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Guglielmo Maria Caporale, Alex Plastun

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Witching Days and Abnormal Profits in the US Stock Market

Abstract

This paper examines price effects related to witching days in the US stock market using both weekly and daily data for three major indices, namely the Dow Jones, SP500 and Nasdaq, over the period 2000-2021. First it analyses whether or not anomalies in price behaviour arise from witching by using various parametric (Student's t-test, and ANOVA) and non-parametric (Mann-Whitney) tests as well as an event study method and regressions with dummies; then it investigates whether or not any detected anomalies give rise to profit opportunities by applying a trading simulation approach. The results suggest the presence of the anomaly in daily returns on witching days which can be exploited by means of suitably designed trading strategies to earn abnormal profits, especially in the case of the Nasdaq index. Such evidence is inconsistent with the Efficient Market Hypothesis (EMH).

JEL-Codes: G120, C630.

Keywords: witching days, abnormal returns, stock markets, anomalies, trading.

*Guglielmo Maria Caporale**
Department of Economics and Finance
Brunel University London
United Kingdom – Uxbridge, UB8 3PH
Guglielmo-Maria.Caporale@brunel.ac.uk

Alex Plastun
Sumy State University
Sumy / Ukraine
o.plastun@gmail.com

*corresponding author

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1 Introduction

A well-known phenomenon commonly observed in stock markets is the so-called expiration effect, namely the sudden increase in the trading of futures or option contracts and the resulting large price changes which occur immediately before expiration as traders close their positions. For example, arbitrageurs create order imbalances by unwinding their cash positions when futures contracts expire (Chamberlain et al., 1989; Stoll and Whaley, 1987, Chay and Ryu, 2006). Also, market participants with large positions in derivative contracts may have incentives to push the underlying asset prices in a given direction to affect the value of their contracts before they expire (Bollen and Whaley, 1999; Chow et al., 2003; Stoll and Whaley, 1991; 1997). Yoo (2017) and Hsieh and Ma (2009) argue that in fact higher trading volumes on expiration days mainly reflect the activities of foreign institutional investors with more complete information sets.

Of particular interest are the so-called “quadruple witching days” when different types of derivatives (single stock derivatives, stock index futures, stock index options and single stock options) expire simultaneously in the US stock market. This happens on the third Friday of the last month of each quarter (March, June, September and December). This paper focuses on price (rather than volume or volatility) effects related to such days to establish whether or not they create abnormal profit opportunities by analysing weekly and daily data for three major US stock market indices, namely the Dow Jones Index, the SP500 and the Nasdaq. More specifically, a number of statistical tests (both parametric and non-parametric) as well as an event study method and regressions with dummies are used to detect any witching related anomalies. A trading simulation approach is then applied to examine whether or not those can be exploited to generate abnormal profits.

The layout of the paper is as follows. Section 2 briefly reviews the relevant literature. Section 3 describes the data and outlines the methodology, whilst Section 4 presents the empirical results. Section 5 offers some concluding remarks.

2 Literature Review

Evidence of expiration day effects in the US stock market was initially provided by Stoll and Whaley (1987) in the case of the “triple witching hour” (the last hour of trading on the third Friday of March, June, September and December). Hancock (1993) concluded instead that since June 1987 market activity had not been different on expiration days compared to others. Barclay et al. (2008) showed that on witching days order flows near futures contract expirations causes large, predictable fluctuations in the S&P 500. Illueca and LaFuente (2006) instead found no significant increase in volatility near expiration for the SP500 index.

Higher trading volumes on expiration days were found for other stock markets by Karolyi (1996), Hsieh (2009), Singh and Shaik (2020), Alkeback and Hagelin (2004), Schlag (1996), Gurgul and Suliga (2019) and others. Chung and Hseu (2008) detected significant price reversals as well as higher volatility and volumes near expiration in the Singapore and Taiwan Futures Exchanges, whilst Batrinca et al. (2020) reported higher trading activity for futures and options in the European equity markets, and Singh and Shaik (2020) found higher trading volumes in the case of Index Futures in India. However, Chow et al. (2003) could not identify any such effects in the Hong Kong stock market.

Edwards (1988), Arago and Fernandez (2002), Vipul (2005) and Gurgul and Suliga (2019) all detected higher price volatility of futures contracts near expiration. By contrast, Schlag (1996) and Bollen and Whaley (1999) could not obtain such evidence for the German stock market and the Hong Kong Futures Exchange respectively. Pope and Yadav (1992) found negative returns as well as higher trading volumes on expiration days in the UK stock market, whilst Stoll and Whaley (1997) and Hsieh (2009) provided evidence of price reversals in the Australian and Taiwanese stock markets. Vipul (2005) found that the underlying assets tend to exhibit negative returns the day before expiration, but significant reversal happens on the next trading day. Chow et al (2003) found that expiration days in Hong Kong are characterised by negative price effects, whereas Yoo (2017) concluded that there are none in the Korean stock market. Chay and Ryu (2006) detected statistically significant price reversals near expiration days in the South Korean KOSPI 200 index. By contrast, Karolyi (1996) found no significant price effects in the Japanese stock market and neither did Corredor et al. (2001) in the Spanish one and Kan (2001) in the Hong Kong one. Finally, Caihong (2014) could not detect any significant volume, volatility, or price effects caused by expiration days in general and by the quadruple witching day in particular in the Swedish stock market.

The above papers provide (conflicting) evidence concerning expiration day effects but none of them examines whether or not these give rise to exploitable profit opportunities. This issue is instead the focus of the present study.

