Rise and Fall of Calendar Anomalies over a Century*

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Abstract

In this paper, we conduct a comprehensive investigation of calendar anomaly evolution in the US stock market (given by the Dow Jones Industrial Average) for the 1900 to 2018 period. We employ various statistical techniques (average analysis, Student's t-test, ANOVA, the Kruskal-Wallis and Mann-Whitney tests, modified cumulative abnormal returns approach), R/S analysis, and the trading simulation approach to analyse the evolution of the following calendar anomalies: day of the week effect, turn of the month effect, turn of the year effect, and the holiday effect. The results revealed that 'golden age' of calendar anomalies was in the middle of the 20th century. However, since the 1980s all calendar anomalies disappeared. This is consistent with the Efficient Market Hypothesis.

Keywords: Calendar Anomalies, Day of the Week Effect, Turn of the Month Effect, Turn of the Year Effect, Holiday Effect, Stock Market, Dow Jones Industrial Average Index.
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1 Introduction

Calendar anomalies have been a subject of study amongst academics since the 1930s (see Cross (1973), Fortune (1998), Barone (1990), Jensen (1978), Lakonishok & Smidt (1988) and Bildik (2004), amongst others). In essence, this line of enquiry rests on the Efficient Market Hypothesis as postulated by Fama (1965) and Fama (1970). That is, markets fully reflect all available information, and therefore calendar anomalies such as the day of the week effect, turn of the month effect, turn of the year effect, and the holiday effect should not exist. Furthermore, the Efficient Market Hypothesis implies that traders should not be in a position to predict and 'beat' the make in order to market abnormal profits.

However, Grossman & Stiglitz (1980), Shiller (2000), Shiller (2003), Lo (2004), and Akerlof & Shiller (2009)) argued against the Efficient Market Hypothesis on the basis that it overlooked transaction costs, information asymmetries, and irrational behaviour of investors (mass panic, herd instinct and mass psychosis). As such financial asset price data can have long memory (persistence), clustered volatility, and fat-tailed distributions.

There are three types of return anomalies in the literature. These are price, firm-size, and calendar anomalies. Price anomalies were originally identified by Basu (1977) who found that stocks with low price earnings ratios or value stocks had higher risk-adjusted returns when compared to stocks with high price earnings ratios or growth stocks. Keim (1983) defined the firm size anomaly as a negative correlation between average returns and firm size, indicating that investors are more likely to gain higher returns from investing in small firms than from larger firms. Calendar anomalies, then, contradict the Efficient Market Hypothesis in that the fluctuation of returns depends on the season of the year or the day of the week.

Empirical studies on calendar anomalies remain mixed. This is as a result of differences in data sets, data frequency, data periods, and methodology employed. Other differences in the analysis emanate from the choice of markets, financial assets, and stock market countries. Therefore, despite the large number of papers devoted to calendar anomalies, one of the questions that remains pertains to how markets evolve over time. As stated by Lo (2004) stock markets must evolve over time from an inefficient to an efficient state (see also Schwert (2003)). Also as shown by Barone (1990) calendar anomalies tend to be unstable over time. More recent studies, such as Steeley (2001) and Kohers et al. (2004) who suggested that stock markets are more efficient, causing the day of the week effect to slowly disappear.

Although not the focus of this study, comparing advanced markets with advanced emerging markets, Seif et al. (2017) found evidence of the day of the week effect, the month of the year effect, and the holiday effect in advanced emerging markets, as had been previously found in advanced markets. This is despite advanced developing markets having different institutional settings and time zones. Seif et al. (2017) refuted these factors as explanations for possible differences between advanced market and advanced developing markets.

Urquhart & McGroarty (2016) demonstrated that stock market return predictability varies over time and is related to the stock market conditions. Urquhart & McGroarty (2016) confirm the Adaptive Market Hypothesis in the S&P500, FTSE100, NIKKEI225 and the EURO STOXX 50. That is, the analogous behaviour of stock market returns varies over time is not omnipresent as suggested by the Efficient Market Hypothesis. However, our analysis differs from Urquhart & McGroarty (2016). Urquhart & McGroarty (2016) focus on the Monday effect, January effect, turn of the month effect, and the Halloween effect. We instead focus on the day of the week effect, turn of the month effect, turn of the year effect, and the Holiday effect. More importantly, we offer an alternative methodological approach to Urquhart & McGroarty (2016) which ultimately indicates a lack of methodological bias on the their paper.

Therefore, to this end, the purpose of this paper is to analyse the evolution of the most common calendar anomalies, that is, the day of the week effect, turn of the month effect, turn of the year effect, and the holiday effect. Unlike previous studies this paper uses a comprehensive sample of the Dow Jones Index (1900 to 2018). Various statistical techniques (average analysis, Student's t-test, Analysis of Variation (ANOVA), Kruskal-Wallis and Mann-Whitney tests) and a trading simulation approach, as well as modified cumulative abnormal returns (CAR) approach, which has never been used before in this area, are employed. Furthermore, using R/S analysis we compare persistence in anomalous periods to persistence in normal periods to determine the evolution of anomalies.

This paper is organised as follows. Section 2 briefly offers a literature review of common calendar anomalies, and Section 3 describes the data and outlines the research method. Section 4 presents the results, followed by Section 5 which offers some concluding remarks.

2 Literature Review

2.1 Day of the Week Effect

Cross (1973) was amongst the first to confirm that the distribution of stock price changes varied according to the day of the week using United States (US) data. In particular, the literature focuses on the distribution of prices on Friday versus Monday, where stock prices are usually higher on Fridays than any other day of the week, and lower on Mondays than any other day of the week. That there is a tendency for different weekdays to have unequal mean returns (Cross (1973); Gibbons & Hess (1981); Cai et al. (2006)). The weekend effect is variation of the day of the week effect were daily returns on Mondays are in general lower compared to other weekdays (French (1980)).

In the US, Agrawal & Tandon (1994) and Olson et al. (2015) found that the day of the week effect had disappeared. Connolly (1989) found that the existence of the day of the week effect seems to depend on the time period and statistical techniques in the US. Fortune (1998) using the S&P 500 index found statistically significant negative returns over weekends pre and post 1987. At a global level, Lakonishok & Smidt (1988) found no evidence of the day of the week effect. In Europe, Chang et al. (1993) found clear evidence of the day of week effect. In the Istanbul stock market, Bildik (2004) investigated whether calendar anomalies exist and found that stock returns were significantly higher on Fridays as compared to Mondays. In Brazil Madureira & Leal (2001) found that the day of the week effect depended on time and that the day of the week effect was absent from recent periods.

Therefore, the existence of the day of the week effect is a subject of debate in the literature. According to Zhang et al. (2017) the day of the week effect can affect investors in deciding portfolio selection, profit management, and overall investment strategy. Furthermore, Zhang et al. (2017) note that this type of phenomena cannot be adequately explained by finance theory and that although the literature has demonstrated that calendar effects exist, there is no uniform agreement in the literature owing to differences in sample data and methods. In addition, Sias & Starks (1995) found some evidence of why the day-of-the-week effect anomaly appears. That investors usually trade less during Mondays, which causes returns to be lower on Mondays when compared to other weekdays. Further, Golder & Macy (2011) found that there is a clear pattern of improving mood during the week, which they argue, could be a reason as to why returns are lower on Mondays.

2.2 Turn of the Month Effect

Ariel (1987), in the US, was the first to find that the mean return of stocks is positive before the end of the preceding month and in the first half of the month combined, and was indistinguishable from zero for the second half of the month. This is, in essence, the turn of the month effect. In the US, Lakonishok & Smidt (1988) found that the cumulative returns between the last day of the month and the following three days of the subsequent month exceed returns over the entire month.

In a wider study, Kunkel et al. (2003) examined stock market indices in 19 countries for the period 1988 to 2000 and found that the four-day turn of the month period accounted for 87% of monthly returns (66% for the US). This was on average found in 16 out of the 19 stock markets where the turn of the month effect existed. Kunkel et al. (2003) concluded that the turn of the month effect is an international phenomenon.

In China, Zhang & Li (2006) found evidence of the day of the week effect, however, since 1997 the turn of the month effect disappeared. Giovanis (2009) investigated turn of month and day of the week effects in 55 stock markets and found that at a global level no calendar anomalies existed at a global level, except for the turn of the month effects which was found in 36 stock markets.

No uniform explanation for the existence of the turn of the month effect is advanced in the literature. However, Ariel (1987) observed that a stock market advisors claimed that a monthly pattern indeed existed. This is because advisors urge clients to make anticipated stock purchases before the start of calendar months, and to postpone sales to after the middle of the month in order to capture the higher than usual returns that accrue in the early days of calendar months. In addition, others such as Maher & Parikh (2013) attributed the existence of the turn of the month effect in India to large institutional investors significantly increasing trading volumes at the end of the month, and thereby increasing stock prices. Sharma & Narayan (2014), using data on 560 firms on the New York Stock Exchange, showed that the turn of the month effect can depend on the sectoral location of firms and on firm size.

2.3 Turn of the Year Effect

Rozeff & Kinney (1976) were amongst the earliest to show that January returns were abnormally high when compared to the rest of the year. Gultekin & Gultekin (1983) showed higher than normal January stock returns in 16 countries.

Furthermore, Rozeff & Kinney (1976) found higher returns for small cap stocks in the month of January. Roll (1983), Reinganum (1983) and others attribute these abnormal returns to tax-loss selling at the end of the financial year. Whilst others such as Keim (1983) attribute them to the small firm effect, and to window dressing and portfolio rebalancing by investors (Lakonishok & Smidt (1988)). Other studies such as Wong et al. (2006), in the Singapore stock market, found that the existence of the of the January effect had largely disappeared.

It is not the case that stock returns were higher in January. In the United Kingdom over a 300 year period Zhang & Jacobsen (2012) found that the turn of the year effect is sample specific. That the turn of the year effect only became prominent in the last 150 years as Christmas become more popular. Ariel (1990) confirmed this by stating that turn of year studies must consider holiday effects. Zhang & Jacobsen (2012) also confirmed this link for the US. Reinganum (1983) (amongst others) showed that much of these abnormal returns occur within the first two weeks of January. This is known as the turn of the year effect.

2.4 Holiday Effect

Using data from the Dow Jones in the early 1900s, Fields (1934) was the first to find evidence of the holiday effect on trading days preceding long holiday weekends. Subsequently, Roll (1983) also found high returns accruing to small firms on trading days prior to New Year's Day. Noting this history of pre-holiday high returns Ariel (1990), using data on the Dow Jones Industrial Average between 1963 and 1982, found that on average pre-holiday returns equated to nine to fourteen times the returns of non-pre holidays. Others such as Lakonishok & Smidt (1988) and Merrill (1966) found similar results in the US.

