The Review of Finance and Banking
Volume 06, Issue 2, Year 2014, Pages 047–067
S print ISSN 2067-2713, online ISSN 2067-3825

FORENSIC FINANCE: MARKET ABUSE AND PRICE MANIPULATION IN SECURITY MARKETS ON THE TRAIL

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Abstract. On 19th March 2009, national newspapers in Austria reported on a "turbo scandal" that had been suspected on the Vienna Stock Exchange. Concerned investors argued that the issuers of turbo certificates tried to raid the underlying prices of these down-and-out call options by pushing down the prices of the underlyingsbelow the barriers of the derivatives. The goal of this research is to find out which variables are crucial for the research, which stocks were manipulated and who their manipulators were. According to our empirical results, we definesuspicious issuers for each stock and classify them as being highly, moderately, less suspicious or rather unsuspicious issuers.

1. Introduction[1]

In this paper, we discuss the so-called "turboscandal", an event that agitated the Austrian public in 2009 when information about the alleged manipulation of turbo certificates on the Vienna Stock Exchange appeared. Turbo certificates are barrier options that are specific to financial markets in the German speaking area. They belong to the so-called Hebelzertifikate (Hebelger. Leverage). As with other leverage derivatives, it is possible for the investor to earn or lose disproportionally.Investors claimed that some issuers of turbo certificates were pushing down the prices of underlying assets on purpose in order to break the barrier level of turbo certificates and in this way make them valueless. A turbo certificate is a financial derivative that belongs to a family of knockout barrier options. Its main characteristic is that it provides high profits to investors if the underlying price settles far above the barrier at expiry and if the barrier was not touched during the life of the derivative. If the barrier is touched during the life of the certificate, it becomes worthless immediately.Therefore the investigated long turbos can be interpreted as a plain vanilla call option with an additional killing barrier. The leading exchange for warrants in Europe is the European Warrant Exchange EUWAX in Germany with more than 1 mio different derivatives and an annual trading volume of 91 mio €. The alleged scandal motivated small investors to organize a special union[2] in order to fight for their rights while the Financial Market Authority in Austria began to overcome the problem. Magazines

Received by the editors January 23, 2014. Accepted by the editors July 28, 2014.
Keywords: market abuse, price manipulation, alarm trigger, turbo certificate, intraday event study.
JEL Classification: D53, G14, G18, N24, K22.

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This paper is in final form and no version of it will be submitted for publication elsewhere.

[1]An earlier version of this paper appeared in the working paper series of the Faculty of Social and Economic Sciences of the Karl-Franzens-University Graz.

[2]Concerned investors organized themselves into a union, in German called VereinfürFinanzmarktausgleich.

and newspapers[3] also wrote about the issue; however, some years later, no scientific research, to our knowledge, has been published regarding this matter.

Market abuse incorporates insider dealings and price manipulation. There is no strict definition of market manipulation, so different authors give different definitions. Even the legal constitutions of some countries (e.g. the US, UK and EU)have been unsuccessful in precisely defining manipulation. US law prohibits manipulation but it leaves it to the courts to define on a case-by-case basis, whereas the UK and EU have proposed a principle-based description of prohibited manipulative practices (Kyle &Viswanathan, 2009). The US regulates market abuse and insider trading with the Securities Exchange Act of 1939, while the EU put into force Directive 2003/6/EC of the European Parliament and of the Council in 2003 on insider dealing and market manipulation. This was a pioneer text that was amended to the Markets in Financial Instruments Directive (MiFID1) whose goal was to encompass new changes on rapidly developing financial markets. Nevertheless, in October 2011 the European Commission adopted a legislative proposal for the revision of MiFID1 (referred to as MiFID2). This newest proposal was designed to take into account technical developments in the trading environment.

Since the turbo scandal belongs to trade-based manipulation, its main characteristic is that actors try to manipulate stock pricesusing different trading strategies. According to the statement by concerned investors, the issuers of turbo certificates tried to crash down the underlying price by making best selling orders with prices under the barrier or by making limited selling orders when the market is deep. These orders were sufficient to break the barrier of turbo certificates. Investors further stated that trading actions were also carried out when the market was thin or during certain parts of the day, such as lunchtime and morning coffee break, when manipulators had enough "privacy" to conduct manipulation activities. Moreover, to hedge the possible risk in long turbo certificates that might occur due to a rise in the prices of the underlyings, issuers used to keep a sufficient amount of stocks underlying these turbo certificates in their portfolios. We later build the hypotheses for the present researchaccording to these statements on the turbo scandal case[4].