3 Data and Methodology

Daily and weekly data for the Dow Jones Index, the SP500 and the Nasdaq over the period 01.01.2000-20.09.2021 are used for the analysis. The source is the Global Financial Database (https://www.globalfinancialdata.com). At both frequencies three subsamples are created corresponding to (i) the witching day or week when witching occurs, (ii) pre-witching (the day or week before witching) and (iii) post-witching (the day or week after witching). The following notation is used in the tables to denote them:

- d(0) – the witching day;
- d(-1) – the day before the witching day;
- d(+1) – the day after the witching day;
- w(0) – the week including the witching day;
- w(-1) – the week before that including the witching day;
- w(+1) – the week after that including the witching day.

Returns are calculated as follows:

$$R_i = \left(\frac{Close_i}{Close_{i-1}} - 1\right) \times 100\% , \qquad (1)$$

where R_i – returns on the *i-th* day in %;

$Close_{i-1}$ – close price on the (*i-1)-th* day;

$Close_i$ – close price on the *i-th* day.

To examine whether witching days are characterised by abnormal price patterns various methods are applied: average analysis to obtain some preliminary evidence, and then both parametric (Student's t-test, ANOVA analysis) and non-parametric (Mann-Whitney) tests given the fat tails and kurtosis characterising the distribution of returns – the aim is to make sure that any detected differences are statistically significant, the Null Hypothesis (H0) being in each case that the data on normal and on witching days respectively belong to the same population, a rejection of the null suggesting the presence of an anomaly.

Next we use an event study methodology which is a modified version of the cumulative abnormal returns approach by MacKinlay (1997). Abnormal returns are defined as follows:

$$AR_t = R_t - E(R_t) \qquad (2)$$

where R_t is the return at time t and $E(R_t)$ is the corresponding average return computed over the whole sample period as follows:

$$E(R_t) = (\frac{1}{T}) \sum_{i=1}^{T} R_i \quad (3)$$

where T is the sample size.

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

$$CAR_i = \sum_{i=1}^{T} \ AR_i \quad (4)$$

The variable CAR_i is then regressed against a trend – a significant p-value for the trend coefficient suggests the presence of an anomaly in price behaviour related to witching days.

To provide additional evidence a multiple regression analysis with dummy variables is carried out:

$$\mathrm{R_i} = \mathrm{a_0} + \mathrm{a_1 D_{1t}} + \varepsilon_{\mathrm{t}} \quad (5)$$

where $\mathrm{R_i}$ is the mean return in period t, $\mathrm{a_0}$ and $\mathrm{a_1}$ stand for returns on normal and witching days respectively, D_i is a dummy variable equal to 1 on a witching day and 0 on a normal day, and ε_{t} is the random error on the *i*-th day. The statistical significance and the sign of the dummy coefficient indicate the existence and the direction of price effects occurring on witching days.

Finally, in order to determine whether any detected anomalies give rise to exploitable profit opportunities a trading simulation approach is used. To see whether market participants can ”beat the market” we use the following trading algorithm: sell right at the start of the witching day, and close positions at the end of the day. An anomaly is said to be present if this strategy results in more than 50 per cent of profitable trades. The approach used here does not incorporate transaction costs (spread, fees to the broker or bank, swaps, etc.) and is only a proxy for actual trading. Nevertheless, it is informative about real trading, given the fact that, thanks to the development of Internet, high-frequency transaction costs and trading spreads tend to be small, typically ranging between 0.01% and 0.02%. Banking and broker fees can affect profitability in the case of a small number of trades but become insignificant for larger numbers (this is the so-called scale effect in trading) and thus overlooking them does not affect our results significantly.

The trading simulation approach consists of the following steps. First the percentage result from each trade is defined as:

$$\%\,result = \frac{100\% \times P_{open}}{P_{close}} \qquad (6)$$

where P_{open} – opening price

P_{close} – closing price

Next, the sum of the results from each deal is taken. A positive total result is an indication of exploitable profits based on that specific market anomaly. To establish whether or not the generated results differ from those associated to random trading a t-test is carried out; this compares the means from two samples (the average profit/loss from a trade applying the trading strategy, and that from random trading without transaction costs, which should be zero) to test whether they belong to the same population; a failure to reject H0 implies that the means from the two samples are not significantly different, i.e. that the detected anomaly does not generate exploitable profit opportunities.

4 Empirical Results

This section provides a summary of the main findings, whilst the complete set of results for the three indices can be found in Appendix A, B and C. Table 1 summarises the results for the Dow Jones Index.

Table 1: Overall results for witching day price effects: the case of the Dow Jones Index

Case analysed	Average analysis	Students t-test	ANOVA	Mann-Whitney test	Modified CAR	Regression with dummy variables	Trading simulation	Overall
d(0)	+	+	+	-	+	+	+	6
d(-1)	+	-	-	-	+	-	-	2
d(+1)	+	-	-	-	+	-	-	2
w(0)	-	-	-	-	+	-	-	1
w(-1)	+	-	-	-	+	+	-	3
w(+1)	+	-	-	+	+	-	-	3

Note: This table presents the overall results for the Dow Jones Index. + (-) indicates that an anomaly is (not) detected. Average analysis suggests the presence of an anomaly if the mean return calculated for the witching related day is much higher (lower) compared with the mean return on normal days. For the statistical tests (both parametric and non-parametric) the null hypothesis is that data for the witching related days and for normal ones belong to the same population; a rejection of the null implies the presence of a statistically significant anomaly. The regression analysis with dummy variables provides evidence of an anomaly if a1 (the dummy coefficient) is statistically significant($p < 0.05$). The MCAR approach implies the existence of an anomaly if the trend model based on cumulative abnormal returns data has a high multiple R-squared, passes the F test, and the regression coefficients are statistically significant (p-$value < 0.05$).