The holiday effect has also been shown to be robust across different asset classes (Liano et al. (1992) and Wilson & Jones (1993)) and different markets such as the United Kingdom and Japan (Kim & Park (1994)), and New Zealand (Cao et al. (2009)). Seif et al. (2017) also found evidence of the holiday effect in advanced emerging stock markets. Seif et al. (2017) further notes that as a test for market efficiency, the holiday effect can be explained by behavioural rather than rational factors. For example, Fabozzi et al. (1994) attributes the holiday effect to several factors such as:

- A delay in settlement procedures as a result of the holiday can have an effect on returns up to a week prior to the holiday.
- Improved investor mood around holidays may induce investors to take positions which result in a short-term market rally.

- The inventory adjustment process has been shown to explain the holiday effect since the loss potential of a short position is more than that of a long position and traders may be reluctant to take short positions prior to a non-trading day.

Ariel (1990) notes that whatever the reason for the holiday effect, holiday effects have been in existence for a protracted period (see Lakonishok & Smidt (1988)) and will need to be considered further, even in turn of the year studies which include holiday periods.

3 Data and Methodology

We utilise daily data on the Dow Jones Industrial Average Index covering the period 1900 to 2018. The data was sourced from the Global Financial Database.[1]. For the holiday effect, US holidays were sourced from the Time and Date website.[2] The data were then split into 10 year sub-periods to allow us to explore the evolution of calendar anomalies. 10 year sub-periods also provide enough data points for robust statistical testing. Therefore, the focus of this study is to test for the following hypotheses:

- H_1: calendar anomalies exist and are not a market myth
- H_2: calendar anomalies evolve over time
- H_3: level of persistence in calendar anomalies related data set differs from that of the normal data

These hypotheses were tested using average analysis, parametric tests (Student's t-test and ANOVA analysis[3]), non-parametric tests (Kruskal-Wallis and Mann-Whitney tests), the trading simulation approach, and the modified cumulative abnormal returns approach.

The average analysis gives preliminary evidence of anomalies if average returns for a day, week or a month associated with calendar anomalies is higher than the rest of that 10 year sub-period. The Student's t tests were conducted using a 5% level of significance and $N-1$[4] degrees of freedom to test if the data on the

[1] https://www.globalfinancialdata.com.

[2] The calendar can be found at: https://www.timeanddate.com/calendar/?country=1.

[3] Results from traditional regression-based analyses with dummies were found to be in line with those obtained from the ANOVA model. Complete details of these results are available upon request from the authors

[4] $N = N_1 + N_2$ in this case.

anomaly is significantly different from that of the rest of the 10 year sub-period. Therefore confirming a calendar anomaly. The t tests were conducted on daily returns which were calculated as follows

$$R_t = \left(\frac{Close_t}{Close_{t-1}} - 1 \right) \times 100 \tag{1}$$

where R_t is the return on the t-th day in percentage, $Close_t$ is the closing price on the t-th day, and $Close_{t-1}$ is the closing price on the $t-1$-th day.

The Kruskal-Wallis and Mann-Whitney tests were also carried out in a similar manner. When an anomaly is detected a further examination, by way of trading simulation, to determine if this anomaly gives rise to a profit exploitation opportunity, was conducted. This approach utilises an algorithm which simulates trader behaviour who opens positions on the Dow Jones Index and holds these positions for a period of time.

The first step in the simulated trading process is to compute the percentage result ($\%Result$) from each deal in the following manner:

$$\%Result = \frac{100 \times P_{open}}{P_{close}} \tag{2}$$

where P_{open} is the opening price, and P_{close} is the closing price.

Then the results from each deal are summed to calculate the total financial result of the simulated trading process. A positive financial result indicates an exploitable market anomaly. Finally, to ensure that this financial result is statistically different from a financial result from random trading, a z-test, which tests if two sample means are the same (or come from the same population), was carried. The z-tests were conducted with a 5% level of significance on samples of more than a 100. In essence, we test if a mean from a trading strategy which exploits an anomaly is significantly different from a mean of a trading strategy which does not. The latter must equate to zero under the Efficient Market Hypothesis.

The cumulative abnormal returns approach is based on MacKinlay (1997) and is standard for event studies. Abnormal returns are defined as follows:

$$AR_t = R_t - E(R_t) \tag{3}$$

where R_t is the return and AR_t is the abnormal return at time t. $E(R_t)$ is the is corresponding average return computed over the entire sample as follows:

$$E(R_t) = \left(\frac{1}{T}\right) \sum\nolimits_{i=1}^{T} R_i \tag{4}$$

where T is the sample size.

The cumulative abnormal return denoted as CAR_i is simply the sum of the abnormal returns

$$CAR_i = \sum\nolimits_{i=1}^{T} AR_i \tag{5}$$

The presence of trend in cumulative abnormal returns data indicates abnormal returns. To check for the trend a simple regression model is build, with a high multiple $R-squared$ and overall model significance ($F-test$), as well as the signs and statistical significance ($p - values$) of the coefficients confirm or reject the presence of trend in the abnormal returns.

Lastly, we test whether the level of persistence in data with calendar anomalies, differs from the level of the normal data. To explore this avenue we utilise R/S analysis as in Caporale et al. (2018). In general the test is as follows.

First, a time series of length M is transformed into one of length $N = M - 1$ using logs and converting stock prices into returns in this manner:

$$N_t = log\left(\frac{Y_t}{Y_{t-1}}\right), t = 1, 2, 3, ..., (M - 1) \tag{6}$$

Second, this length is divided into contiguous A sub-periods with length n, such that $A_n = N$, then each sub-period is identified as I_a, given the that $a = 1, 2, 3..., A$. Each element I_a is represented as N_k with $k = 1, 2, 3..., N$. For each I_a with length n the average is defined as e_a:

$$e_a = \frac{1}{n}\sum_{k=1}^{n} N_{k,a}, k = 1, 2, 3, ...N, a = 1, 2, 3, ...A \tag{7}$$

Thirdly, the accumulated deviations $X_{k,a}$ from the average e_a for each sub-period I_a are defined as follows:

$$X_{k,a} = \sum_{i=1}^{k} (N_{i,a} - e_a) \tag{8}$$

The range is defined as the maximum index $X_{k,a}$ minus the minimum $X_{k,a}$, within each sub-period I_a:

$$R_{I_a} = maxX_{k,a} - minX_{k,a}, 1 \leq k \leq n \tag{9}$$

Fourthly, the standard deviation $S_{I_a}$is calculated for each sub-period I_a as:

$$S_{I_a} = \left(\left(\frac{1}{n}\right) \sum_{k=1}^{n} (N_{k,a} - e_a)^2\right)^{0.5} \tag{10}$$

Fifthly, each range R_{I_a} is normalised by dividing by the corresponding S_{I_a} . Therefore, the re-normalised scale during each sub-period I_a is R_{I_a}/S_{I_a}. In step 2 above, adjacent sub-periods of length n are obtained. Thus, the average R/S for length n is defined as:

$$(R/S)_n = \frac{1}{A} \sum_{i=1}^{A} (R_{I_a}/S_{I_a}) \tag{11}$$

Sixthly, the length n is increased to the next higher level, $(M - 1)/n$, and must be an integer number. In this case, n-indexes that include the start and end points of the time series are used, and steps 1 to 5 are repeated until $n = (M-1)/2$.

The least square method is used to estimate the equation $log(R/S) = log(c) + H * log(n)$. The slope is an estimate of the Hurst exponent (H) (Hurst (1951)). On the basis of the H values three categories can be identified:

- That the series are anti-persistent and returns are negatively correlated ($0 \leq H < 0.5$);
- The series are random and returns are uncorrelated. Or there is no memory in the series ($H = 0.5$);
- The series are persistent and returns are highly correlated. Or there is memory in price dynamics ($0.5 < H \leq 1$).

4 Empirical Results

4.1 Day of the Week Effect

The empirical results for the day of the week effect are presented in Appendix A. Table A.1 and Figure A.1 show, in terms of the average analysis, that between the 1920s until the end of the 1980s Monday was the worst day of the week in terms of returns. This is confirmed by the significant ANOVA-multiplier.[5] The higher ANOVA-multiplier is the more anomalous is the difference (see Table A.2). The ANOVA results clearly point to a 'golden age' of the day of the week effect in the period 1900 to 2000. During this period there were statistically significant differences between return in different days of the week.

Most of these results are confirmed by Kruskal-Wallis test (see Table A.3). At the same time, it should be mentioned that over the analysed period day of the week effect was present not only on Mondays but on other days as well. To show this, a number of t-tests for different days of the week were conducted and the results are presented in Table A.4. In the sub-periods 1900-1909, 1920-1929, 1950-1959 and 1960-1969 abnormally positive returns on Fridays were detected. In addition, during the sub-period 1960-1969 abnormal positive returns were detected on Wednesdays. This can partially explain the differences about the existence of the weekend effect in the literature. However, the results also show that the day of the week effect disappeared after the year 2000.

The trading simulation provides additional evidence of the existence of the day of week effect and its recent disappearance. The algorithm of the trading strategy is developed according to the classical variant of the day of the week anomaly (abnormally negative returns of Mondays). That is, a trader sells on Friday close price and closes position on Monday close price. Transaction costs (spread, commissions to the broker and commissions to the bank, amongst others) are almost impossible to incorporate correctly for such as long period of time, and were, therefore, ignored.

The results of the trading simulations are presented in Table A.5 and Figure A.2, and these confirm that it was possible to exploit profits from the day of the week effect in the 1920s until the end of the 1980s. However, since the 1980s it is impossible to generate abnormal profits from trading based on the day of the week effect. Therefore, in general, these results are consistent with the other tests.

[5] The ANOVA-multiplier uses the $\frac{F}{F_{CV}}$ ratio to test for the statistical significance of anomalies, where F_{CV} is the critical value of the F-statistic. A value of above 1 indicates statistical significance.