Although issuers of retail derivatives usually hedge their positions and gain a riskless margin at the time of issuance of their products there still remains an incentive to knock-out their turbos, because in the knock-out event the issuers can close their valueless open short positions and sell the valuable hedging positions. For example, if the issuer hedges his short turbo position simply with a static hedge in the form of 1 to 1 long positions in the underlying, there is always an incentive to manipulate the price of the underlying to kill the turbo because in this case the issuer gets rid of his short position and he can sell the long underlying position and receives the selling price as his revenue. Without a manipulation the issuer is always worse off because he has always to fear that the holder of the turbo will exercise the turbo. Even for hedged issuers of plain vanilla call options there is an incentive to kill the short call after the issuance and before the expiration because the investor of the short position has always to fear that the holder of the call will exercise his call, which would result in a negative pay-off for the call writer.

Since this research examines trade-based manipulation, a short insight into the literature on this type of manipulation is now given. Several studiesinvestigate closing price manipulation because of the wide usage of closing price as a benchmark in praxis as well as in science. Kumar

[3]Many Austrian newspapers published articles about the issue e.g.:
http://www.fondsprofessionell.at/news/aktuelle-news/?tx_fp_pi1[nid]=957346,
http://aktien-portal.at/shownews.html?id=17870,
http://diepresse.com/home/wirtschaft/international/462677/Marktmanipulation-bei-Turbozertifikaten?from=gl.home.wirtschaft_International,
http://derstandard.at/1237227827340/Verein-fuer-Finanzmarktausgleich-Anlegerverein-wittert-Turbo-Skandal,
http://www.oe24.at/wirtschaft/Anleger-wollen-Finanzaufsicht-klagen/422857.

[4]A complete statement of the Verein in its original form can be found on
http://www.amtshaftung.at/downloads/VereinFA_Presseinfo_Turboskandal.pdf. [12.11.2012].

and Seppi (1992) construct examples of equilibrium manipulation in the context of a modified Kyle (1985) model,whileHillion and Souminen (2004) are intrigued by the last minute trading on the Paris Bourse,which was the most traded period during the day before call auction was introduced. They use an agency-based model of closing price manipulation and show that closing call auctions decrease manipulation.

Several papers develop models by which they try to prove or at least indicate market manipulation. Some of the pioneer working papers that build models include Hart (1977), Kyle (1985), Jarrow (1994) and Allen and Gale (1992). In recent times, studies of underlying prices on option expiration dates have appeared. For example, Stoll and Whaley (1991) and Ni et al. (2005) find positive evidence that stock prices change their behavior on expiration dates, indicating that one of the main reasons for clustering is stock price manipulation by investors. Gallagher et al. (2009) find evidence that managers with low performing results are keener to engage in manipulative trading strategies than high performing managers.

Studies of prosecuted manipulation cases are rare. Aggarwal and Wu (2006) research the cases prosecuted by the US Securities and Exchange Commission (SEC). They note that stock prices were increasing during the manipulation period but decreasing in the post-manipulation period. Another study that examines prosecuted cases by the SEC is that byComerton-Forde and Putninš (2011). Their sample shows that manipulation is mostly driven by managers, brokers and larger shareholders. In their research, they develop an index that can be broadly used across different markets for thedetection of price manipulation.

In this paper, we investigate stocks for which concerned investors state that significant suspicion exists about possible manipulation. To verify whether there might be scientific proof or at least an indication of market abuse and price manipulation we pursue our research based on daily and intraday analyses.

The remainder of the article is structured as follows. Section 2 presents the methodology and data. Section 3 describes the theoretical framework and research tools. Section 4 analyses the results and gives explanations,whileSection 5 concludes.

