Losing Sleep at the Market: The Daylight Saving Anomaly

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We have all struggled through the day after a poor night's sleep, weighed down by weariness, fighting lethargy, and perhaps even facing despondency. Fortunately, few people suffer from acute sleeping disorders that, according to sleep researchers, can destroy motivation and cause deep depression and even death.[1] Nevertheless, even relatively minor sleep imbalances have been shown to cause errors in judgment, anxiety, impatience, less efficient processing of information, and loss of attention. Indeed, it has been argued that an important thread connecting the nuclear accident at Chernobyl, the near meltdown at Three Mile Island, the massive oil spill from the Exxon *Valdez,* and the explosion of the space shuttle *Challenger,* is people making mistakes because of workshift changes and consequent imbalances of sleep.[2] Equally tragic but less publicized consequences of sleep-related errors have resulted from accidents, which each year "cost the United States over $56 billion, cause nearly 25,000 deaths and result in over 2.5 million disabling injuries."[3] Despite all these negative consequences of sleep problems, the modern hero is the person who seems to defy nature, filling every day with continuous, productive activity, and surviving on far less sleep than is needed by virtually everyone else.

Stock market participants, including investment fund managers and others handling vast financial assets, are almost certainly well represented among those who have reduced the average time spent sleeping by more than two hours per day in the last century, bringing human sleep to several hours less than that of closely related primates. We appear to be fighting evolution, which has made sleep as essential as food and water. The need for sleep is so acute that a common, most successful form of torture is to force people to remain awake until delusion and confusion forces them to reveal their secrets. If the need for sleep is so obvious in the circadian rhythm of our evolutionary relatives and in the tactics of military interrogators, might sleep have consequences in financial markets? This is the question addressed in this paper.

The paper is organized as follows: Section I presents evidence of some well-established negative effects arising from changes in sleep patterns. Results shown in Section II demonstrate that daylight-saving weekends are typically followed by large negative returns on financial-market indices. We argue that the effect could be a direct result of changes in sleep patterns. Conclusions are presented in Section III.

I. Sleep Research

Although sleep researchers have been able to perform controlled experiments to study the effect of sleep on problem-solving ability and response time, when it comes to the effects of sleep on accidents, like economists, they are forced to use other, nonexperimental data sources. One profitable avenue has proved to be the effects of the sleep pattern changes associated with clock shifting at the beginning and end of daylight saving time.[4] The results have been striking. For example, it has been shown that automobile accidents take a statistically

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[1] The psychological and physiological consequences of sleep are discussed in detail in Stanley Coren (1996).

[2] Coren (1996 p. ix and p. 269).

[3] Coren (1996 p. x).

[4] Noncontrolled experiments of sleep researchers also include the study of shift workers and pilots who suffer from jet lag. Case studies and tests on aggregate statistics reveal serious effects of sleep pattern changes on such workers.

significant jump on the days following daylight-saving clock shifts, both in the spring, when clocks go forward causing a one-hour sleep loss, and in the fall, when clocks go back and an hour is regained.[5]

It has been claimed that the effect on accidents, whether sleep is lost or gained, is similar to what happens to sufferers of jet lag: response time and problem-solving ability are adversely affected whether the travel involves a "lag" by traveling west to east, or a "lead" from traveling east to west. In the sleep literature jargon, negative consequences are suffered whenever there is desynchronosticity in circadian rhythm; if travel in one direction compresses the traveler's day, then travel in the other direction stretches it, and both effects cause desynchronosis.

The linkage between desynchronosis and market returns may work through anxiety that itself may result from the difficulty of solving problems and reaching rational decisions throughout the first trading session following a time change. Specifically, if sleep desynchronosis causes market participants to suffer greater anxiety about a given situation, ceteris paribus, they may prefer safer investments and shun risk in trades during the trading day following such a disturbance in their sleep patterns. This could push down stock prices following daylight-saving shifts when the desynchronosis is systematic: although the clock changes are known in advance, the consequences are not. Such a linkage is, of course, a conjecture. Interest in establishing how daylight saving time shifts influence the market really depends on whether an empirical association exists. This paper sets out to evaluate the empirical association in U.S., Canadian, U.K., and German stock market indices, leaving it to others such as experimental sleep researchers to identify the likely pathway.