As can be seen, there is prima facie evidence of differences in returns between normal and witching days (see Table A.1 and Figure A.1 for details); however, in most cases these are not statistically significant, and they do not provide profitable trading opportunities (statistically different from those generated by random trading). The single exception concerns the Dow Jones index, for which prices decrease on witching days in 55% of the cases and a trading strategy based on this anomaly generates abnormal profits different from those associated with random trading.

Table 2 shows the corresponding results for the SP500 Index. Again the average analysis points to differences between normal and witching days (see Table B.1 and Figure B.1 for details), but these are not statistically significant except for d(0), when in 57% of cases negative returns are observed which are significantly different from those on other days; moreover, the detected anomaly can be exploited to generate abnormal profits significantly different from those arising from random trading (see Table B.7 and Figure B.2 for details).

Table 2: Overall results for witching day price effects: the case of the SP500 Index

Case analysed	Average analysis	Students t-test	ANOVA	Mann-Whitney test	Modified CAR	Regression with dummy variables	Trading simulation	Overall
d(0)	+	+	+	+	+	+	+	7
d(-1)	-	-	-	-	+	-	-	1
d(+1)	+	-	-	-	+	-	-	2
w(0)	+	-	-	-	+	-	-	2
w(-1)	+	-	-	-	-	-	-	1
w(+1)	+	-	-	+	+	-	-	3

Note: This table presents the overall results for the SP500 Index. + (-) indicates that an anomaly is (not) detected. Average analysis suggests the presence of an anomaly if the mean return calculated for the witching related day is much higher (lower) compared with the mean return on normal days. For the statistical tests (both parametric and non-parametric) the null hypothesis is that data for the witching related day and for normal ones belong to the same population; a rejection of the null implies the presence of a statistically significant anomaly. The regression analysis with dummy variables provides evidence of an anomaly if a1 (the dummy coefficient) is statistically significant ($p < 0.05$). The MCAR approach implies the existence of an anomaly if the trend model based on cumulative abnormal returns data has a high multiple R-squared, passes the F test, and the regression coefficients are statistically significant ($p\text{-}value < 0.05$).

Finally, Table 3 displays the findings for the Nasdaq Index. Once again the differences in returns (see Table C.1 and Figure C.1 for details) are not statistically significant, and again the one exception is d(0), for which in 67% of the cases price decrease; exploiting this anomaly generates abnormal profits.

Table 3: Overall results for witching day price effects: the case of the Nasdaq Index

Case analysed	Average analysis	Students t-test	ANOVA	Mann-Whitney test	Modified CAR	Regression with dummy variables	Trading simulation	Overall
d(0)	+	+	+	+	+	+	+	7
d(-1)	+	-	-	-	-	-	-	1
d(+1)	+	-	-	-	+	-	-	2
w(0)	+	-	-	-	+	-	-	2
w(-1)	+	-	-	-	+	-	-	2
w(+1)	+	-	-	-	+	-	-	2

Note: This table presents the overall results for the Nasdaq Index. + (-) indicates that an anomaly is (not) detected. Average analysis suggests the presence of an anomaly if the mean return calculated for the witching related day is much higher (lower) compared with the mean return on normal days. For the statistical tests (both parametric and non-parametric) the null hypothesis is that data for the witching related day and for normal ones belong to the same population; a rejection of the null implies the presence of a statistically significant anomaly. The regression analysis with dummy variables provides evidence of an anomaly if a1 (the dummy coefficient) is statistically significant ($p < 0.05$). The MCAR approach implies the existence of an anomaly if the trend model based on cumulative abnormal returns data has a high multiple R-squared, passes the F test, and the regression coefficients are statistically significant ($p\text{-}value < 0.05$).

5 Conclusions

This paper examines price effects related to witching days in the US stock market using both weekly and daily data for three major indices, namely the Dow Jones, SP500 and Nasdaq over the period 2000-2021. The aim is to establish whether or not anomalies in price behaviour arise from witching, and whether or not these can be exploited to generate abnormal profits. The first issue is analysed using various parametric (Student's t-test, and ANOVA) and non-parametric (Mann-Whitney) tests as well as an event study method and regressions with dummies, whilst the second is investigated applying a trading simulation approach.

The results suggest the presence of the anomaly in daily returns on witching days which can be exploited by means of suitably designed trading strategies to earn abnormal profits, especially in the case of the Nasdaq index. Such evidence of exploitable profit opportunities is inconsistent with the Efficient Market Hypothesis (EMH). Future work should investigate the reasons behind these findings.

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Appendix A

Dow Jones Index

Table A.1: Average returns for normal days and witching related days: the case of the Dow Jones Index

Case analysed	Normal day	Witching related day	Anova multiplier
d(0)	0,02%	-0,22%	1,28
d(-1)	0,02%	0,12%	0,20
d(+1)	0,02%	0,19%	0,63
w(0)	0,13%	0,12%	0,00
w(-1)	0,13%	0,01%	0,05
w(+1)	0,13%	-0,14%	0,28

FigureA.1: Average returns for the normal days and witching related days: the case of the Dow Jones Index

