints $\beta^i_m = \beta^i_w = \beta^i_h = \beta^i_f = 0$ for all i. This test has $4n$ degrees of freedom, where n is the number of security returns being estimated simultaneously.

H2: "All Seasonality Identical": The mean daily return is allowed to vary across regular days of the week, but each security's deviation from its own overall mean return is constrained to equal the deviation of all the other securities. Specifically, we impose on the equation system (2) the constraints $\beta^i_m = \bar{\beta}_m$, $\beta^i_w = \bar{\beta}_w$, $\beta^i_h = \bar{\beta}_h$, $\beta^i_f = \bar{\beta}_f$ for all i. This test has $4n - 4$ degrees of freedom, where n is the number of security returns being estimated simultaneously.

H3: "Monday Seasonality Identical": No constraints are placed on any security's return for other days of the week, but Monday average return deviations are constrained to be equal across securities. Specifically, we impose on the equation system (2) the constraints $\beta^i_m = \bar{\beta}_m$ for all i. This test has $n - 1$ degrees of freedom, where n is the number of security returns being estimated simultaneously.

H4, H5, H6: "Each Day's Seasonality Identical": The securities' return deviations are constrained to be equal for Wednesday, Thursday, and Friday, respectively. These tests are analogous to the test of H3.

The first column of Table V reports test results for the set of all ten assets estimated together. The first entry in this column indicates that the joint hypothesis of no seasonality in adjusted asset returns (H1) is easily rejected at a very high confidence level. Next, we test whether the intra-week seasonality pattern is uniform across all asset returns (H2). The test statistic of 123.7 rejects this hypothesis as well. The last four entries of the first column report statistics on whether seasonal deviations are equal for any one day of the week (H3–H6). The hypotheses of uniform seasonality across all ten assets are rejected for each day of the week.

We investigate the source of this nonuniform seasonality by conducting the same tests separately for the Treasury securities as a group and for the stock indices as a group. These tests indicate whether the rejection of uniformity comes from differences *between* the Treasury group and the stock group returns or from differences *within* each securities group as well. The first row of columns (2) and (3) in Table V indicates that the hypothesis of "No Seasonality" (H1) is rejected soundly for the Treasury and stock returns separately. The hypothesis of "All Seasonality Identical" (H2) is rejected soundly only across the three stock returns, and it is rejected at the ten percent level for Treasury returns alone. Reading further down column (3), the rejection of uniform stock return seasonality (H2) seems to come from the Thursday and Friday returns. By contrast, the rejection of H2 for the Treasury returns appears due to their Monday and Wednesday behavior. Not surprisingly, these results correspond closely to the dispersion of the single-equation coefficient estimates across securities reported in Table II.

To summarize, Table V shows that intra-week seasonality is not uniform across assets. Two principal factors seem to be responsible for this overall lack of uniformity. First, stock and Treasury securities' seasonal patterns are substantially different from one another. Second, within the stock group and within the Treasury group, seasonal mean return deviations differ across individual assets. Monday and (to a lesser extent) Wednesday seasonal deviations are not uniform across Treasuries, while Thursday and Friday seasonal deviations are not uniform across stocks.

C. Characterizing the Pattern of Monday Seasonality

At the start of this research project, we had collected return data for only seven securities: the three stock indices and the four Treasury bills. After applying our institutional and statistical corrections, we noted that Monday bill returns were more negative for longer maturity bills. In order to determine whether this particular pattern also characterizes longer maturity bonds, we collected return data for three-, seven-, and thirty-year Treasury bonds. Table II above indicates that the Monday pattern indeed continues for longer maturity Treasuries.

We can determine whether this apparent regularity is statistically significant by constraining the Monday return coefficients to be a linear function of the securities' durations. Specifically, we estimate an equation system (of the form (1)) for the seven Treasury return series and then impose the constraint:

$$\alpha_m^i = a_0 + a_1 D_i, \tag{3}$$

where D_i is the average Macauley's duration of the ith Treasury security over the estimation period.[15] The estimated coefficients are

$$a_0 = -0.42 \quad (t = 3.24),$$

$$a_1 = -1.48 \quad (t = 2.65).$$

Both coefficients are significantly negative at the one percent level (one-tailed test). Furthermore, the data do not reject the restriction (3) ($\chi_5^2 = 5.68$). To an

[15] Each bill's duration was taken to equal its nominal maturity, and the bond durations were set to their average values over the 1977 through 1984 period: 2.64, 5.09, and 9.52 years, respectively, for the three-, seven-, and thirty-year bonds. We also tested the constraint (3) on Monday Treasury coefficients using maturity in place of duration. The resulting coefficients are

$$a_0 = -0.48 \quad (t = 3.73),$$

$$a_1 = -0.31 \quad (t = 2.51).$$

This linear constraint on Monday coefficients also is not rejected by the data ($\chi_5^2 = 6.37$).

extent, these statistics must be regarded as documentation rather than a pure test of any relation because the "test" was suggested by a subset of the data. However, the results do support the impression that there is a systematic negative relation between the Monday Treasury returns and duration.

It is also interesting to note that the mean Monday return for the thirty-year Treasury is quite similar to those of the stock indices. While it would have been informative to extend the test of (3) to the stock indices, doing so would have required an estimated duration for each index. This task would have been both difficult and controversial. We can, however, indicate informally how well the stock indices fit the duration pattern. Table II reports that the representative stock index has an estimated mean Monday return of approximately minus fifteen basis points, with a standard deviation of five basis points. If the mean Monday return to a security with a duration of 9.52 years (that is, to TB360) is minus 16.57 basis points and if Monday returns are linear in duration, then the implied duration for the representative stock index is 8.6 years (= (15/16.57) × 9.52). Moreover, a ninety-five percent confidence interval for the stock indices' duration includes three and fourteen years, which seem to encompass a range of plausible values.