II. Weekend Effects

Weekend effects have been identified in the foreign-exchange and money markets as well as in stock market returns.[6] Significantly negative effects of weekends on stock returns have been observed for Belgium, Brazil, Canada, New Zealand, Switzerland, the United Kingdom, and the United States, although the effect appears to be stronger in the 1970's than in earlier or later times.[7] Richard Rogalski's (1984) study of closing versus opening prices has shown the effect is from Friday closing to Monday opening, hence the label "weekend effect." This weekend anomaly appears to be present when allowance is made for the January effect, and like other anomalies, is generally stronger for small firms and hence manifest to a greater degree in equally weighted than in value-weighted stock indices.

A. *Daylight Saving Time Changes*

The notion of daylight saving time changes was first proposed by Benjamin Franklin in 1784. The idea did not become popularized until much later, when many nations aimed to conserve energy during World War I. In the United States, a bill was passed to enforce daylight saving in 1917. However, this bill was repealed in August 1919 amid farmers' protests. Although some municipal and state legislations boldly adopted daylight saving during the interwar period, it took World War II to truly revive widespread interest. In fact, by 1966, 36 states had adopted daylight saving time. In 1967, Congress officially passed a daylight saving act, although a few states have chosen not to participate.

Daylight saving implies the loss or gain of an hour twice a year, at 2:00 a.m. Sunday. In the United States and Canada, until 1986, the spring time change always occurred on the last Sunday in April. As of 1987, the spring time change takes place on the first Sunday in April. The fall time change has always occurred on the last Sunday in October. There were no time changes

[5] See Timothy H. Monk (1980) and Robert A. Hicks et al. (1983). Although the data from the United Kingdom, United States, Germany, and other countries show positive effects of both clockshifts, Coren (1996) finds a drop in accidents after clocks go back in Canada.

[6] See Kenneth French (1980), Michael Gibbons and Patrick Hess (1981), Donald B. Keim and Robert F. Stambaugh (1984), Jeffery Jaffe and Randolph Westerfield (1985), and Robert A. Connolly (1989), for weekend effects on stock returns; Maurice D. Levi (1978, 1988) for weekend effects on exchange rates; and Warren L. Coats, Jr. (1981) and Peter C. Eisemann and Stephen G. Timme (1982) for weekend effects in the money market. Many of these papers are summarized by Richard H. Thaler (1987).

[7] See Leda Condoyanni et al. (1988) and Anup Agrawal and Kishore Tandon (1994) for the international evidence.

during World War II or in the year 1974; clocks were kept ahead in both periods to conserve energy. In Germany there were no daylight saving changes from 1950 to 1979. In 1980 the spring change occurred on May 5 and on the last Sunday in March from 1981 onward, whereas the fall change took place on the last Sunday in September from 1980 onward. For the United Kingdom there were no daylight saving changes in 1969 and 1970, and there was no spring daylight saving change in 1971. From 1972 to 1980 the U.K. spring change took place on the third Sunday in March, on March 22 in 1981 and on the last Sunday in March from 1982 onward. The fall daylight saving change in the United Kingdom was on October 31 in 1971, on the fourth Sunday in October from 1972 to 1984, and on the last Sunday in October from 1985 onward. Useful references for this information include Doris C. Doane (1980, 1985, 1991) and Thomas G. Shanks (1985).

Given the distinct effect of sleep desynchronosis observed by sleep researchers mentioned earlier in this paper, we must ask whether the two daylight saving time change weekends lead to different financial market effects than on the other weekends. In testing for the economic effect arising from the daylight saving time change, we look at the first trading day following a daylight saving time change using several different indices. These include U.S., Canadian, U.K., and German indices. Canada shares with the United States a largely common daylight-saving date pattern, but the United Kingdom and Germany have daylight-saving dates that are notably different from those in the United States, Canada, and each other. This makes the U.K. and German data particularly interesting to explore. Same-day market-spillover effects will not contaminate the U.K. and German daylight saving weekend returns data as they do the Canadian and U.S. daylight saving weekend returns data. Furthermore, if the daylight-saving effect was spurious in the North American data, we would be unlikely to find a similar pattern in a country that observes daylight saving on other dates altogether.