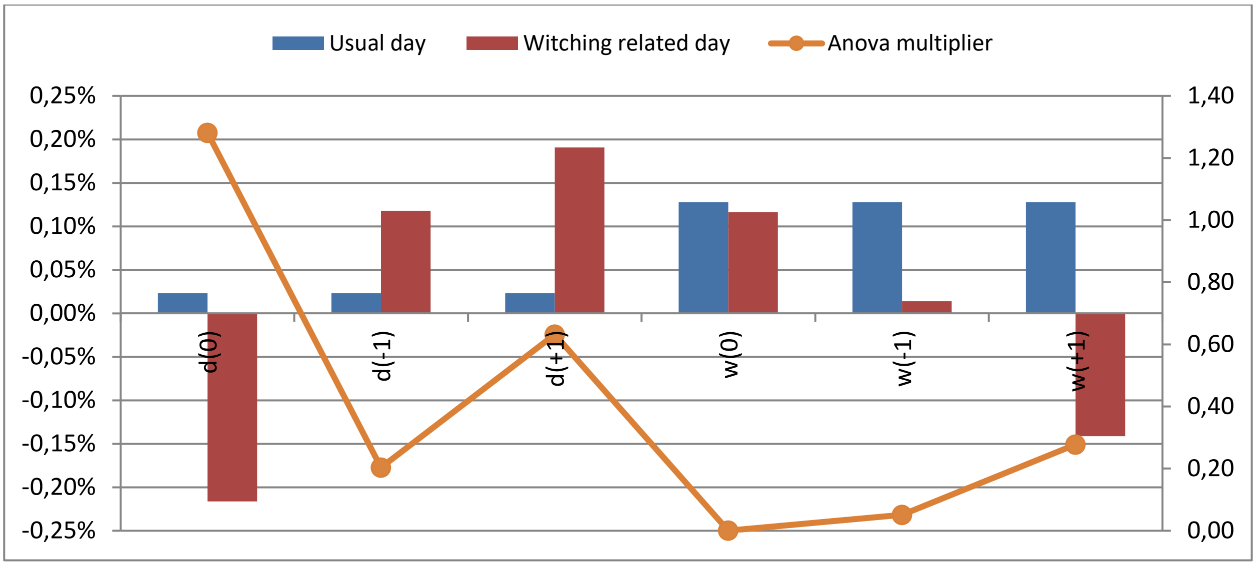


Table A.2: ANOVA test of the witching price effects for the case of the Dow Jones Index

Case analysed	F	p-value	F critical	Null hypothesis	Anomaly	Anova multiplier
d(0)	4,92	0,03	3,84	rejected	confirmed	1,28
d(-1)	0,78	0,38	3,84	not rejected	not confirmed	0,20
d(+1)	2,43	0,12	3,84	not rejected	not confirmed	0,63
w(0)	0,00	0,97	3,85	not rejected	not confirmed	0,00
w(-1)	0,20	0,66	3,85	not rejected	not confirmed	0,05
w(+1)	1,07	0,30	3,85	not rejected	not confirmed	0,28

Table A.3: Mann-Whitney test of the witching price effects for the case of the Dow Jones Index

Case analysed	Adjusted H	d.f.	P value	Critical value	Null hypothesis	Anomaly	Mann-Whitney multiplier
d(0)	3,73	1,00	0,05	3,84	not rejected	not confirmed	0,97
d(-1)	2,36	1,00	0,12	3,84	not rejected	not confirmed	0,34
d(+1)	1,29	1,00	0,26	3,84	not rejected	not confirmed	0,25
w(0)	0,96	1,00	0,33	3,84	not rejected	not confirmed	0,25
w(-1)	0,66	1,00	0,42	3,84	not rejected	not confirmed	0,17
w(+1)	5,99	1,00	0,01	3,84	rejected	confirmed	1,56

Table A.4: T-test of the witching price effects for the case of the Dow Jones Index

<table>
<tr><td colspan="10">Daily returns</td></tr>
<tr><td>Period</td><td>Parameter</td><td>Normal day</td><td>Witching related day</td><td>Period</td><td>Normal day</td><td>Witching related day</td><td>Period</td><td>Normal day</td><td>Witching related day</td></tr>
<tr><td rowspan="6">d(0)</td><td>Mean,%</td><td>0,02%</td><td>-0,22%</td><td rowspan="3">d(-1)</td><td>0,02%</td><td>0,12%</td><td rowspan="3">d(+1)</td><td>0,02%</td><td>0,19%</td></tr>
<tr><td>Stand. Dev., %</td><td>1,00%</td><td>1,08%</td><td>1,00%</td><td>1,08%</td><td>1,00%</td><td>1,12%</td></tr>
<tr><td>Number of values</td><td>6038</td><td>86</td><td>6038</td><td>86</td><td>6038</td><td>86</td></tr>
<tr><td>t-criterion</td><td colspan="2">2,03</td><td rowspan="3"></td><td colspan="2">0,81</td><td rowspan="3"></td><td colspan="2">1,38</td></tr>
<tr><td>Null hypothesis</td><td colspan="2">rejected</td><td colspan="2">not rejected</td><td colspan="2">not rejected</td></tr>
<tr><td>Anomaly</td><td colspan="2">confirmed</td><td colspan="2">not confirmed</td><td colspan="2">not confirmed</td></tr>
</table>

Weekly returns									
Period	Parameter	Normal day	Witching related day	Period	Normal day	Witching related day	Period	Normal day	Witching related day
w(0)	Mean,%	0,13%	0,12%	w(-1)	0,13%	0,01%	w(+1)	0,13%	-0,14%
	Stand. Dev., %	2,29%	2,99%		2,29%	2,22%		2,29%	2,78%
	Number of values	1040	86		1040	86		1040	86
	t-criterion	0,03			0,46			0,87	
	Null hypothesis	not rejected			not rejected			not rejected	
	Anomaly	not confirmed			not confirmed			not confirmed	

Table A.5: Modified CAR approach: results of the witching price effects for the case of the Dow Jones Index*

Case analysed	Multiple R	F-test	a0	a1	Anomaly
d(0)	0,48	25,46 (0,00)	-0,0388 (0,00)	-0,0008 (0,00)	confirmed
d(-1)	0,81	164,67 (0,00)	-0,0291 (0,00)	0,0014 (0,00)	confirmed
d(+1)	0,84	194,40 (0,00)	0,0261 (0,00)	0,0017 (0,00)	confirmed
w(0)	0,78	132,02 (0,00)	-0,1956 (0,00)	0,0036 (0,00)	confirmed
w(-1)	0,45	20,76 (0,00)	-0,0816 (0,00)	0,0011 (0,00)	confirmed
w(+1)	0,89	327,80 (0,00)	0,0020 (0,87)	-0,0046 (0,00)	confirmed