2. Methodology and Data

2.1. **Methodology.** The main idea of our research is that there exists a suspicion about price manipulation when the price or trading volume[5] of the underlying is outside its confidence intervals. We call these days alarm days. Therefore, we investigate knocked out turbo certificates (KO turbos hereafter) and their issuers on days with and without price or volume alarms. We deem that if the knocking out of turbo certificates (Figure 1) were performed on purpose, then crashing down the price would probably lead to the triggering of a price alarm on the down limit. This means that the number of KO turbos per day would be larger on days when there is a price alarm on the down limit than when there is no price alarm. Further, we want to see whether the knockout of turbo certificates (KO event hereafter) is correlated with volume; in other words, whether the KO event was performed more on days when the traded volume was small i.e. when the market was thinner when it was large. Finally, price manipulation is assumed to have been carried out by those issuers who have adisproportionate high share of KO turbos on alarm days

We base our methodology for constructing the confidence intervals for daily price and volume (in units) movements onMinenna (2003). We use Ornstein-Uhlenbeck as the underlying price process with an estimation window of 15 days and a 99% confidence level. For volume, we take the Geometric Brownian Motion instead of Ornstein-Uhlenbeck as the underlying process with an estimation window of 15 days and a confidence level of 95%.

If the stock price on a certain day touches or goes beneath the down limit of the confidence interval, an alarm on the down limit will be triggered; by contrast, if it touches or goes above the upper limit, an alarm on the upper limit will be triggered. Since we investigate only long

[5]We use the volume of stocks in units.

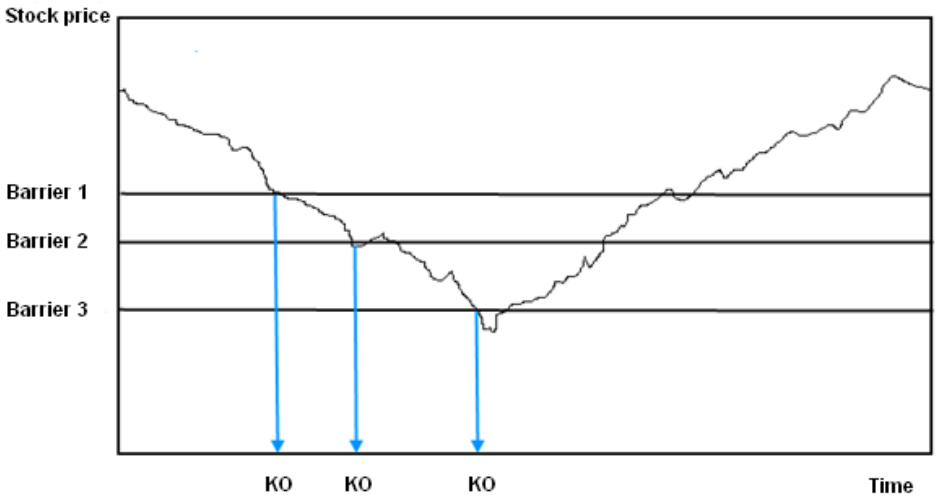

FIGURE 1. Price process and the KO events of turbo certificates. Note: This figure depicts the KO events of turbo certificates. The stock price falls steadily until it reaches the level of the minimal barrier on a certain day. After the KO event, the price begins to rise again and very soon returns to its previous level. At the point when the price touches the barrier (signed as KO), the turbo certificate is knocked out and it instantly becomes valueless.

turbo certificates, we concentrate our research only on the down limit of the confidence interval for price movement and consequently divide the space for price movement into two parts: (i) a price alarm on the down limit and (ii) no price alarm on the down limit. The latter comprises the space between the two limits of the confidence interval and the space above the upper limit of the confidence interval. Thespace within the limits of the confidence intervals for volume are divided into three parts: (i) volume alarm on the down limit (ii) no volume alarm and (iii) volume alarm on the upper limit.

Since no useable software already exists, all the research from confidence intervals to three-way contingency tables, volatility measures, continuous returns and various key figures are programmed in Matlab. Hypotheses are tested according to categorical data analysis in SPSS, which is pursued on daily and intraday results obtained from the programmed software. The categorical data analysis includes loglinear modeling, association and symmetric measures for two- and three-dimensional contingency tables[6]. We apply the Chi-square test of independence and the Chi-square test of homogeneity on two- and three-way tables to see which of the investigated variables are dependent and which are independent or irrelevant for further research. The significance of the key figures from the intraday analysis are tested with Welch's test andthe histograms for the KO times of death with the Kolmogorov–Smirnoff test. None of the statistical methodologies and tests applied in our paper can actually prove price manipulation in a legal sense, but they indicate significant difference between the various subgroups of observations.