Table 1: Summary of the day of the week effect results

Period	Average analysis	Students t-test	ANOVA	Kruskal -Wallis test	Modified CAR	R/S analysis	Trading simulation	Overall
1900-1909	+	+	+	+	+	+	-	6
1910-1919	-	-	-	-	+	+	-	2
1920-1929	+	+	+	+	+	+	+	7
1930-1939	+	+	+	+	+	+	+	7
1940-1949	+	+	+	-	+	+	-	5
1950-1959	+	+	+	+	+	+	+	7
1960-1969	+	+	+	+	+	+	+	7
1970-1979	+	+	+	+	+	-	+	6
1980-1989	+	+	+	-	+	-	-	4
1990-1999	+	+	+	+	-	-	+	5
2000-2009	-	-	-	-	-	-	-	0
2010-2018	-	-	-	-	+	-	-	1

Note: + means the the anomaly is present, and - means that it is not present. The Overall column simply counts the number of + with a higher number indicating stronger evidence of the anomaly

The results of the Modified CAR approach (Table A.6) confirm the presence of abnormal price behaviour on Mondays during all of the analysed periods except 1990-1999 and 2000-2009. The R/S analysis (Table A.7) shows that in general, the Hurst exponent on Mondays during 1900-1969 was close to 0.60, indicating the presence of persistence in data. Since 1970 the level of persistence decreased on Mondays. There are sub-periods in which the other days exceeded 0.60, however, not as consistently as on Monday. The decline in persistence after 1970 may be an indication of increased market efficiency.

Table 1 summarises all the day of the week results. We conclude from Table 1 that there is convincing evidence of the day of the week effect exists, and therefore that the day of the week is not a market myth. Furthermore, Table 1 is consistent with the Adaptive Markets Hypothesis. That is, in terms of the day of the week effect, the US stock market became more efficient over time.

4.2 Turn of the Month Effect

The results for the turn of the month effect are presented in Appendix B. Specifically, the results of the simple average analysis are displayed in Table B.1 and Figure B.1. These reveal that returns at the start of the month for most of the sub-periods were higher than those of the rest of the month. In most sub-periods returns were more than 10 times higher. Using the ANOVA-multiplier (see Figure B.1 and Table B.2), the turn of the month effect was statistically significant from the 1920s until the end of the 1970s.

Detailed results of the other statistical tests are presented in Table B.3 (Mann-Whitney test), and Table B.4 (t-tests). Despite some differences in the results of the different tests, the overall picture that from the 1920s up to the 1980s, the turn of the month effect was statistically significant holds. In the 1980s the turn of the month effect started to fade and eventually disappeared in the 2000s. The results of the trading simulations (Table B.5 and Figure B.2) confirms this on the basis of the buy on the last day of the previous month and close position after the 3rd day of the month algorithm.

The modified CAR approach (Table B.6) confirms the presence of abnormal price behaviour at the start of the month. The only exception is the 2010-2018 sub-period. The R/S analysis (Table B.7) shows that persistence on the start of the month was higher than on the rest of the month during 1970-1999. But overall we find no convincing evidence of differences in persistence levels.

Table 2: Summary of the turn of the month effect results

Period	Average analysis	Students t-test	ANOVA	Mann-Whitney test	Modified CAR	R/S analysis	Trading simulation	Overall
1900-1909	+	-	-	+	+	-	+	4
1910-1919	-	-	-	-	+	-	-	1
1920-1929	+	+	+	+	+	-	+	6
1930-1939	+	+	+	+	+	-	+	6
1940-1949	+	+	+	+	+	-	+	6
1950-1959	+	+	+	+	+	-	+	6
1960-1969	+	+	+	+	+	-	+	6
1970-1979	+	+	+	+	+	+	+	7
1980-1989	+	-	-	+	+	+	+	5
1990-1999	+	-	-	-	+	+	+	4
2000-2009	+	-	-	-	+	-	-	2
2010-2018	-	-	-	-	+	+	-	1

Note: + means the the anomaly is present, and - means that it is not present. The Overall column simply counts the number of + with a higher number indicating stronger evidence of the anomaly

A summary of the turn of the month effect results is presented in Table 2. We conclude that the turn of the month effect is not a market myth and in fact existed for a long period of time. In addition, the turn of the month effect generated exploitable profits from trading. Similar to the day of the week effect Furthermore, Table 2 is consistent with the Adaptive Markets Hypothesis. That is, in terms of the turn of the month, the US stock market evolved to be more efficient over time.

4.3 Turn of the Year Effect

The results of the turn of the year effect are presented in Appendix C. The average analysis (Table C.1 and Figure C.1) reveals that between 1900 and the end of the 1980s, returns on the last week of December and the first two weeks of January, were higher than returns at other times of the year. However, the size of this difference was very unstable and deviated from 2-3 to 10-20 times. Nevertheless, the ANOVA-multiplier shows that these differences were statistically insignificant (see Table C.2).

To expand on these results we provide additional tests (Mann-Whitney test (Table C.3) and t-tests (Table C.4)). These results clearly corroborate the ANOVA tests, that is, the turn of the year effect is statically insignificance for most of the 1900 to 2018 period. The turn of the year effect was only significant between 1960 and 1979. The trading simulations (Table C.5 and Figure C.2) further confirms.

Nevertheless, the modified CAR approach (Table C.6) confirms the presence of abnormal price behaviour at the start of the year, with the 2010-2018 sub-period being the only exception. The R/S analysis (Table C.7) also shows that the persistence on the start of the year, in general, was higher than that of the rest of the year, with very few exceptions. Thus the Hurst exponent at the start of the year exceeded 0.60 during most of the analysed periods, thereby clearly indicating the presence of persistence. A summary of results is presented in Table 3. Therefore, it can be concluded from Table 3 that the turn of the year effect is a market myth and never existed in the US stock market. These results support the Efficient Market Hypothesis.

4.4 Holiday Effect

The results for the holiday effect are presented in Appendix D. The results of the average analysis (Table D.1 and Figure D.1) show that between 1900 and the end of the 1970s average returns on the last trading day before a holiday were much higher than returns on the other days of the year. For example, in 1920-1929 sub-period average returns were 0.68% on the last day before a holiday versus 0.02%

Table 3: Summary of the turn of the year effect results

Period	Average analysis	Students t-test	ANOVA	Mann-Whitney test	Modified CAR	R/S analysis	Trading simulation	Overall
1900-1909	+	-	-	-	+	+	-	3
1910-1919	+	-	-	-	+	+	-	3
1920-1929	+	-	-	-	+	-	-	2
1930-1939	+	+	-	+	+	-	-	4
1940-1949	+	-	-	-	+	-	-	2
1950-1959	+	-	-	-	+	-	-	2
1960-1969	+	+	-	-	+	-	+	4
1970-1979	+	+	+	-	+	+	+	6
1980-1989	+	-	-	-	+	+	-	3
1990-1999	-	-	-	-	+	+	-	2
2000-2009	-	-	-	-	+	+	-	2
2010-2018	-	-	-	-	-	+	-	1

Note: + means the the anomaly is present, and - means that it is not present. The Overall column simply counts the number of + with a higher number indicating stronger evidence of the anomaly

on the other days. However, this difference was rather unstable in terms of size and statistical significance. For example, the ANOVA-multiplier was above the division line only 4 out of 12 times (Figure D.1 and Table D.2).

The rest of the results are presented in Table D.3 (Mann-Whitney test), and Table D.4 (t-tests). The 'golden age' of the holiday effect was between 1950 and 1979. The holiday effect was also detected in the 1920-1929 sub-period. However, since the 1980s the holiday effect disappeared from the US stock market. These results are confirmed by the trading simulations (Table D.5 and Figure D.2). Exploitable profits were generated on the basis of the buy on the final day before the holiday and close position before the holiday starts algorithm during the 1920-1929, 1950-1959, 1960-1969, and 1970-1979 sub-periods.

In Table D.6, using the modified CAR approach we confirm the presence of abnormal price behaviour on the last day before a holiday, with exceptions in the 1990-1999 and 2000-2009 sub-periods. The R/S analysis (Table D.7) also shows persistence on the last day before a holiday was higher than on the other days of the year. Thus the Hurst exponent on the last day before holiday exceeded 0.60 during most of the analysed sub-periods except for the 1990-1999 sub-period. These results confirm persistence in the data and the anomaly.

A summary of the holiday effect results is presented in Table 4. We conclude that the holiday effect is not a market myth and was prominent in the middle of the 20th century. But similar to the day of the week and turn of the month effects, the holiday effect since the 1980s has disappeared. Furthermore, Table 4 is consistent with the Adaptive Market Hypothesis. That is, in terms of the holiday effect, the US stock market became more efficient over time.

Table 4: Summary of the holiday effect results

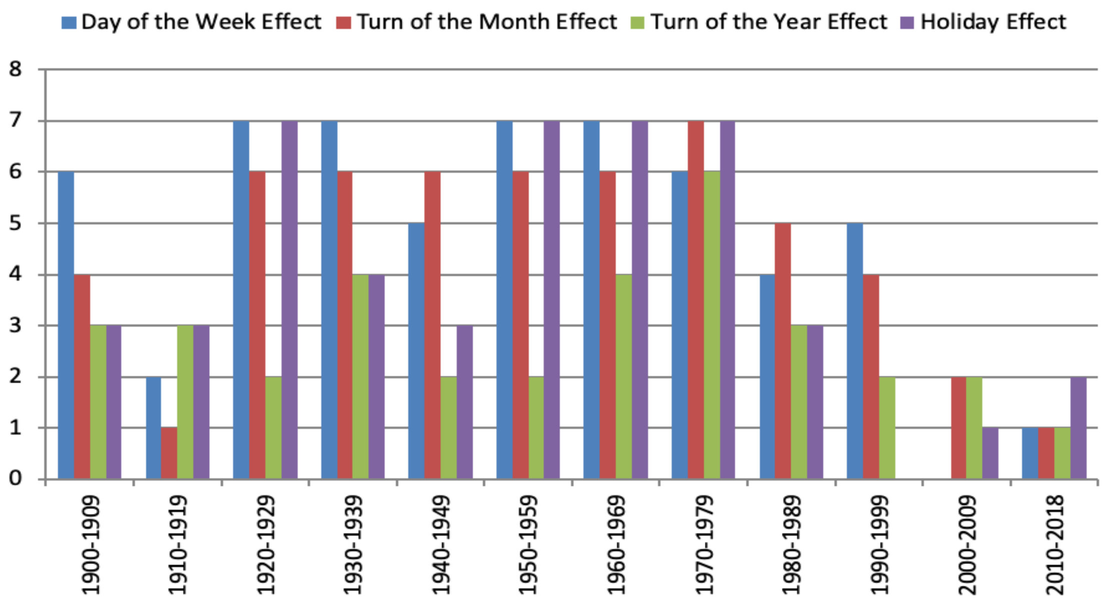
Period	Average analysis	Students t-test	ANOVA	Mann-Whitney test	Modified CAR	R/S analysis	Trading simulation	Overall
1900-1909	+	-	-	-	+	+	-	3
1910-1919	+	-	-	-	+	+	-	3
1920-1929	+	+	+	+	+	+	+	7
1930-1939	+	-	-	+	+	+	-	4
1940-1949	+	-	-	-	+	+	-	3
1950-1959	+	+	+	+	+	+	+	7
1960-1969	+	+	+	+	+	+	+	7
1970-1979	+	+	+	+	+	+	+	7
1980-1989	+	-	-	-	+	+	-	3
1990-1999	-	-	-	-	-	-	-	0
2000-2009	-	-	-	-	-	+	-	1
2010-2018	-	-	-	-	+	+	-	2

Note: + means the the anomaly is present, and - means that it is not present. The Overall column simply counts the number of + with a higher number indicating stronger evidence of the anomaly

5 Conclusion

This paper examined calendar anomalies (day of the week effect, turn of the month effect, turn of the year effect, and the holiday effect) in the US stock market over the period 1900 to 2018 using different methods (average analysis, modified cumulative abnormal returns approach, R/S analysis, the Students t-test and ANOVA, Kruskal-Wallis and Mann-Whitney tests, and the trading simulation approach). This paper sought to investigate how these calendar anomalies evolved in the 20th century, to test whether the US stock market was efficient in line with the Efficient Market Hypothesis.