* P-values are in parentheses

Table A.6: Regression analysis with dummy variables: results of the witching price effects for the case of the Dow Jones Index*

Case analysed	Multiple R	F-test	a0	a1	Anomaly
d(0)	0,03	4,92 (0,02)	0,0002 (0,07)	-0,0024 (0,02)	confirmed
d(-1)	0,01	0,78 (0,37)	0,0002 (0,07)	0,0009 (0,37)	not confirmed
d(+1)	0,02	2,43 (0,12)	0,0002 (0,07)	0,0017 (0,12)	not confirmed
w(0)	0,00	0,0014 (0,97)	0,0013 (0,08)	-0,0001 (0,97)	not confirmed
w(-1)	0,06	5,66 (0,02)	0,0004 (0,00)	-0,0018 (0,02)	confirmed
w(+1)	0,03	1,07 (0,30)	0,0013 (0,08)	-0,0027 (0,30)	not confirmed

* P-values are in parentheses

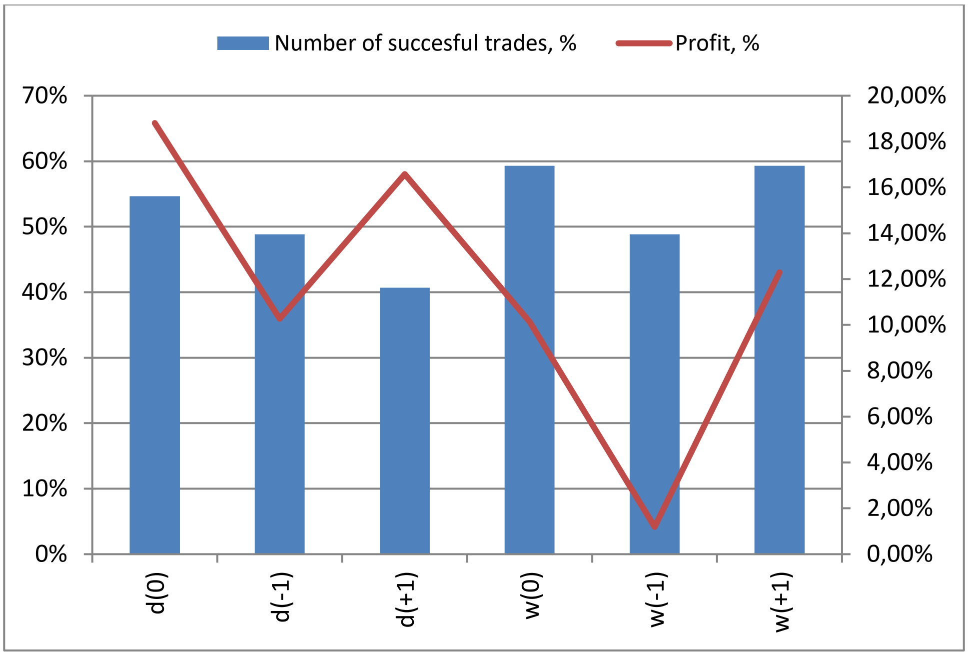
Table A.7: Trading simulation results of the witching price effects for the case of the Dow Jones Index

Case analysed	Number of trades, units	Number of successful trades, unit	Number of successful trades, %	Profit, %	Profit % per trade	t-test calculated value	t-test status
d(0)**	86	47	55%	18,81%	0,22%	1,87	rejected
d(-1)*	86	42	49%	10,27%	0,12%	1,03	not rejected
d(+1)*	86	35	41%	16,58%	0,19%	1,59	not rejected
w(0)*	86	51	59%	10,14%	0,12%	0,37	not rejected
w(-1)*	86	42	49%	1,19%	0,01%	0,06	not rejected
w(+1)**	86	51	59%	12,30%	0,14%	0,48	not rejected

* positive returns

** negative returns

Figure A.2: Trading simulation results of the witching price effects for the case of the Dow Jones Index



Appendix B

SP500 Index

Table B.1: Average returns for the normal days and witching related days: the case of the SP500 Index

Case analysed	Normal day	Witching related day	Anova multiplier
d(0)	0,02%	-0,24%	1,40
d(-1)	0,02%	0,02%	0,00
d(+1)	0,02%	0,05%	0,02
w(0)	0,13%	0,22%	0,03
w(-1)	0,13%	-0,04%	0,10
w(+1)	0,13%	-0,18%	0,34

FigureB.1: Average returns for the normal days and witching related days: the case of the SP500 Index