The systematic relation between security duration and Monday mean returns is not easy to explain. The fact that Monday returns are negative for two dissimilar types of securities strongly suggests that some common factor is responsible. When considering stock returns alone, such an anomaly could result from either a change in expected cash flows or a change in the market's vector of discount rates. With Treasury securities, however, the cash flows are riskless (except for the relatively minor coupon-reinvestment risk), suggesting that discount-rate shifts must be responsible.

One possibility we considered at some length is that market discount rates systematically rise over the weekend. However, if these rate increases were anticipated by traders, the weekend holding-period returns to all bonds would be equal to one another (except for possibly nonzero term premia). Recurring, *unanticipated* rate increases each weekend would generate the observed return pattern confirmed by (3), but we find such an explanation implausible in sophisticated and developed financial markets.

One viable explanation (for which we can offer no direct empirical evidence) is that *term premia* contained in the interest rates used to discount future cash flows tend to rise over the weekend because nontrading periods are characterized by different risks and information flows. Term premia compensate the holders of longer term bonds for the risk of new information arriving in the market during the holding period. Intertemporal fluctuations in such premia are not arbitrageable and could generate heterogeneous returns across days of the week. An attractive feature of this hypothesis is that stock and bond returns both must reflect the same term premia; in other words, term premia fluctuations could explain the Monday seasonals in Table II for all the securities. Note, however, that persistent negative returns to any security require transaction costs in addition to the fundamental generating process or else traders would systematically liquidate their stock and bond holdings each Friday and re-establish them on Monday.

V. Summary and Conclusions

Our empirical results fall into three general categories. First, we have established that intra-week seasonality in net security returns is not an unusual phenomenon. Rather, the alternative hypothesis that returns are homogeneous across days of the week is generally inconsistent with the data. Significant intra-week seasonality exists in Treasury returns as well as in stocks, and these seasonals are apparent in a recent time period (1977 through 1984) despite earlier claims that the significance of weekly seasonals had diminished recently.

Second, return seasonals are not uniform across securities. Treasuries as a group have markedly different seasonal patterns from the stocks as a group, which indicates that intra-week return seasonality is unlikely to derive exclusively from broad economic forces that affect all asset markets similarly. Moreover, seasonal patterns also differ across similar securities. The equally weighted, value-weighted, and S&P 500 stock indices exhibit substantially different Thursday and Friday deviations from their own overall mean returns, while Treasury return deviations differ from one another on Monday and (less reliably) on Wednesday. The fact that similar securities exhibit significantly different seasonal patterns suggests that market-specific, institutional features cannot explain all seasonality. Taking these two observations together, there appears to be no parsimonious explanation for return seasonality.

Our final conclusion is that one aspect of intra-week seasonality—negative Monday returns—may be subject to a unified explanation across all securities. The particular pattern of Treasury securities' Monday returns is consistent with intra-week variations in the market discount rates' term premia. If term premia systematically rose over the weekend, longer term securities would be affected more substantially, as our findings indicate they are.

Appendix: Data Construction

The raw data for our analysis were obtained from DRI (for the RP and Treasury information) and CRSP (for the three stock indices). The RP rates were quoted on a 360-day basis, which we converted to a 365-day basis. Our daily T-bill returns were computed as the overnight percent change in price $((P_t - P_{t-1})/P_{t-1})$, where the bill's price was computed from the average of reported bid and ask discount yields. For coupon bonds, we computed daily returns as

$$\frac{P_t - P_{t-1}}{P_{t-1}} + \frac{C}{P_{t-1}} \times \frac{n}{365},$$

where P is the average of bid and ask prices, C is the coupon rate for the bond, and n is the number of calendar days until the settlement date. For instance, n is 3 for normal (no holidays) Thursday returns and n is 1 for other normal days. Note that holidays will influence n.

The daily CRSP stock return series are well known and require no explanation here. As noted in the text, however, there is no way to construct a true "constant-maturity" daily Treasury security series. The security with maturity closest to the desired value changes through time, which means that one must switch securities frequently in order to construct a daily return series. We use the following conventions in constructing our constant-maturity bill and note return series.

TB1. A thirteen-week bill is auctioned each Monday for delivery at the close of business Thursday. The series we use is centered approximately on twenty-nine days to maturity, with the bill changing every Friday. Thus, the Friday return each week is calculated as the overnight price change for the bill with twenty-seven days to maturity, while the Monday return comes from a bill with thirty-one days to maturity on Monday.

TB3. Technically, the "new" thirteen-week bill auctioned each week is a reopening of the twenty-six-week bill first issued thirteen weeks previously. We therefore took prices for that twenty-six-week bill, centered around the day it had ninety days remaining to maturity. The actual bill changes every Tuesday; Monday's return is calculated from the bill with eighty-seven remaining days to maturity, while Tuesday's return comes from the bill with ninety-three days to maturity on Tuesday.

TB6. A new twenty-six-week bill is auctioned each Monday. The five daily returns for each week's TB6 series are accordingly constructed from the first six prices available on the most recently issued twenty-six-week bill.

TB12. New fifty-two-week bills are issued every fourth week. To construct the TB12 return series, we use prices for the first twenty-nine calendar days of each bill's life to construct twenty-eight returns (dated the second through twenty-ninth days of each bill's life).

TB36, TB84, TB360. Unlike bills, there are no regular weekly or monthly times at which new notes are issued. We selected the notes for our three-, seven-, and thirty-year maturity series that were closest to the nominal maturity. Whenever possible, we selected notes with prices close to par to minimize the effect of tax treatment for capital gains. Also, we rotated the shift days through the days of the week, so that essentially an equal number of shifts occur each day of the week in each of the series.

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