Figure 1: Evolution of calendar anomalies in the US



Note: The scale is from 0 to 7, where 0 is total absence of anomaly and 7 is the most convincing presence of the anomaly

What can we conclude, therefore, about the evolution of these anomalies? Figure 1 shows the evolution of the day of the week effect, turn of the month effect, turn of the year effect, and the holiday effect in the 20th century. It is clear that the 'golden age' for calendar anomalies was the middle of the 20th century, except for the turn of the year effect which was found to be statistically insignificant. However, by the 2010-2018 sub-period, no calendar anomalies existed. The results of this study provide convincing evidence that the US stock market evolved from being inefficient with a number of calendar anomalies to being efficient such that it is impossible to find 'holes' in price dynamics that can generate exploitable profits.

Although we did not formally test for pre and post-publication bias, these can be explained by the observations of McLean & Pontiff (2016) who state that these anomalies tend to disappear after academic publication. That is, the anomalies are mainly a result of mis-pricing. McLean & Pontiff (2016) show that post-publication:

- First, the variance, dollar volume, and short interest rates all increase significantly which is consistent with drawing attention to anomaly trading strategies, resulting in more of the same trading and thereby reducing abnormal profits.
- Portfolios that are more costly to arbitrage, decline less post-publication.
- Finally, the correlation of an analogous portfolio with yet to be published portfolios declines post-publication, and the correlation with published portfolios increases at the same time.

On the other hand, the results of the R/S analysis, which showed that market efficiency tended to increase over time using price changes, are well in line with the work of Cajueiro & Tabak (2004) who found that in the main market efficiency increased over time, the recent work of Tiwari et al. (2019) who found that markets were more efficient in the long term than in the short term, however, efficiency levels have varied over time, and the work of Hull & McGroarty (2014) who found weak evidence of increased market efficiency over time in emerging markets. Therefore, based on this evidence we can conclude that the results of our study are in line with the Adaptive Market Hypothesis. In particular, our results seem to be tied with the business cycle events of the US economy, with anomalies being observed more strongly during the volatile periods between the two wars, which also included the "Great Depression", then the post World War II period which was characterized by the inflationary episodes in the wake of the oil shocks, and then as the management of monetary policy improved post 1980 and the global economy entered into the so-called "Great Moderation" phase, the anomalies seem to die down, but did not disappear completely in the wake of the bout of recent crises, namely the "Global Financial Crisis" and the European sovereging debt crisis.

From a practical perspective, as highlighted by Tiwari et al. (2019) these results have implications for investors, policy makers, regulators, and corporate managers. As shown in the results of our trading analysis, in certain instances exploitable profits could be generated by the various anomalies. This suggests room for further improvements in the transparency of market information, better trading technologies, and stronger regulatory institutions in order to further enhance market efficiency.

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Appendices

A Day of the Week Effect

Table A.1: Average returns for the day of the week effect

Period	Monday	Tuesday	Wednesday	Thursday	Friday
1900-1909	-0.01%	0.01%	-0.01%	-0.02%	0.18%
1910-1919	-0.06%	0.06%	-0.02%	-0.01%	0.05%
1920-1929	-0.26%	0.04%	0.07%	0.13%	0.15%
1930-1939	-0.30%	0.06%	0.11%	0.01%	0.00%
1940-1949	-0.08%	-0.01%	0.05%	0.04%	-0.02%
1950-1959	-0.14%	0.02%	0.10%	0.08%	0.18%
1960-1969	-0.17%	0.03%	0.09%	0.02%	0.08%
1970-1979	-0.12%	-0.04%	0.07%	0.05%	0.07%
1980-1989	-0.06%	0.13%	0.11%	0.01%	0.07%
1990-1999	0.16%	0.06%	0.06%	-0.03%	0.05%
2000-2009	0.03%	0.06%	-0.02%	0.03%	-0.08%
2010-2018	0.03%	0.07%	0.04%	0.05%	0.03%

Figure A.1: Average returns for the day of the week effect

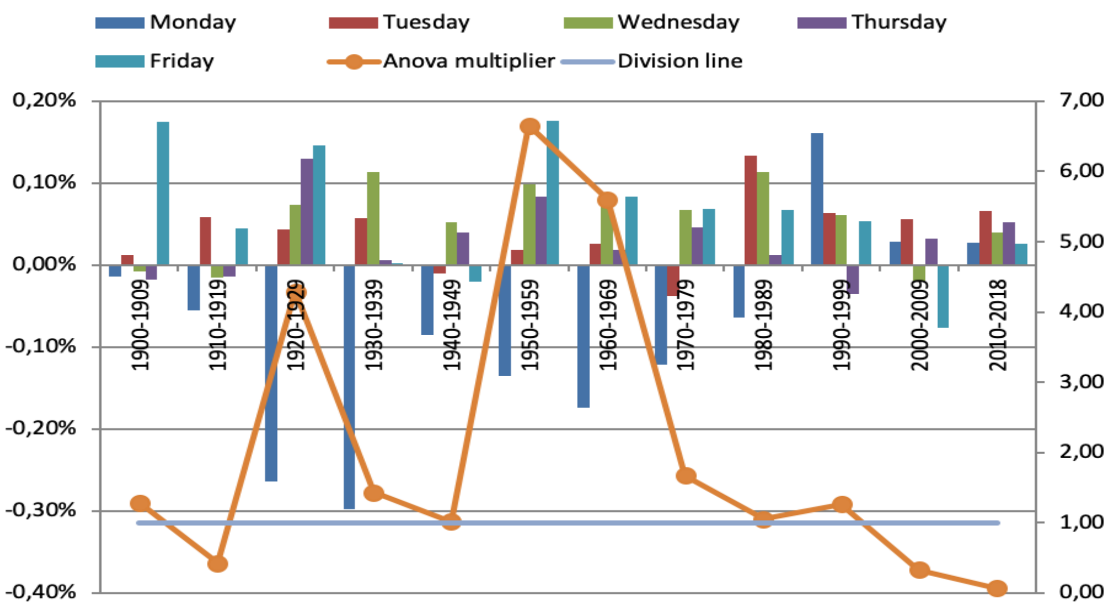


Table A.2: ANOVA test for the day of the week effect

Period	F	p-value	F critical	Null hypothesis	Anomaly	ANOVA multiplier
1900-1909	3.05	0.02	2.38	rejected	confirmed	1.28
1910-1919	1.01	0.40	2.38	not rejected	not confirmed	0.42
1920-1929	10.20	0.00	2.38	rejected	confirmed	4.29
1930-1939	3.40	0.01	2.38	rejected	confirmed	1.43
1940-1949	2.41	0.05	2.38	rejected	confirmed	1.02
1950-1959	15.81	0.00	2.38	rejected	confirmed	6.65
1960-1969	13.31	0.00	2.38	rejected	confirmed	5.60
1970-1979	3.97	0.00	2.38	rejected	confirmed	1.67
1980-1989	2.50	0.04	2.38	rejected	confirmed	1.05
1990-1999	3.01	0.02	2.38	rejected	confirmed	1.27
2000-2009	0.79	0.53	2.38	not rejected	not confirmed	0.33
2010-2018	0.16	0.96	2.38	not rejected	not confirmed	0.07

Table A.3: Kruskal -Wallis test for the day of the week

Period	Adj. H	d.f.	p-value	Crit. value	Null hypothesis	Anomaly	Kruskall multiplier
1900-1909	8.63	4	0.07	9.49	rejected	confirmed	0.91
1910-1919	7.34	4	0.12	9.49	not rejected	not confirmed	0.77
1920-1929	40.94	4	0.00	9.49	rejected	confirmed	4.32
1930-1939	18.65	4	0.00	9.49	rejected	confirmed	1.97
1940-1949	8.40	4	0.08	9.49	not rejected	not confirmed	0.89
1950-1959	52.11	4	0.00	9.49	rejected	confirmed	5.49
1960-1969	55.74	4	0.00	9.49	rejected	confirmed	5.87
1970-1979	16.49	4	0.00	9.49	rejected	confirmed	1.74
1980-1989	4.26	4	0.37	9.49	not rejected	not confirmed	0.45
1990-1999	17.58	4	0.00	9.49	rejected	confirmed	1.85
2000-2009	3.25	4	0.52	9.49	not rejected	not confirmed	0.34
2010-2018	1.89	4	0.76	9.49	not rejected	not confirmed	0.20

Table A.4: T-test for the day of the week effect

Period	Parameter	Monday	Tuesday	Wednesday	Thursday	Friday
1900-1909	Mean,%	-0.01%	0.01%	-0.01%	-0.02%	0.18%
	t-criterion	-0.95	-0.44	-0.96	-1.09	3.44
	Null hypothesis	not rejected	not rejected	not rejected	not rejected	rejected
	Anomaly	not detected	not detected	not detected	not detected	detected
1910-1919	Mean,%	-0.06%	0.06%	-0.02%	-0.01%	0.05%
	t-criterion	-1.32	1.37	-0.50	-0.39	1.05
	Null hypothesis	not rejected	not rejected	not rejected	not rejected	not rejected
	Anomaly	not detected	not detected	not detected	not detected	not detected
1920-1929	Mean,%	-0.26%	0.04%	0.07%	0.13%	0.15%
	t-criterion	-5.85	0.36	0.93	2.29	2.82
	Null hypothesis	rejected	not rejected	not rejected	rejected	rejected
	Anomaly	detected	not detected	not detected	detected	detected
1930-1939	Mean,%	-0.30%	0.06%	0.11%	0.01%	0.00%
	t-criterion	-3.61	1.10	1.64	0.38	0.30
	Null hypothesis	rejected	not rejected	not rejected	not rejected	not rejected
	Anomaly	detected	not detected	not detected	not detected	not detected
1940-1949	Mean,%	-0.08%	-0.01%	0.05%	0.04%	-0.02%
	t-criterion	-2.53	-0.18	1.87	1.51	-0.57
	Null hypothesis	rejected	not rejected	not rejected	not rejected	not rejected
	Anomaly	detected	not detected	not detected	not detected	not detected
1950-1959	Mean,%	-0.14%	0.02%	0.10%	0.08%	0.18%
	t-criterion	-6.14	-1.14	1.93	1.39	5.41
	Null hypothesis	rejected	not rejected	not rejected	not rejected	rejected
	Anomaly	detected	not detected	not detected	not detected	detected