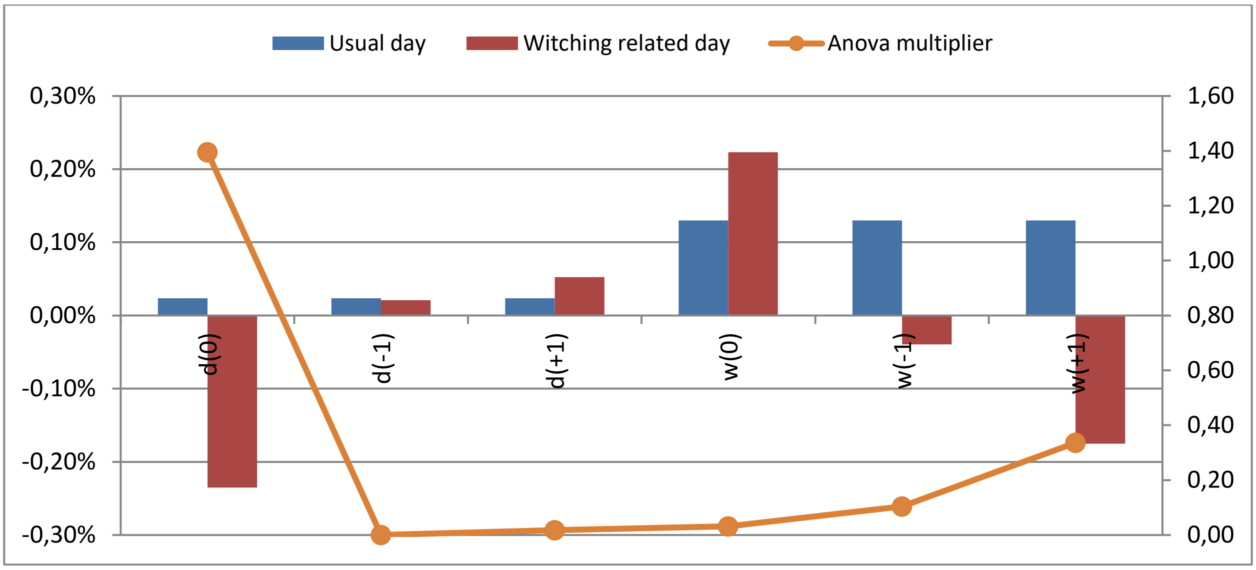


Table B.2: ANOVA test of the witching price effects for the case of the SP500 Index

Case analysed	F	p-value	F critical	Null hypothesis	Anomaly	Anova multiplier
d(0)	5,36	0,02	3,84	rejected	confirmed	1,40
d(-1)	0,00	0,98	3,84	not rejected	not confirmed	0,00
d(+1)	0,07	0,79	3,84	not rejected	not confirmed	0,02
w(0)	0,12	0,73	3,85	not rejected	not confirmed	0,03
w(-1)	0,40	0,53	3,85	not rejected	not confirmed	0,10
w(+1)	1,30	0,26	3,85	not rejected	not confirmed	0,34

Table B.3: Mann-Whitney test of the witching price effects for the case of the SP500 Index

Case analysed	Adjusted H	d.f.	P value	Critical value	Null hypothesis	Anomaly	Mann-Whitney multiplier
d(0)	5,44	1,00	0,02	3,84	rejected	confirmed	1,42
d(-1)	0,44	1,00	0,50	3,84	not rejected	not confirmed	0,00
d(+1)	0,01	1,00	0,92	3,84	not rejected	not confirmed	0,51
w(0)	1,94	1,00	0,16	3,84	not rejected	not confirmed	0,51
w(-1)	1,44	1,00	0,23	3,84	not rejected	not confirmed	0,37
w(+1)	6,14	1,00	0,01	3,84	rejected	confirmed	1,60

Table B.4: T-test of the witching price effects for the case of the SP500 Index

Daily returns										
Period	Parameter	Normal day	Witching related day	Period	Normal day	Witching related day	Period	Normal day	Witching related day
d(0)	Mean,%	0,02%	-0,24%	d(-1)	0,02%	0,02%	d(+1)	0,02%	0,05%
	Stand. Dev., %	1,02%	0,93%		1,02%	1,00%		1,02%	0,81%
	Number of values	5457	82		5457	82		5457	82
	t-criterion	2,50			0,02			0,32	
	Null hypothesis	rejected			not rejected			not rejected	
	Anomaly	confirmed			not confirmed			not confirmed	

Weekly returns									
Period	Parameter	Normal day	Witching related day	Period	Normal day	Witching related day	Period	Normal day	Witching related day
w(0)	Mean,%	0,13%	0,22%	w(-1)	0,13%	-0,04%	w(+1)	0,13%	-0,18%
	Stand. Dev., %	2,34%	2,73%		2,34%	2,22%		2,34%	2,46%
	Number of values	986	82		986	82		986	82
	t-criterion	0,30			0,66			1,08	
	Null hypothesis	not rejected			not rejected			not rejected	
	Anomaly	not confirmed			not confirmed			not confirmed	

Table B.5: Modified CAR approach: results of the witching price effects for the case of the SP500 Index*

Case analysed	Multiple R	F-test	a0	a1	Anomaly
d(0)	0,85	207,25 (0,00)	0,0012 (0,83)	-0,0017 (0,00)	confirmed
d(-1)	0,80	140,69 (0,00)	-0,0878 (0,00)	0,0012 (0,00)	confirmed
d(+1)	0,50	27,00 (0,00)	0,0002 (0,96)	0,0005 (0,00)	confirmed
w(0)	0,92	473,55 (0,00)	-0,2187 (0,00)	0,0053 (0,00)	confirmed
w(-1)	0,01	0,02 (0,90)	-0,0457 (0,00)	-0,0000 (0,90)	not confirmed
w(+1)	0,93	527,74 (0,00)	0,0096 (0,35)	-0,005 (0,00)	confirmed

* P-values are in parentheses

Table B.6: Regression analysis with dummy variables: results of the witching price effects for the case of the SP500 Index*

Case analysed	Multiple R	F-test	a0	a1	Anomaly
d(0)	0,03	5,36 (0,02)	0,0002 (0,09)	-0,0026 (0,02)	confirmed
d(-1)	0,00	0,0004 (0,98)	0,0002 (0,09)	-0,0000 (0,98)	not confirmed
d(+1)	0,00	0,0696 (0,79)	0,0002 (0,09)	0,0003 (0,79)	not confirmed
w(0)	0,01	0,12 (0,72)	0,0013 (0,08)	0,0009 (0,72)	not confirmed
w(-1)	0,02	0,40 (0,52)	0,0013 (0,08)	-0,0017 (0,52)	not confirmed
w(+1)	0,03	1,29 (0,25)	0,0013 (0,08)	-0,0031 (0,25)	not confirmed