2.2. **Data.** All knocked out derivatives for the period 2nd January 2007 until 31st December 2010 are obtained from the EUWAX Stock Exchange. After filtering out titles that are not turbo certificates, the database is left with 3,757 KO turbos. The database includes title and ISIN number, name of the product, underlying, KO time of death and date, barrier level, delisting, due date, issuer of the title and first trading date. The prices of the stocks including

[6]An outstanding overview of contingency tables including an explanation of loglinear modeling for two- and multidimensional contingency tables can be found in Agresti (2002).

dividends, splits and rights as well as volume for each day in the period 2nd January 2007 until 31st December 2010 are obtained from DataStream. Ticks and order size data are obtained from the Vienna Stock Exchange for the period January 2nd 2007 until November 28th 2008 (we pursue intraday analysis only on KO turbos in that period). Missing data are turbo certificates that are not knocked out (not available) and information about the buyer/seller that are under data protection.

We investigate 12 Austrian stocks that investors claim have been manipulated. Since these stocks cannot be deemed as having been manipulated until the research has been completed, we call them manipulable stocks. These stocks are Andritz, Austrian Airlines, Bwin, CA Immobilien Anlagen, Erste Group Bank, Intercell, Meinl European Land, Raiffeisen Bank Int., RHI, Verbund, Voestalpine andWienerberger. Both daily analyses are pursed on all 12 stocks,while the intraday analysis is not pursued on the Meinl European Land stock due to missing tick data. Table 1 shows the number of turbo certificates divided by stock, issuer and analysis period.

Table 1: Number of knocked out turbo certificates

1423	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	6	0	0	0	0	0	6	0	12
225	30	26	37	0	34	17		27	13	17	37	30	268
	35	30	44	0	56	21	45	44	22	30	50	41	418
371	22	19	22	36	20	10		21	25	11	40	15	241
	23	19	26	42	29	44	23	28	45	20	70	23	392
432	11	3	14	7	16	10		25	13	16	14	12	141
	11	0	19	7	23	23	7	36	18	30	19	20	213
438	69	0	0	0	80	0		62	19	21	66	64	381
	107	0	4	0	131	0	9	133	21	64	132	113	714
525	69	50	54	20	69	44		84	27	32	81	45	575
	110	50	104	20	158	73	25	190	52	58	148	89	1,077
581	8	2	15	4	12	17		16	10	7	14	12	117
	12	0	24	4	24	42	0	34	22	18	22	27	229
584	0	0	2	0	0	0		0	0	0	8	0	10
	0	0	2	0	0	0	0	0	0	0	8	0	10
613	6	0	30	0	34	0		43	0	6	24	7	150
	29	0	49	0	75	0	0	80	0	26	53	25	337
6622	0	0	0	0	0	0		1	0	0	0	0	1
	0	0	0	0	0	0	0	1	0	0	0	0	1
803	0	0	46	48	0	14		10	12	0	5	0	135
	0	0	46	48	0	14	37	10	12	0	5	0	172
9013	0	0	0	0	0	0		0	0	0	0	0	0
	10	0	37	0	21	34	0	21	11	14	20	20	188
Sum 2007–2008	215	100	220	115	265	112		289	119	110	289	185	2,019
Sum 2007–2010	337	99	355	121	523	251	146	577	203	260	533	358	3,763

1. Owing to missing and/or incorrect data, the intraday analysis is pursued for only 27 KO turbos even though 115 KO turbos were found in the period 1.1.2007 to 28.11.2008.

2. Since there is only one KO turbo from issuer 662, both the KO turbo and the issuer were excluded from further research.

3. Since issuers 142 and 901 have KO turbos only after 28th November 2008, both were excluded from the intraday analysis due to missing tick data for that period.

3. Theoretical Background and Tools for the Analysis

Our external forensic financial research is divided into three major parts: two daily analyses and one intraday analysis. Daily analyses are based on the characteristics of KO turbo days,

i.e. whether there is a price and/or volume alarm on a certain day, how many KO turbos are knocked out per day, who is the issuer of KO turbos and whether this KO turbo is that with the minimal barrier of a day. The intraday analysis is based on tick data and the investigation of only those KO turbos whose barriers are the minimal barriers on KO turbo days.