1960-1969	Mean,%	-0.17%	0.03%	0.09%	0.02%	0.08%
	t-criterion	-6.48	0.61	2.98	0.39	3.25
	Null hypothesis	rejected	not rejected	rejected	not rejected	rejected
	Anomaly	detected	not detected	detected	not detected	detected
1970-1979	Mean,%	-0.12%	-0.04%	0.07%	0.05%	0.07%
	t-criterion	-3.19	-1.21	1.61	1.17	1.77
	Null hypothesis	rejected	not rejected	not rejected	not rejected	not rejected
	Anomaly	detected	not detected	not detected	not detected	not detected
1980-1989	Mean,%	-0.06%	0.13%	0.11%	0.01%	0.07%
	t-criterion	-2.00	1.91	1.46	-1.02	0.32
	Null hypothesis	rejected	not rejected	not rejected	not rejected	not rejected
	Anomaly	detected	not detected	not detected	not detected	not detected
1990-1999	Mean,%	0.16%	0.06%	0.06%	-0.03%	0.05%
	t-criterion	2.57	0.10	0.03	-2.64	-0.18
	Null hypothesis	rejected	not rejected	not rejected	not rejected	not rejected
	Anomaly	detected	not detected	not detected	not detected	not detected
2000-2009	Mean,%	0.03%	0.06%	-0.02%	0.03%	-0.08%
	t-criterion	0.41	0.98	-0.46	0.53	-1.64
	Null hypothesis	not rejected	not rejected	not rejected	not rejected	not rejected
	Anomaly	not detected	not detected	not detected	not detected	not detected
2010-2018	Mean,%	0.03%	0.07%	0.04%	0.05%	0.03%
	t-criterion	-0.39	0.65	-0.07	0.24	-0.44
	Null hypothesis	not rejected	not rejected	not rejected	not rejected	not rejected
	Anomaly	not detected	not detected	not detected	not detected	not detected

Table A.5: Trading simulations for the day of the week effect

Period	Number of trades, units	Number of successful trades, units	Number of successful trades, %	Profit, %	Profit % per year	z-test	result
1900-1909	497	236	47%	5%	0%	0.18	failed
1910-1919	472	241	51%	26%	3%	1.08	failed
1920-1929	489	267	55%	129%	13%	4.68	passed
1930-1939	485	289	60%	144%	14%	3.52	passed
1940-1949	423	210	50%	31%	3%	1.85	failed
1950-1959	480	260	54%	68%	7%	4.05	passed
1960-1969	488	296	61%	86%	9%	5.49	passed
1970-1979	484	272	56%	59%	6%	2.70	passed
1980-1989	483	244	51%	31%	3%	0.92	failed
1990-1999	480	189	39%	-79%	-8%	-3.66	passed
2000-2009	472	228	48%	-17%	-2%	-0.52	failed
2010-2018	394	196	50%	-11%	-1%	- 0.61	failed

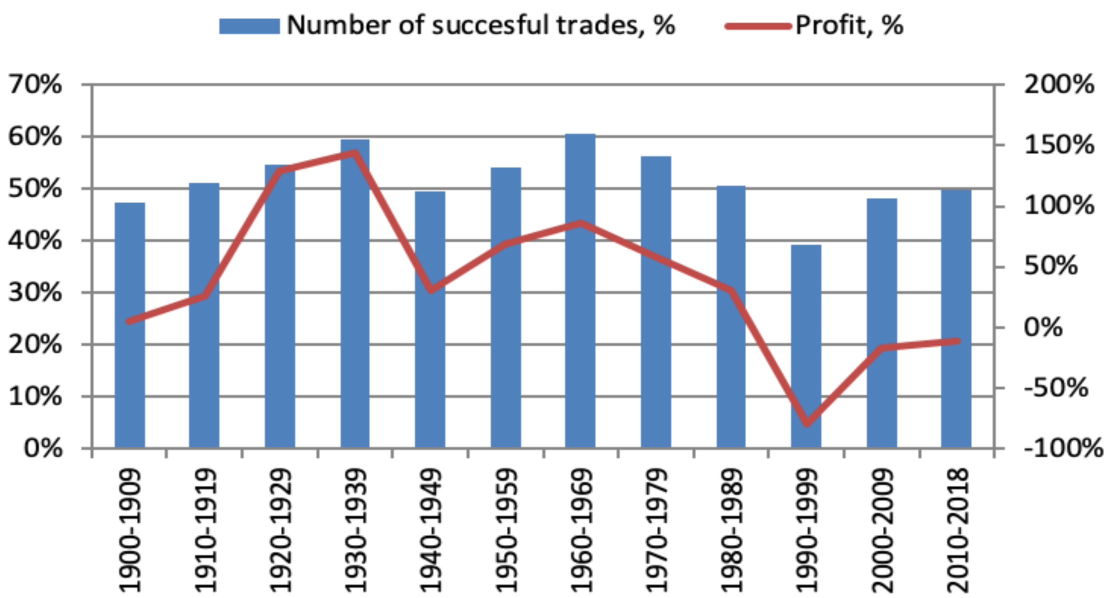
Table A.6: Modified CAR results for the day of the week effect

Period	Multiple R	F-test	a0	a1	Anomaly
1900-1909	0.70	448.38	-0.0899	-0.0004	confirmed
		(0.00)	(0.00)	(0.00)	
1910-1919	0.66	360.41	-0.1007	-0.0004	confirmed
		(0.00)	(0.00)	(0.00)	
1920-1929	0.99	35281.52	-0.1025	-0.0030	confirmed
		(0.00)	(0.00)	(0.00)	
1930-1939	0.96	5009.29	-0.1970	-0.0030	confirmed
		(0.00)	(0.00)	(0.00)	
1940-1949	0.85	1228.71	0.0322	-0.0007	confirmed
		(0.00)	(0.00)	(0.00)	
1950-1959	0.99	20065.55	0.0453	-0.0024	confirmed
		(0.00)	(0.00)	(0.00)	
1960-1969	0.99	29736.43	-0.0665	-0.0020	confirmed
		(0.00)	(0.00)	(0.00)	
1970-1979	0.92	2796.67	-0.1273	-0.0015	confirmed
		(0.00)	(0.00)	(0.00)	
1980-1989	0.91	2312.00	-0.0606	-0.0012	confirmed
		(0.00)	(0.00)	(0.00)	
1990-1999	0.99	24458.57	-0.0492	0.0014	not
		(0.00)	(0.00)	(0.00)	confirmed
2000-2009	0.35	67.81	0.1355	0.0002	not
		(0.00)	(0.00)	(0.00)	confirmed
2010-2018	0.91	1702.78	0.0722	-0.0006	confirmed
		(0.00)	(0.00)	(0.00)	

Table A.7: R/S analysis for the day of the week effect

Period	Monday	Tuesday	Wednesday	Thursday	Friday
1900-1909	0.57	0.46	0.66	0.54	0.58
1910-1919	0.59	0.55	0.49	0.63	0.45
1920-1929	0.61	0.64	0.59	0.54	0.64
1930-1939	0.58	0.55	0.57	0.46	0.54
1940-1949	0.60	0.54	0.60	0.60	0.59
1950-1959	0.60	0.48	0.61	0.58	0.66
1960-1969	0.61	0.58	0.55	0.50	0.58
1970-1979	0.57	0.62	0.53	0.62	0.64
1980-1989	0.57	0.51	0.63	0.61	0.55
1990-1999	0.48	0.60	0.52	0.65	0.63
2000-2009	0.58	0.57	0.64	0.48	0.58
2010-2018	0.50	0.62	0.49	0.54	0.58
Average	**0.57**	**0.56**	**0.57**	**0.56**	**0.59**

Figure A.2: Trading simulations for the day of the week effect



B Turn of the Month Effect

Table B.1: Average returns for the turn of the month effect

Period	Start of the month	Rest of the month
1900-1909	0.09%	0.00%
1910-1919	0.03%	0.02%
1920-1929	0.16%	0.01%
1930-1939	0.16%	-0.03%
1940-1949	0.14%	-0.01%
1950-1959	0.20%	0.02%
1960-1969	0.12%	-0.02%
1970-1979	0.09%	-0.01%
1980-1989	0.13%	0.04%
1990-1999	0.10%	0.05%
2000-2009	0.04%	0.00%
2010-2018	0.03%	0.05%