* P-values are in parentheses

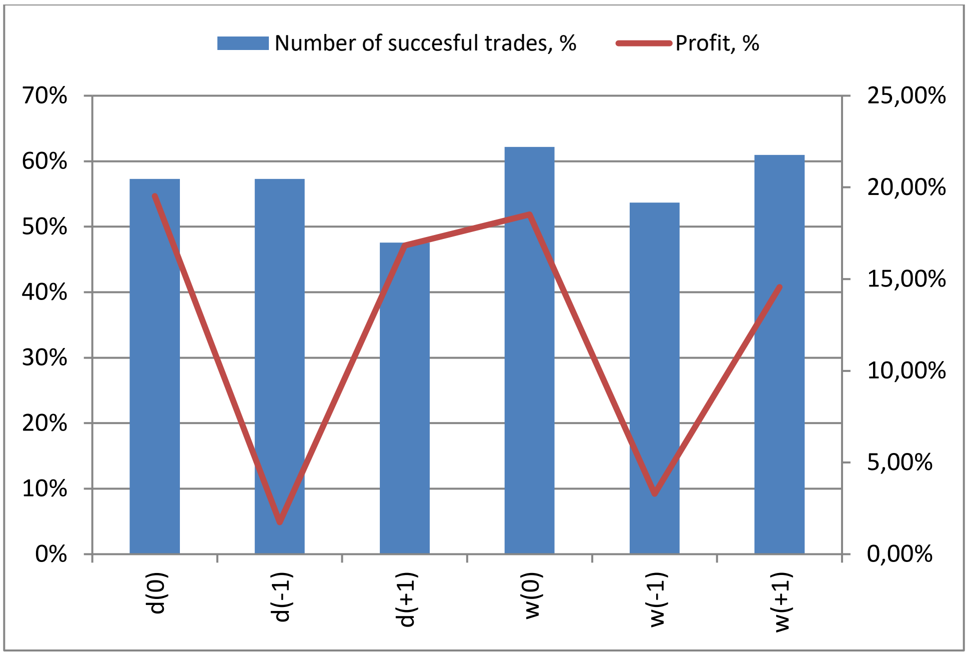
Table B.7: Trading simulation results of the witching price effects for the case of the SP500 Index

Case analysed	Number of trades, units	Number of successful trades, unit	Number of successful trades, %	Profit, %	Profit % per trade	t-test calculated value	t-test status
d(0)**	82	47	57%	19,53%	0,24%	2,32	rejected
d(-1)*	82	47	57%	1,74%	0,02%	0,19	not rejected
d(+1)*	82	39	48%	16,83%	0,21%	1,68	not rejected
w(0)*	82	51	62%	18,52%	0,23%	0,75	not rejected
w(-1)*	82	44	54%	3,29%	0,04%	0,16	not rejected
w(+1)**	82	50	61%	14,56%	0,18%	0,65	not rejected

* positive returns

** negative returns

Figure B.2: Trading simulation results of the witching price effects for the case of the SP500 Index



Appendix C

Nasdaq Index

Table C.1: Average returns for the normal days and witching related days: the case of the NASDAQ Index

Case analysed	Normal day	Witching related day	Anova multiplier
d(0)	0,01%	-0,32%	1,05
d(-1)	0,01%	-0,08%	0,07
d(+1)	0,01%	-0,05%	0,04
w(0)	0,19%	-0,17%	0,24
w(-1)	0,19%	0,12%	0,01
w(+1)	0,19%	-0,06%	0,12

FigureC.1: Average returns for the normal days and witching related days: the case of the NASDAQ Index

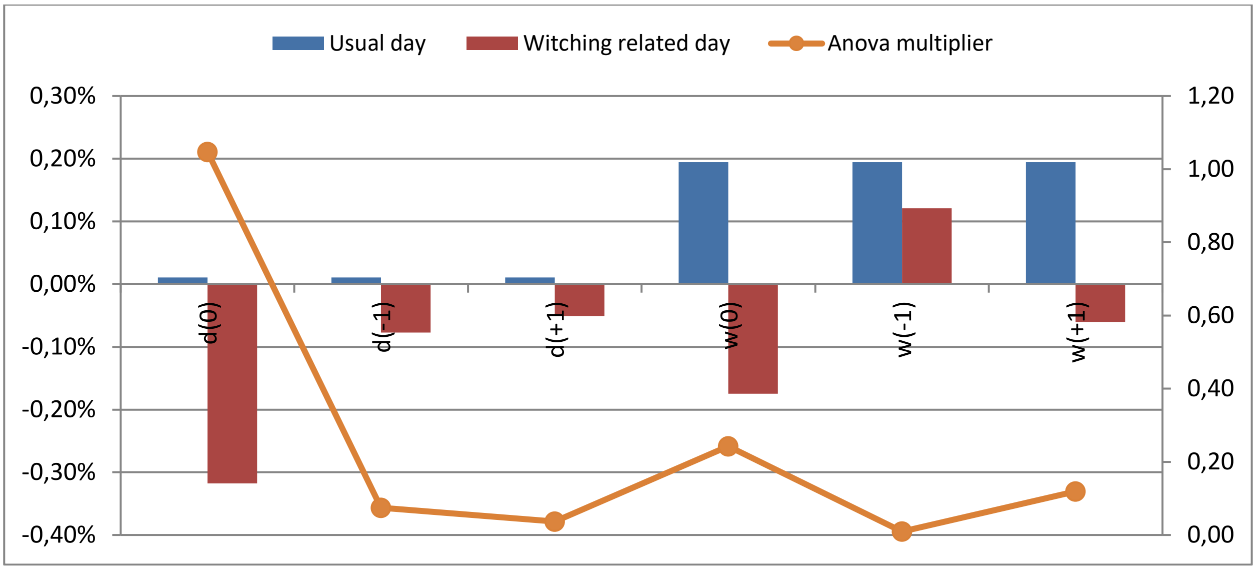


Table C.2: ANOVA test of the witching price effects for the case of the NASDAQ Index