We base our analysis on Minenna (2003), who suggests that price and volume alarmsboth be checked when searching for market abuse due to the possible interactions between these two variables. Oscillations in prices and trading volumes outside the predicted confidence intervals are the first step to checking for market abuse.

3.1. **Daily Analysis I: Day Counts.** Analysis I has two goals. The first is to find out which variables among the price alarm, volume alarm and number of KO turbos per day are significant for the research and their relations. The second is to find out which of the 12 stocks were indeed manipulated in the period from January 2nd 2007 until December 31st 2010.

Analysis I is based on the characterization of the days in the period of investigation for all 12 stocks according to the following characteristics:

(i) variable A: whether there is a KO turbo on that day (no, yes),

(ii) variable B: whether there is a price alarm on the down limit on that day (no, yes) and

(iii) variable C: whether there is a volume alarm on that day (no, yes on the upper limit, yes on the down limit).

For each day, our algorithm counts how many turbo certificates are knocked out and classifies that day as a day with no KO turbos or with one, two, three, four or five or more KO turbos (0, 1, 2, 3, 4 and ≥ 5).

In this way, seven types of contingency tables are constructed: two three-dimensional tables and five two-dimensional tables. The three-dimensional tables have as their variables the number of KO turbos (variable A), price alarm (variable B) and volume alarm (variable C). Variable A is combined in two ways. One way is that it has all six outcomes (0, 1, 2, 3, 4, $\geq$ 5) and the other way that it has only two outcomes, namely the days on which there are no KO turbos and days on which there are one or more KO turbos (0, ≥ 1). We apply loglinear analysis to the three-dimensional tables to assess the interactionsbetween variables A, B and C[7]. Further, we apply the Chi-square test of independence on the two- and three-way tables to calculate the directional and symmetrical measures[8] about which we discuss Cramer's V due to its wide applicability.

For the two-dimensional tables, a Chi-square test of independence is used in order to see whether the two variables A*B, A*C or B*C are independent when there is no third variable checking for the existence of the Simpson Paradox. The most significant results are obtained for the combination of variables A and B. These tables show for all manipulable stocks that the number of days on which there is a price alarm on the down limit and on which there is at least one KO turbo per day is much higher than what it should be in the case of independence. This type of table is discussed in Section 4.

Further, to find out which of the stocks were indeed manipulated we first calculate the conditional probabilities that when there is a KO turbo on a certain day that then there is also a price alarm on the down limit on that day. We calculate the conditional probability P(Alarm/KO) for each stock and compare this with the conditional probability P(Alarm/KO) for the remaining stocks. For this, we use the z test of equality between two proportions on the down limit over the Bayesian statistics calculated for the A and B variable combination.This variable combination is crucial for detecting manipulated stocks because it can affirm or disapprove the allegation that turbo certificates were knocked out on purpose (see Section 1). In other words, the crashing down of underlying prices would have triggered a price alarm on the down limitwith a high probability and thus the occurrence of these two variables together by

[7]Contingency tables are analyzed in SPSS.

[8]The directional and symmetrical measures belong to the association measures among which Goodman and Kruskal's Lambda, the Contingency Coefficient and Phi were analyzed.

a certain stock implie that the stock was manipulated. The suspicion of being manipulated is given to those stocks whose P(Alarm/KO)[9] is significantly higher than the P(Alarm/KO) of the remaining stocks together.

3.2. **Analysis II: KO Turbo Counts.** Our second analysis also tackles the days in the period 2nd January 2007 until 31st December 2010 but with different variable combinations. This time, we characterize days according to: (i) the issuer of KO turbo, (ii) whether the KO turbo represents the KO turbo with the minimal barrier on a KO turbo day (no, yes) (iii) and whether there is a price alarm on the down limit on that KO turbo day (no, yes). For each category, the number of KO turbos is counted. For this purpose another algorithm in Matlab was programmed in order to construct three-way contingency tables and to process the data obtained by the first algorithm for confidence intervals.