B. *The Impact of Daylight Saving Time Changes*

The indices used include market returns for the NYSE, AMEX, and NASDAQ series, with dividends where possible, over the time period January 1, 1967, to December 31, 1997. We also examine S&P 500 returns from January 1, 1928, to December 31, 1997.[8] Given that daylight saving was in effect only in parts of the United States from 1917 onward, we expect similar, albeit perhaps weaker, effects during this longer time span. For Canada we use the Toronto Stock Exchange (TSE) 300 index, over the period January 1, 1969, to December 17, 1998. For the United Kingdom we have a total market return index over the period January 1, 1969, to December 18, 1998. For Germany we use the DAX 100, extending from January 1, 1973, to December 18, 1998.[9]

Table 1 reports the mean of raw returns over the relevant periods for the various market indices from the United States, Canada, the United Kingdom, and Germany. "Spring" refers to the spring daylight-saving weekend mean return, "Fall" to the fall daylight-saving weekend mean return, "Weekend" to all other weekends' mean return, and "Other days" to all days other than weekends' mean return.[10] The "Joint *t*-test" refers to a test that the mean of the two daylight-saving return weekends, spring and fall, are jointly no different from the average regular (non-daylight saving) weekend return. What we see in the mean returns is remarkable evidence of a daylight-saving effect, across time periods and nations.[11] The mean daylight saving weekend is always a

[8] The U.S. data, including NYSE, AMEX, NASDAQ, and S&P 500, were obtained from the Center for Research in Security Prices (CRSP).

[9] The Canadian, British, and German data were obtained from Datastream. Note that Datastream indicates some holidays with a zero return and some holidays with a missing value. All holidays, including those indicated with zero returns, were treated as nontrading days as appropriate.

[10] In calculating "Weekend," we typically use the return between the Friday closing price and the following Monday closing price. On occasion, however, Tuesday is the first trading day after the weekend, so we use the Tuesday close in place of Monday's close. Results using only weekends that end with a Monday trading day are virtually identical to those we present.

[11] We see a similar U. S. pattern if we use the full CRSP indices from July 1962, but the effect is somewhat lessened. The smaller pre-1967 effect is not surprising as daylight saving was not even on the same weekend across the jurisdictions that participated before the 1967 Uniform Time Act. Note that breaking the data into smaller subperiods, such as decades, produced little qualitative variation in the daylight-saving results, though significance was reduced as

TABLE 1—MEAN OF DAILY RAW RETURNS DATA

Index	Weighting	Other days	Weekend	Spring	Fall	Joint t test
NYSE[a]	Equal-weighted	0.0010231	−0.0007010	−0.0018132	−0.0062768	−3.3212
		(6,187)	(1,558)	(30)	(30)	(0.0004)
NYSE[a]	Value-weighted	0.0007423	−0.0003271	−0.0013355	−0.0052693	−2.6736
		(6,187)	(1,558)	(30)	(30)	(0.0038)
AMEX[a]	Equal-weighted	0.0014718	−0.0008528	−0.0021036	−0.0066178	−3.4116
		(6,187)	(1,558)	(30)	(30)	(0.0003)
AMEX[a]	Value-weighted	0.0009327	−0.0014191	−0.0018282	−0.0066984	−2.5463
		(6,187)	(1,558)	(30)	(30)	(0.0054)
NASDAQ[a]	Equal-weighted	0.0014928	−0.0009951	−0.0015897	−0.0074183	−3.9970
		(5,022)	(1,259)	(24)	(24)	(0.0000)
NASDAQ[a]	Value-weighted	0.0010091	−0.0012841	−0.0014848	−0.0080746	−2.8208
		(5,022)	(1,259)	(24)	(24)	(0.0024)
S&P 500[b]	Index	0.0005906	−0.0004079	−0.0014334	−0.0054827	−2.5820
1967–1997		(6,187)	(1,558)	(30)	(30)	(0.0049)
S&P 500[b]	Index	0.0007735	−0.0020642	−0.0044665	−0.0070133	−2.4223
1928–1966		(8,823)	(1,960)	(35)	(35)	(0.0077)
TSE 300[c]	Index	0.0005298	−0.0008212	−0.0024809	−0.0037031	−2.1455
		(5,995)	(1,498)	(29)	(29)	(0.0160)
U.K. total market[d]	Index	0.0007169	−0.0009675	−0.0042295	−0.0043035	−2.3754
		(6,156)	(1,386)	(27)	(28)	(0.0088)
DAX 100[e]	Index	0.0004190	−0.0002614	−0.0014780	−0.0001821	−0.3337
		(5,299)	(1,274)	(19)	(19)	(0.3693)