Figure B.1: Average returns for the turn of the month effect

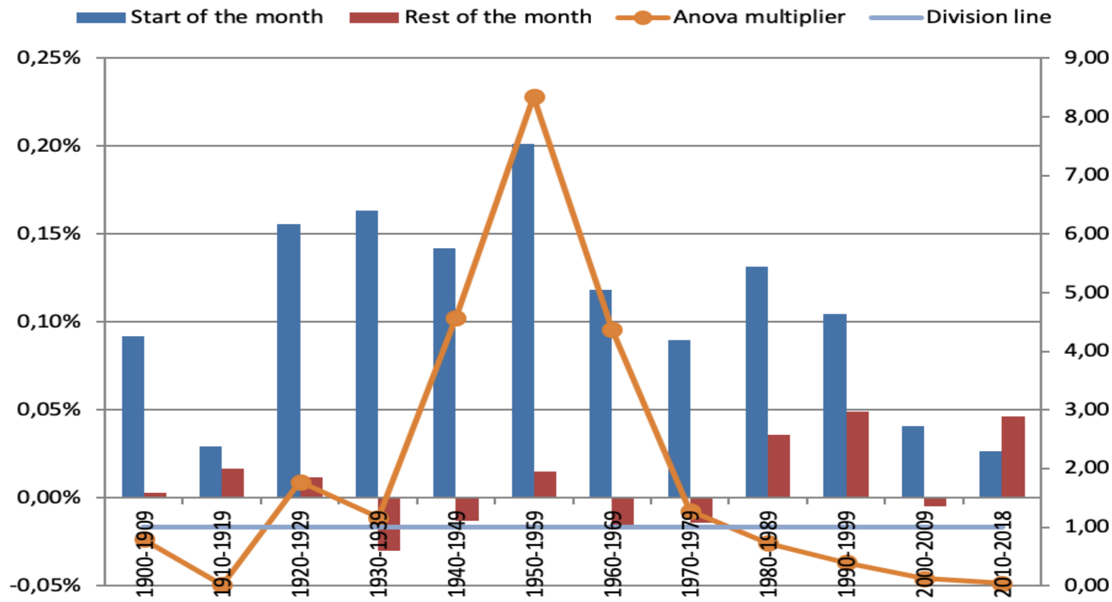


Table B.2: ANOVA test for the turn of the month effect

Period	F	p-value	F critical	Null hypothesis	Anomaly	ANOVA multiplier
1900-1909	3.03	0.08	3.84	not rejected	not confirmed	0.79
1910-1919	0.07	0.80	3.84	not rejected	not confirmed	0.02
1920-1929	6.81	0.01	3.84	rejected	confirmed	1.77
1930-1939	4.46	0.03	3.84	rejected	confirmed	1.16
1940-1949	17.58	0.00	3.84	rejected	confirmed	4.57
1950-1959	32.07	0.00	3.85	rejected	confirmed	8.34
1960-1969	16.81	0.00	3.85	rejected	confirmed	4.37
1970-1979	4.92	0.03	3.85	rejected	confirmed	1.28
1980-1989	2.78	0.10	3.85	not rejected	not confirmed	0.72
1990-1999	1.52	0.22	3.85	not rejected	not confirmed	0.40
2000-2009	0.46	0.50	3.85	not rejected	not confirmed	0.12
2010-2018	0.17	0.68	3.85	not rejected	not confirmed	0.04

Table B.3: Mann-Whitney test for the turn of the month effect

Period	Adj. H	d.f.	P value	Crit. value	Null hypothesis	Anomaly	Kruskall multiplier
1900-1909	6.08	1	0.01	3.84	rejected	confirmed	1.58
1910-1919	1.01	1	0.31	3.84	not rejected	not confirmed	0.26
1920-1929	20.88	1	0.00	3.84	rejected	confirmed	5.44
1930-1939	8.16	1	0.00	3.84	rejected	confirmed	2.13
1940-1949	22.25	1	0.00	3.84	rejected	confirmed	5.80
1950-1959	36.20	1	0.00	3.84	rejected	confirmed	9.43
1960-1969	13.65	1	0.00	3.84	rejected	confirmed	3.55
1970-1979	7.21	1	0.01	3.84	rejected	confirmed	1.88
1980-1989	4.74	1	0.03	3.84	rejected	confirmed	1.23
1990-1999	2.17	1	0.14	3.84	not rejected	not confirmed	0.57
2000-2009	2.96	1	0.09	3.84	not rejected	not confirmed	0.77
2010-2018	0.73	1	0.39	3.84	not rejected	not confirmed	0.19

Table B.4: T-test for the turn of the month effect

Period	Parameter	Start of the month	Rest of the month
1900-1909	Mean,%	0.09%	0.00%
	t-criterion	1.86	-1.86
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected
1910-1919	Mean,%	0.03%	0.02%
	t-criterion	0.23	-0.23
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected
1920-1929	Mean,%	0.16%	0.01%
	t-criterion	2.56	-2.57
	Null hypothesis	rejected	rejected
	Anomaly	detected	detected
1930-1939	Mean,%	0.16%	-0.03%
	t-criterion	2.22	-2.22
	Null hypothesis	rejected	rejected
	Anomaly	detected	detected
1940-1949	Mean,%	0.14%	-0.01%
	t-criterion	4.57	-4.59
	Null hypothesis	rejected	rejected
	Anomaly	detected	detected
1950-1959	Mean,%	0.20%	0.02%
	t-criterion	5.78	-5.80
	Null hypothesis	rejected	rejected
	Anomaly	detected	detected
1960-1969	Mean,%	0.12%	-0.02%
	t-criterion	4.06	-4.07
	Null hypothesis	rejected	rejected
	Anomaly	detected	detected
1970-1979	Mean,%	0.09%	-0.01%
	t-criterion	2.14	-2.15
	Null hypothesis	rejected	rejected
	Anomaly	detected	detected
1980-1989	Mean,%	0.13%	0.04%
	t-criterion	1.82	-1.82
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected

1990-1999	Mean,%	0.10%	0.05%
	t-criterion	1.21	-1.22
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected
2000-2009	Mean,%	0.04%	0.00%
	t-criterion	0.71	-0.72
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected
2010-2018	Mean,%	0.03%	0.05%
	t-criterion	-0.40	0.40
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected

Table B.5: Trading simulations for the turn of the month effect

Period	Number of trades, units	Number of successful trades, units	Number of successful trades, %	Profit, %	Profit % per year	z-test	result
1900-1909	480	272	57%	44%	4%	2.13	passed
1910-1919	464	241	52%	14%	1%	0.56	failed
1920-1929	480	297	62%	75%	7%	3.03	passed
1930-1939	480	265	55%	79%	8%	2.08	passed
1940-1949	480	286	60%	68%	7%	4.72	passed
1950-1959	480	321	67%	97%	10%	6.99	passed
1960-1969	480	274	57%	57%	6%	3.95	passed
1970-1979	480	256	53%	43%	4%	2.05	passed
1980-1989	480	251	52%	63%	6%	2.87	passed
1990-1999	480	261	54%	50%	5%	2.53	passed
2000-2009	480	248	52%	20%	2%	0.73	failed
2010-2018	408	211	52%	11%	1%	0.60	failed

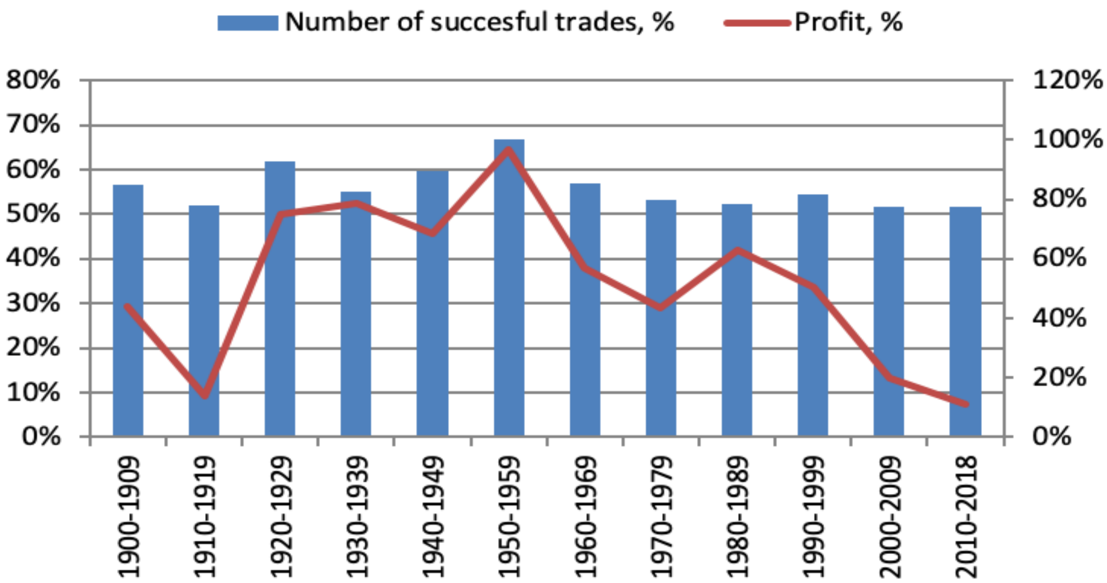
Table B.6: Modified CAR results for the turn of the month effect

Period	Multiple R	F-test	a0	a1	Anomaly
1900-1909	0.87	1558.10	-0.0875	0.0008	confirmed
		(0.00)	(0.00)	(0.00)	
1910-1919	0.66	374.03	-0.1694	0.0003	confirmed
		(0.00)	(0.00)	(0.00)	
1920-1929	0.99	22936.40	-0.0641	0.0014	confirmed
		(0.00)	(0.00)	(0.00)	
1930-1939	0.96	6223.93	-0.1328	0.0020	confirmed
		(0.00)	(0.00)	(0.00)	
1940-1949	0.99	38023.80	0.0303	0.0015	confirmed
		(0.00)	(0.00)	(0.00)	
1950-1959	0.99	24034.32	-0.0057	0.0020	confirmed
		(0.00)	(0.00)	(0.00)	
1960-1969	0.97	7379.32	0.0305	0.0012	confirmed
		(0.00)	(0.00)	(0.00)	
1970-1979	0.89	1832.31	0.0769	0.0007	confirmed
		(0.00)	(0.00)	(0.00)	
1980-1989	0.84	1117.74	-0.0482	0.0006	confirmed
		(0.00)	(0.00)	(0.00)	
1990-1999	0.67	378.85	0.0264	0.0003	confirmed
		(0.00)	(0.00)	(0.00)	
2000-2009	0.70	457.39	0.0681	0.0004	confirmed
		(0.00)	(0.00)	(0.00)	
2010-2018	0.76	640.45	0.1006	-0.0003	not
		(0.00)	(0.00)	(0.00)	confirmed

Table B.7: R/S analysis results for the turn of the month effect

Period	Start of the month	Rest of the month
1900-1909	0.54	0.59
1910-1919	0.55	0.58
1920-1929	0.53	0.58
1930-1939	0.50	0.55
1940-1949	0.54	0.57
1950-1959	0.51	0.58
1960-1969	0.54	0.58
1970-1979	0.61	0.57
1980-1989	0.61	0.55
1990-1999	0.61	0.53
2000-2009	0.53	0.54
2010-2018	0.58	0.47
Average	**0.55**	**0.56**

Figure B.2: Trading simulations for the turn of the month effect



C Turn of the Year Effect

Table C.1: Average returns for the turn of the year effect

Period	Start of the year	Rest of the year
1900-1909	0.11%	0.01%
1910-1919	0.09%	0.03%
1920-1929	0.12%	0.03%
1930-1939	0.24%	-0.01%
1940-1949	0.09%	0.01%
1950-1959	0.10%	0.05%
1960-1969	0.11%	0.00%
1970-1979	0.16%	0.00%
1980-1989	0.11%	0.05%
1990-1999	0.03%	0.06%
2000-2009	-0.04%	0.01%
2010-2018	0.01%	0.04%