The second analysis aims to identify the suspicious issuers for each underlying.In order to identify suspicious issuers, we apply the Chi-square test of homogeneity to our KO turbocount tables. To be able to do that, we define our two variables, namely minimal barrier and a price alarm on the down limit, as one variable but with four outcomes[10], that is, we make two-dimensional tables out of the three-dimensional tables. After applying the Chi-square test to theKO turbocounts table, we check whether it is homogeneous at the 5% and 1% significance levels. If the table is heterogeneous, we identify suspicious issuers in it and eliminate them from the table until it reaches homogeneity. We then define a positive deviation as the percentage between the observed and expected frequencies in the variable combination – a price alarm on the down limit and KO turbo is the KO turbo with the minimal barrier on the KO turbo day – as the key factor for identifying suspicious issuers. We call this factor the elimination measure. Issuers with a positive elimination measure are step-wisely eliminated from the table until the table reaches homogeneity. The elimination process starts with the highest positive elimination measure and ends with the lowest one. In other words, the above-mentioned variable combination is the key factor in discovering real suspected issuers, because we suppose that those issuers who wanted to knock out turbo certificates on purpose were probably interested in knocking out those turbo certificates with the minimal barrier on that particular day. Reaching the price level of the minimal barrier enables issuers to knock out at once all other turbo certificates whose barriers are higher than the minimal one or.In other words, issuers receive the so-called "cascade" knocking out in which dozens of turbo certificates can be knocked out in just one step.

3.3. **Analysis III: Intraday Event Study.** Analysis III is divided into two parts: (i) key figures and (ii) histograms. In the following section, we provide an overview of the methods used to find the results.

3.3.1. *Key Figures.* The third part of the empirical investigation is based on tick data for the period 2nd January 2007 until 28th November 2008, for which we conducted an event study. All intraday data are analyzed for each underlying, separately for alarm days and non-alarm days and for each issuer. We base our event study on Bommel and Rossetto (2009). For each knockout day, separately for alarm days and non-alarm days, an event window of six hours is calculated for each KO turbo, which is the KO turbo with the minimal barrier on the KO turbo day[11]. For each second three hours before and three hours after the KO event, a price index and a volume index are calculated and analyzed. Since we use order-based tick data, first we have to

[9]P (Alarm/KO) describes the conditional probability that when there is a knockout on a certain day, then there is also a price alarm on the down limit on that day.

[10]The four outcomes for the KO turbo counts table are now (1) price alarm on the down limit (no) and min barrier (no), (2) price alarm on the down limit (no) and min barrier (yes), (3) price alarm on the down limit (yes) and min barrier (no) and (4) price alarm on the down limit (yes) and min barrier (yes).

[11]In cases when the KO turbo was knocked out at the beginning or at the end of a day, so that the price and volume indices could not be calculated for the entire three hours before or after the KO event, we shortened the event window for that KO turbo until the opening/closing of the stock exchange.

transform them into second-based ticks. In order to do that, we build a 21,600-space vector and split it into two parts:–10,800 seconds to the left representing three hours before theKO event and +10,800 seconds to the right representing three hours after the KO event. The standardized event second 0 is split into 0-, 0 and 0+, resulting in 21,603 spaces. For each second, we calculate the price and volume indices and normalize them with the price of the knockout order (KO price) and size of the knockout order (KO order size) to ascertain a normalized KO price at 100 EUR and a normalized KO volume at 1 unit. In order to aggregateKO turbos according to certain characteristics i.e. for each stock and for each issuer, separately for alarm days and non-alarm days and for both of these variants together, we place 21,603-space vectors of each KO turbo one upon the other and calculate the mean and standard deviation through each second. Since not every second in a 21,603-space vector has an index, we apply linear interpolation to connect empty spaces. We define the mean reverting behavior of the price movement after the KO event as a sign that the knockout was forced by price manipulation, whereas its absence signals no manipulation activity.

Further analysis incorporates the calculation of different key figures: (i) various continuous returns: ln(C/O), ln(H/O), ln(L/O), ln(C/H), ln(H/L) and ln(C/L)[12]; (ii) intraday volatility according to Rogersand Satchell. (1991); and (iii) various ratios: Low Price/Min Barrier, KO Order Size/Average Volume of the Day and the Mean Reversion Ratio (ln Price Index-max(t,t+3h)/100)). We apply Welch's test of equality between the two means to test these key figures.