Notes: "Spring" refers to the spring daylight saving weekend mean return, "Fall" to the fall daylight saving weekend mean return, "Weekend" to all other weekends' mean return, and "Other days" to all days other than weekends' mean return. The "Joint t-test" refers to a test that the mean of the two daylight-saving return weekends, spring and fall, are jointly no different from the average regular (non-daylight saving) weekend return. When the first business day of the week is a Tuesday, the Tuesday return is used in place of the Monday. Figures in brackets under the returns for "Other days," "Weekend," "Spring," and "Fall" denote the number of observations used to compute the mean. Figures in brackets under "Joint t-test" denote the p-value for the joint t-test (i.e., the cumulative probability of the statistic using the appropriate t-distribution).

[a] NYSE, AMEX, and NASDAQ indices obtained from CRSP: January 1, 1967, to December 31, 1997.

[b] S&P 500 index obtained from CRSP: January 1, 1928, to December 31, 1997.

[c] TSE 300 index obtained from Datastream: January 1, 1969, to December 17, 1998.

[d] U.K. total market return index obtained from Datastream: January 1, 1969, to December 18, 1998.

[e] DAX 100 index obtained from Datastream: January 1, 1973, to December 18, 1998.

larger negative return than the mean regular weekend for every index we looked at, and the magnitude of the mean return on spring daylight saving weekends (under the column labeled "Spring") is between two to five times (200 to 500 percent) that of ordinary weekends (under the column labeled "Weekend") for the indices considered. The effect of the daylight saving time change on returns is even stronger in the fall. Intuitively, it might seem that the effect of spring should be at least as large as that of the fall, because of the loss of an hour's sleep in the spring, versus a gain in the fall. However, as mentioned earlier, desynchronosis has adverse effects as judged by task performance, whether time "stretches" or "shrinks."

The joint t-test results of the daylight-saving returns versus the regular weekend returns are shown in the last column of Table 1. The table shows that the daylight-saving effect is slightly more significant for equally weighted indices than for value-weighted indices, and also for broad-market value-weighted indices versus large-capitalization value-weighted indices like the S&P 500. The daylight-saving effect would appear to be particularly pronounced for small firms that have relatively larger prominence in the equally weighted index. The daylight-saving effect is extremely significant—stronger than the 1-percent level—for the U.S. and U.K. indices, and strongly significant for the Canadian index, stronger than the 5-percent level. For the

a result of the smaller number of observations. Results are available on request.

German index—our smallest collection of daylight saving changes and the only insignificant result—the magnitude of the effect is consistent with that found in other countries, roughly six times the regular weekend return. Even with this large difference between regular weekends and daylight-saving weekends, however, the mean of German weekend returns is so small and the variance so large that this difference is rendered statistically insignificant. We apparently need many more years of data for Germany, where daylight savings did not occur from 1950 to 1979, to be able to statistically significantly distinguish this difference in returns from zero. It can be noted that, unlike the other indices we consider, the regular weekend effect itself is insignificant for Germany, the same conclusion documented by Anup Agrawal and Kishore Tandon (1994). Furthermore, we can infer that the insignificance of the daylight-saving effect in the German data is the result of a single observation, October 1, 1990, when the index surged over 5 percent. Absent this observation the daylight-saving effect is significant at the 10-percent level.