Figure C.1: Average returns for the turn of the year effect

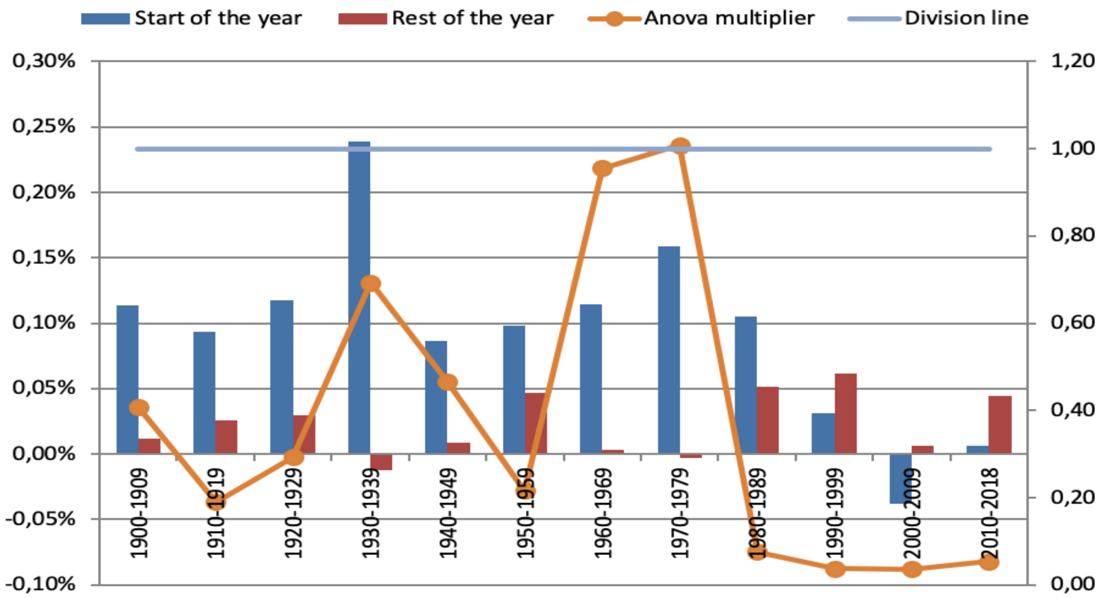


Table C.2: ANOVA test for the turn of the year effect

Period	F	p-value	F critical	Null hypothesis	Anomaly	ANOVA multiplier
1900-1909	1.57	0.21	3.84	not rejected	not confirmed	0.41
1910-1919	0.73	0.39	3.84	not rejected	not confirmed	0.19
1920-1929	1.13	0.29	3.84	not rejected	not confirmed	0.29
1930-1939	2.67	0.10	3.84	not rejected	not confirmed	0.69
1940-1949	1.79	0.18	3.84	not rejected	not confirmed	0.47
1950-1959	0.83	0.36	3.85	not rejected	not confirmed	0.22
1960-1969	3.67	0.06	3.85	not rejected	not confirmed	0.96
1970-1979	3.88	0.05	3.85	rejected	confirmed	1.01
1980-1989	0.29	0.59	3.85	not rejected	not confirmed	0.08
1990-1999	0.14	0.71	3.85	not rejected	not confirmed	0.04
2000-2009	0.14	0.71	3.85	not rejected	not confirmed	0.04
2010-2018	0.21	0.65	3.85	not rejected	not confirmed	0.05

Table C.3: Mann-Whitney test for the turn of the year effect

Period	Adj. H	d.f.	p-value	Crit. value	Null hypothesis	Anomaly	Kruskall multiplier
1900-1909	3.01	1.00	0.08	3.84	not rejected	not confirmed	0.78
1910-1919	0.61	1.00	0.43	3.84	not rejected	not confirmed	0.16
1920-1929	2.27	1.00	0.13	3.84	not rejected	not confirmed	0.59
1930-1939	4.68	1.00	0.03	3.84	rejected	confirmed	1.22
1940-1949	0.47	1.00	0.49	3.84	not rejected	not confirmed	0.12
1950-1959	1.26	1.00	0.26	3.84	not rejected	not confirmed	0.33
1960-1969	3.29	1.00	0.07	3.84	not rejected	not confirmed	0.86
1970-1979	2.64	1.00	0.10	3.84	not rejected	not confirmed	0.69
1980-1989	2.04	1.00	0.15	3.84	not rejected	not confirmed	0.53
1990-1999	0.07	1.00	0.79	3.84	not rejected	not confirmed	0.02
2000-2009	0.00	1.00	0.98	3.84	not rejected	not confirmed	0.00
2010-2018	0.35	1.00	0.55	3.84	not rejected	not confirmed	0.09

Table C.4: T-test of the turn of year the effect

Period	Parameter	Start of the year	Rest of the year
1900-1909	Mean,%	0.11%	0.01%
	t-criterion	1.15	-1.16
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected
1910-1919	Mean,%	0.09%	0.03%
	t-criterion	0.82	-0.83
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected
1920-1929	Mean,%	0.12%	0.03%
	t-criterion	1.12	-1.13
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected
1930-1939	Mean,%	0.24%	-0.01%
	t-criterion	1.92	-1.93
	Null hypothesis	rejected	rejected
	Anomaly	detected	detected
1940-1949	Mean,%	0.09%	0.01%
	t-criterion	1.38	-1.39
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected
1950-1959	Mean,%	0.10%	0.05%
	t-criterion	0.86	-0.88
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected
1960-1969	Mean,%	0.11%	0.00%
	t-criterion	2.09	-2.12
	Null hypothesis	rejected	rejected
	Anomaly	detected	detected
1970-1979	Mean,%	0.16%	0.00%
	t-criterion	1.94	-1.96
	Null hypothesis	rejected	rejected
	Anomaly	detected	detected
1980-1989	Mean,%	0.11%	0.05%
	t-criterion	0.51	-0.52
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected

1990-1999	Mean,%	0.03%	0.06%
	t-criterion	-0.39	0.39
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected
2000-2009	Mean,%	-0.04%	0.01%
	t-criterion	-0.45	0.45
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected
2010-2018	Mean,%	0.01%	0.04%
	t-criterion	-0.54	0.54
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected

Table C.5: Trading simulations for the turn of the year effect

Period	Number of trades, units	Number of successful trades, units	Number of successful trades, %	Profit, %	Profit % per year	z-test	result
1900-1909	158	85	54%	18%	2%	1.32	failed
1910-1919	159	82	52%	15%	1%	1.18	failed
1920-1929	159	95	60%	19%	2%	1.56	failed
1930-1939	157	81	52%	38%	4%	1.91	failed
1940-1949	159	89	56%	14%	1%	1.59	failed
1950-1959	139	79	57%	14%	1%	1.71	failed
1960-1969	132	81	61%	15%	2%	2.25	passed
1970-1979	133	72	54%	21%	2%	1.98	passed
1980-1989	132	73	55%	14%	1%	1.04	failed
1990-1999	133	72	54%	4%	0%	0.42	failed
2000-2009	132	69	52%	-5%	-1%	- 0.40	failed
2010-2018	114	57	50%	1%	0%	0.09	failed

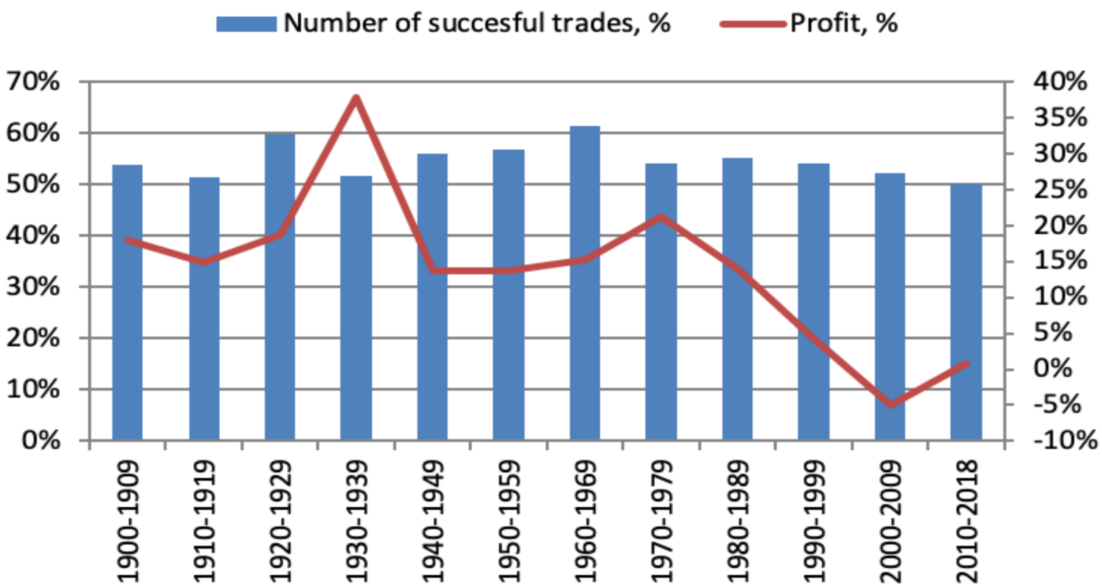
Table C.6: Modified CAR results of the turn of the year effect

Period	Multiple R	F-test	a0	a1	Anomaly
1900-1909	0.89	598.26	-0.1376	0.0017	confirmed
		(0.00)	(0.00)	(0.00)	
1910-1919	0.88	525.00	-0.0748	0.0012	confirmed
		(0.00)	(0.00)	(0.00)	
1920-1929	0.84	377.58	0.0006	0.0008	confirmed
		(0.00)	(0.00)	(0.00)	
1930-1939	0.92	897.05	0.0468	0.0025	confirmed
		(0.00)	(0.00)	(0.00)	
1940-1949	0.91	800.70	-0.0069	0.0011	confirmed
		(0.00)	(0.00)	(0.00)	
1950-1959	0.88	513.24	0.0274	0.0006	confirmed
		(0.00)	(0.00)	(0.00)	
1960-1969	0.97	2745.22	-0.0304	0.0016	confirmed
		(0.00)	(0.00)	(0.00)	
1970-1979	0.79	261.25	0.0062	0.0015	confirmed
		(0.00)	(0.00)	(0.00)	
1980-1989	0.73	175.61	0.0282	0.0005	confirmed
		(0.00)	(0.00)	(0.00)	
1990-1999	0.86	448.30	-0.0663	0.0008	confirmed
		(0.00)	(0.00)	(0.00)	
2000-2009	0.69	138.92	-0.0089	0.0004	confirmed
		(0.00)	(0.00)	(0.00)	
2010-2018	0.52	59.33	0.0438	-0.0004	not
		(0.00)	(0.00)	(0.00)	confirmed