Case analysed	F	p-value	F critical	Null hypothesis	Anomaly	Anova multiplier
d(0)	4,03	0,04	3,84	rejected	confirmed	1,05
d(-1)	0,29	0,59	3,84	not rejected	not confirmed	0,07
d(+1)	0,14	0,71	3,84	not rejected	not confirmed	0,04
w(0)	0,93	0,33	3,85	not rejected	not confirmed	0,24
w(-1)	0,04	0,85	3,85	not rejected	not confirmed	0,01
w(+1)	0,46	0,50	3,85	not rejected	not confirmed	0,12

Table C.3: Mann-Whitney test of the witching price effects for the case of the NASDAQ Index

Case analysed	Adjusted H	d.f.	P value	Critical value	Null hypothesis	Anomaly	Mann-Whitney multiplier
d(0)	9,74	1,00	0,00	3,84	rejected	confirmed	2,54
d(-1)	0,13	1,00	0,72	3,84	not rejected	not confirmed	0,06
d(+1)	0,22	1,00	0,64	3,84	not rejected	not confirmed	0,01
w(0)	0,03	1,00	0,87	3,84	not rejected	not confirmed	0,01
w(-1)	1,23	1,00	0,27	3,84	not rejected	not confirmed	0,32
w(+1)	1,05	1,00	0,31	3,84	not rejected	not confirmed	0,27

Table C.4: T-test of the witching price effects for the case of the NASDAQ Index

Daily returns									
Period	Parameter	Normal day	Witching related day	Period	Normal day	Witching related day	Period	Normal day	Witching related day
d(0)	Mean,%	0,01%	-0,32%	d(-1)	0,01%	-0,08%	d(+1)	0,01%	-0,05%
	Stand. Dev., %	1,52%	1,10%		1,52%	1,45%		1,52%	1,49%
	Number of values	5353	85		5353	85		5353	85
	t-criterion	2,72			0,56			0,38	
	Null hypothesis	rejected			not rejected			not rejected	
	Anomaly	confirmed			not confirmed			not confirmed	

Weekly returns									
Period	Parameter	Normal day	Witching related day	Period	Normal day	Witching related day	Period	Normal day	Witching related day
w(0)	Mean, %	0,19%	-0,17%	w(-1)	0,19%	0,12%	w(+1)	0,19%	-0,06%
	Stand. Dev., %	3,42%	3,44%		3,42%	2,90%		3,42%	2,50%
	Number of values	1045	86		1045	86		1045	86
	t-criterion	0,96			0,22			0,88	
	Null hypothesis	not rejected			not rejected			not rejected	
	Anomaly	not confirmed			not confirmed			not confirmed	

Table C.5: Modified CAR approach: results of the witching price effects for the case of the NASDAQ Index*

Case analysed	Multiple R	F-test	a0	a1	Anomaly
d(0)	0,95	783,51 (0,00)	0,0537 (0,00)	-0,0031 (0,00)	confirmed
d(-1)	0,12	1,19 (0,28)	-0,0971 (0,00)	-0,000 (0,28)	not confirmed
d(+1)	0,63	54,42 (0,00)	-0,0315 (0,00)	-0,0009 (0,00)	confirmed
w(0)	0,48	24,51 (0,00)	-0,5248 (0,00)	0,0028 (0,00)	confirmed
w(-1)	0,57	39,22 (0,00)	0,0771 (0,00)	-0,0013 (0,00)	confirmed
w(+1)	0,92	445,80 (0,00)	0,0035 (0,72)	-0,0042 (0,00)	confirmed

* P-values are in parentheses

Table C.6: Regression analysis with dummy variables: results of the witching price effects for the case of the NASDAQ Index*

Case analysed	Multiple R	F-test	a0	a1	Anomaly
d(0)	0,03	4,03 (0,04)	0,0001 (0,60)	-0,0033 (0,04)	confirmed
d(-1)	0,01	0,29 (0,59)	0,0001 (0,60)	-0,0009 (0,59)	not confirmed
d(+1)	0,01	0,14 (0,71)	0,0001 (0,60)	-0,0006 (0,71)	not confirmed
w(0)	0,03	0,93 (0,33)	0,0019 (0,07)	-0,0037 (0,33)	not confirmed
w(-1)	0,01	0,03 (0,85)	0,0019 (0,06)	-0,0007 (0,85)	not confirmed
w(+1)	0,02	0,46 (0,50)	0,0019 (0,06)	-0,0026 (0,50)	not confirmed

* P-values are in parentheses

Table C.7: Trading simulation results of the witching price effects for the case of the NASDAQ Index

Case analysed	Number of trades, units	Number of successful trades, unit	Number of successful trades, %	Profit, %	Profit % per trade	t-test calculated value	t-test status
d(0)**	85	57	67%	27,31%	2,73%	0,32%	2,70
d(-1)*	85	43	51%	6,64%	0,66%	0,08%	0,50
d(+1)*	85	43	51%	4,41%	0,44%	0,05%	0,32
w(0)*	86	36	42%	15,18%	1,52%	0,18%	0,48
w(-1)*	86	43	50%	10,54%	1,05%	0,12%	0,39
w(+1)**	86	42	49%	5,23%	0,52%	0,06%	0,23

* positive returns

** negative returns

Figure C.2: Trading simulation results of the witching price effects for the case of the NASDAQ Index