For all countries, the t-test results could have been adversely affected by autocorrelation and heteroskedasticity in stock returns. A straightforward remedy is to model returns to control for autocorrelation and heteroskedasticity. We found results were qualitatively unchanged even after accounting for autocorrelation and heteroskedasticity.[12,13]

III. Conclusion

The notion that financial-market participants may be impacted by psychological factors is not new. For example, the effect of indices crossing psychological barriers, such as the 9,000 level of the Dow, is discussed by R. Glen Donaldson and Harold Y. Kim (1993). In this paper, we have suggested a psychological mechanism by which daylight saving time changes impact on the functioning of financial markets on two particular weekends every year.

There already exist various explanations for stock market behavior on weekends. For example, the regular weekend effect has been attributed to payment and check-clearing settlement lags in a paper by Josef Lakonishok and Maurice D. Levi (1982).[14] Several other authors, including Edward M. Miller (1988), Edward A. Dyl and Clyde W. Holland (1990), Josef Lakonishok and Edwin Maberly (1990), and Abraham Abraham and David L. Ikenberry (1994), have attributed the weekend effect to the mid-week time pressures on individuals and the tendency for financial advice to be provided after Monday strategy-setting meetings.[15] Bid-ask spreads may also play a role: a large percentage of closing prices may represent purchases from dealers on Fridays—at dealer ask prices—whereas Monday closing prices may involve disproportionately more sales to dealers, at dealer bid prices.[16]

[12] We performed standard maximum likelihood estimation (MLE) of a GARCH(1,1) model with an AR(1) model for the mean. Where this model was rejected by the data we estimated a Glosten et al. (1993) asymmetric ARCH model, which was not rejected by the data for the series and data periods we investigated. The MLE estimates for both the spring and fall daylight-saving weekend returns are very similar in magnitude, and roughly double the regular weekend effect. The daylight-saving effect, that is, the average Spring-Fall daylight-saving coefficient minus the regular Weekend coefficient, is typically statistically significant at the 10-percent level. Further details may be found in Kamstra et al. (1998).

[13] Alternatively, bootstrap estimation can be applied to the differences in mean returns between daylight-saving and ordinary weekends. The bootstrap approach, originally introduced by Bradley Efron (1979) and since used by Francis X. Diebold and Celia Chen (1996), Dimitrios Malliaropulos (1996), and Christopher Z. Mooney (1996), also safeguards against nonnormality of returns: see Efron and Tibshirani (1993). Bootstrap results confirm the significance of the daylight-saving effect. Results are available on request.

[14] With the five-business-day settlement through most of the period studied, and with one day for check clearing, payments for Monday–Thursday stock purchases were settled after eight days, versus ten days for Friday stock purchases. The jump in Friday prices by two-business-days' interest explains a lower return from Friday closing to Monday opening, albeit less than the observed effect.

[15] Individuals, it is argued, do not have time to check their investments during the week, and leave much of this to the weekends. On Mondays, they take action and do a large part of their selling when institutional investors are attending meetings to set strategy for the upcoming week. Later in the week the advice is provided to individuals, with this being more likely advice to buy than to sell. Selling advice is relevant to fewer individuals because it applies only to those with a stock, whereas buying advice applies to all.

[16] This argument was offered by a reviewer of this journal.

The daylight saving time change weekend effect found in this paper adds sleep desynchronosis to these other "rational" explanations for the weekend effect. The magnitude of the daylight saving effect, roughly 200 to 500 percent of the regular weekend effect, is both statistically and economically significant in several international financial markets. In the United States alone, the daylight saving effect implies a one-day loss of $31 billion on the NYSE, AMEX, and NASDAQ exchanges. We believe that the importance of daylight saving time changes indicated in this paper makes the issue something well worth sleeping on, and a matter that is as worthy of further study as other explanations of the weekend anomaly. If, as other literature suggests, sleep desynchronosis is responsible for physical property loss in addition to the sort of impact investigated here, an obvious policy implication is to do away with the time change altogether. We hope that this contribution will be viewed as interesting enough to prompt more detailed investigation of further related issues, including the effect of daylight saving time changes on intraday volatility, transactions volume, and close-to-open returns.

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