Table C.7: R/S analysis results of the turn of the year effect

Period	Start of the year	Rest of the year
1900-1909	0.68	0.60
1910-1919	0.48	0.42
1920-1929	0.61	0.58
1930-1939	0.60	0.58
1940-1949	0.61	0.59
1950-1959	0.50	0.56
1960-1969	0.57	0.56
1970-1979	0.77	0.56
1980-1989	0.66	0.54
1990-1999	0.67	0.52
2000-2009	0.64	0.53
2010-2018	0.65	0.48
Average	**0.62**	**0.54**

Figure C.2: Trading simulations for the turn of the year effect



D Holiday Effect

Table D.1: Average returns for the holiday effect

Period	Last day before holiday	Other days of the year
1900-1909	0.19%	0.01%
1910-1919	0.15%	0.02%
1920-1929	0.68%	0.02%
1930-1939	0.24%	0.00%
1940-1949	0.14%	0.01%
1950-1959	0.31%	0.04%
1960-1969	0.22%	0.00%
1970-1979	0.30%	0.00%
1980-1989	0.16%	0.05%
1990-1999	0.07%	0.06%
2000-2009	-0.04%	0.01%
2010-2018	0.07%	0.04%

Figure D.1: Average returns for the holiday effect

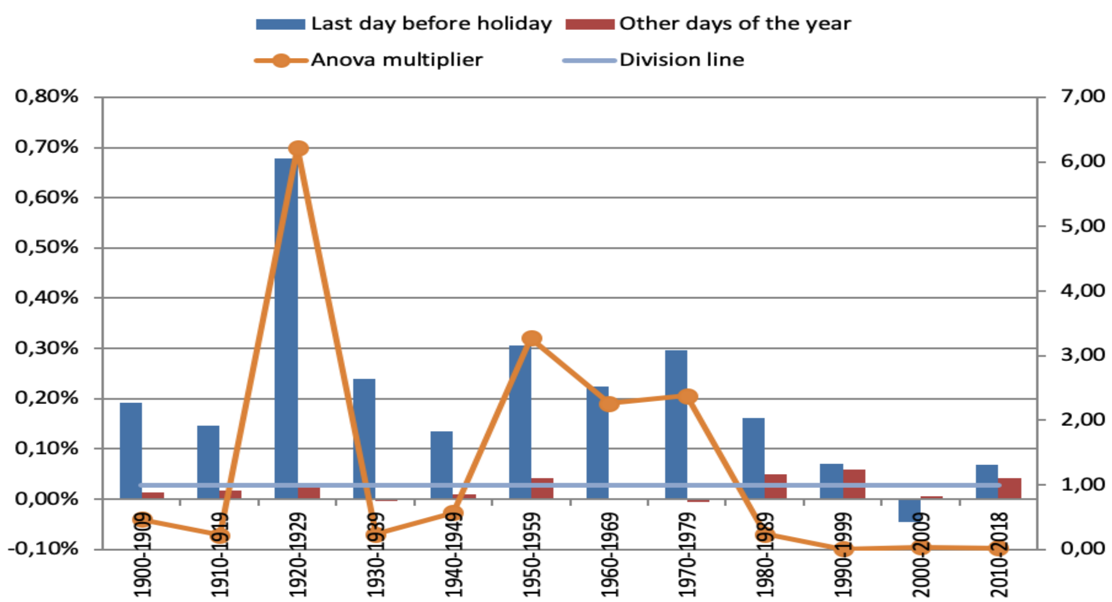


Table D.2: ANOVA test for the holiday effect

Period	F	p-value	F critical	Null hypothesis	Anomaly	ANOVA multiplier
1900-1909	1.78	0.18	3.84	not rejected	not confirmed	0.46
1910-1919	0.85	0.36	3.84	not rejected	not confirmed	0.22
1920-1929	23.87	0.00	3.84	rejected	confirmed	6.21
1930-1939	0.92	0.34	3.84	not rejected	not confirmed	0.24
1940-1949	2.19	0.14	3.84	not rejected	not confirmed	0.57
1950-1959	12.59	0.00	3.85	rejected	confirmed	3.28
1960-1969	8.70	0.00	3.85	rejected	confirmed	2.26
1970-1979	9.16	0.00	3.85	rejected	confirmed	2.38
1980-1989	0.90	0.34	3.85	not rejected	not confirmed	0.23
1990-1999	0.01	0.90	3.85	not rejected	not confirmed	0.00
2000-2009	0.14	0.71	3.85	not rejected	not confirmed	0.04
2010-2018	0.07	0.79	3.85	not rejected	not confirmed	0.02

Table D.3: Mann-Whitney test for the holiday effect

Period	Adj. H	d.f.	p-value	Crit. value	Null hypothesis	Anomaly	Kruskall multiplier
1900-1909	3.50	1	0.06	3.84	not rejected	not confirmed	0.91
1910-1919	0.00	1	0.98	3.84	not rejected	not confirmed	0.00
1920-1929	27.86	1	0.00	3.84	rejected	confirmed	7.26
1930-1939	4.26	1	0.04	3.84	rejected	confirmed	1.11
1940-1949	2.08	1	0.15	3.84	not rejected	not confirmed	0.54
1950-1959	13.26	1	0.00	3.84	rejected	confirmed	3.45
1960-1969	9.07	1	0.00	3.84	rejected	confirmed	2.36
1970-1979	10.69	1	0.00	3.84	rejected	confirmed	2.78
1980-1989	1.51	1	0.22	3.84	not rejected	not confirmed	0.39
1990-1999	0.00	1	0.95	3.84	not rejected	not confirmed	0.00
2000-2009	0.40	1	0.52	3.84	not rejected	not confirmed	0.11
2010-2018	0.45	1	0.50	3.84	not rejected	not confirmed	0.12

Table D.4: T-test for the holiday effect

Period	Parameter	Last day before holiday	Other days of the year
1900-1909	Mean,%	0.19%	0.01%
	t-criterion	1.72	-1.77
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected
1910-1919	Mean,%	0.15%	0.02%
	t-criterion	0.74	-0.77
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected
1920-1929	Mean,%	0.68%	0.02%
	t-criterion	5.45	-5.62
	Null hypothesis	rejected	rejected
	Anomaly	detected	detected
1930-1939	Mean,%	0.24%	0.00%
	t-criterion	1.07	-1.10
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected
1940-1949	Mean,%	0.14%	0.01%
	t-criterion	1.71	-1.75
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected
1950-1959	Mean,%	0.31%	0.04%
	t-criterion	3.84	-3.92
	Null hypothesis	rejected	rejected
	Anomaly	detected	detected
1960-1969	Mean,%	0.22%	0.00%
	t-criterion	3.90	-3.97
	Null hypothesis	rejected	rejected
	Anomaly	detected	detected
1970-1979	Mean,%	0.30%	0.00%
	t-criterion	3.39	-3.45
	Null hypothesis	rejected	rejected
	Anomaly	detected	detected
1980-1989	Mean,%	0.16%	0.05%
	t-criterion	1.25	-1.28
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected

1990-1999	Mean,%	0.07%	0.06%
	t-criterion	0.12	-0.13
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected
2000-2009	Mean,%	-0.04%	0.01%
	t-criterion	-0.47	0.48
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected
2010-2018	Mean,%	0.07%	0.04%
	t-criterion	0.30	-0.32
	Null hypothesis	not rejected	not rejected
	Anomaly	not detected	not detected

Table D.5: Trading simulations for the holiday effect

Period	Number of trades. units	Number of successful trades. units	Number of successful trades. %	Profit. %	Profit % per year	z-test	result
1900-1909	58	39	67%	11%	1%	1.94	failed
1910-1919	47	23	49%	7%	1%	0.87	failed
1920-1929	48	41	85%	33%	3%	5.91	passed
1930-1939	53	35	66%	13%	1%	1.10	failed
1940-1949	76	45	59%	10%	1%	1.91	failed
1950-1959	77	55	71%	24%	2%	4.61	passed
1960-1969	76	47	62%	17%	2%	4.13	passed
1970-1979	87	55	63%	26%	3%	3.48	passed
1980-1989	91	50	55%	15%	1%	1.90	failed
1990-1999	97	52	54%	7%.	1%	0.84	failed
2000-2009	98	47	48%	-4%	0%	-0.44	failed
2010-2018	80	51	64%	6%	1%	0.82	failed

Table D.6: Modified CAR results for the holiday effect

Period	Multiple R	F-test	a0	a1	Anomaly
1900-1909	0.94	341.34	-0.0108	0.0024	confirmed
		(0.00)	(0.00)	(0.00)	
1910-1919	0.82	89.22	-0.0280	0.0016	confirmed
		(0.00)	(0.00)	(0.00)	
1920-1929	0.98	1296.12	0.0263	0.0057	confirmed
		(0.00)	(0.00)	(0.00)	
1930-1939	0.83	93.80	0.0106	0.0023	confirmed
		(0.00)	(0.00)	(0.00)	
1940-1949	0.89	263.62	-0.0272	0.0016	confirmed
		(0.00)	(0.00)	(0.00)	
1950-1959	0.92	429.86	0.0052	0.0018	confirmed
		(0.00)	(0.00)	(0.00)	
1960-1969	0.97	1112.73	0.0117	0.0017	confirmed
		(0.00)	(0.00)	(0.00)	
1970-1979	0.92	400.03	-0.0213	0.0040	confirmed
		(0.00)	(0.00)	(0.00)	
1980-1989	0.77	129.95	-0.0130	0.0007	confirmed
		(0.00)	(0.00)	(0.00)	
1990-1999	0.75	109.25	-0.010	-0.0006	not
		(0.00)	(0.00)	(0.00)	confirmed
2000-2009	0.06	2.060	-0.0489	-0.0001	not
		(0.63)	(0.00)	(0.63)	confirmed
2010-2018	0.72	74.09	-0.0196	0.0008	confirmed
		(0.00)	(0.00)	(0.00)	

Table D.7: R/S analysis results of the holiday effect

Period	Last day before holiday	Other days of the year
1900-1909	0.67	0.60
1910-1919	0.68	0.57
1920-1929	0.71	0.55
1930-1939	0.68	0.56
1940-1949	0.67	0.58
1950-1959	0.72	0.55
1960-1969	0.60	0.58
1970-1979	0.84	0.57
1980-1989	0.60	0.53
1990-1999	0.53	0.50
2000-2009	0.72	0.53
2010-2018	0.72	0.50
Average	**0.68**	**0.55**

Figure D.2: Trading simulations for the holiday effect