As testing groups for each stock, we define the following combinations: (i) each issuer against all other issuers for non-alarm days, (ii) each issuer against all other issuers for alarm days and (iii) each issuer against all other issuers for alarm days compared with non-alarm days. We also calculate the mean for all issuers together for each type of day in order to see which particular issuer deviates upwards from the mean of the group. We concentrate our analysis on choosing the representative key figures on the mean of the group and not on the statistical significance obtained by Welch's test statistics. This is due to the very high standard deviations i.e. very small sample sizes s1[13]. The most intriguing results are obtained for the key figure mean reversion, which is thoroughly analyzed in Section 4.

Further, we search for the 10KO turbos with the highest mean reversion rates among the KO turbos with minimal barriers on KO turbo days. These 10turbo certificates form the Top Ten Tables, which represent single outliers on each stock among all KO turbos with the minimal barrier issued on a particular stock.

3.3.2. *Histograms of Times of Death.* According to the concerned investors, one more statement about knocking out turbo certificates must be checked. These investors assert that knocking out used to be performed at specific parts of the day. In order to check this allegation, we build histograms for the exact KO times of death of KO turbos with minimal barriers on KO turbo days for each stock. We do this for all issuers together, for each issuer separately and for days when a price alarm is on the down limit and when it is not. We then apply the Kolmogorov–Smirnoff test in order to see if there exists significant differences in the distribution of KO times of death between the above-mentioned groups (see Section 3.3.1.).

4. Empirical Results

In the following subsections, the results of Analysis I explain which variables are the most important for further research and how they interact. Further, we explain how manipulated stocks are identified by using a z test of equality between two proportions based on the 2×2 table results from Analysis I. Moreover, we gradually show how the suspicious issuers for each

[12]O, L, H and C are symbols for open, low, high and close prices.

[13]Here, s_1 represents samples containing KO turbos with minimal barriers on KO turbo days issued only by one particular issuer. Very often, samples s1 contain fewer than five KO turbos, which leads to wide confidence intervals and consequently to no rejection of H_0.

stock are detected from the results of Analysis II and Analysis III and provide a graphical presentation of the key figure mean reversion as well as the histograms for the KO time of death of KO turbos.

4.1. **Searching for the Relevant Variables.** In almost all table combinations, variable C is insignificant, which can be seen by low Cramer's V values in the two-way tables of the variable combinations A*C and B*C. By contrast, in the three-dimensional tables it is either jointly independent of variable A (the loglinear model is AB, C) or it is only conditionally dependent on variable A through variable B (the loglinear model is then AB, AC). As we can see, variable C does not influence KO turbos. For the three-dimensional tables, the p value for the likelihood ratio is provided to describe how well the model fits the data[14].

Table 2a: Analysis I: Contingency table combinations for the variables number of KO turbos, price alarm and volume alarm for 12 stocks (I)

		A*B*C			
		Loglinear Model	Likelihood Ratio	p value	Independence at 5% or 1%
ANDRITZ	with KO c.	A*B; C	16.15	0.809	yes
	w/o KO c.	A*B; C	7.99	0.239	yes
AUSTRIAN AIRLINES	with KO c.	A*B; C	19.36	0.623	yes
	w/o KO c.	A*B; C	8.45	0.996	yes
BWIN	with KO c.	A*B; A*C	8.07	0.779	yes
	w/o KO c.	A*B; C	7.85	0.998	yes
CA IMMOBILIEN ANLAGEN	with KO c.	A*B; B*C	12.92	0.881	yes
	w/o KO c.	A*B; B*C	4.70	n.a.	n.a.
ERSTE GROUP BANK	with KO c.	A*B; B*C	23.84	0.249	yes
	w/o KO c.	A*B; B*C	6.97	0.997	yes
INTERCELL	with KO c.	A*B; B*C	15.50	0.747	yes
	w/o KO c.	A*B; B*C	6.95	0.139	yes
MEINL EUROPEAN LAND	with KO c.	A*B; B*C	12.62	0.893	yes
	w/o KO c.	A*B; A*C; B*C	0.03	0.986	yes
RAIFFEISEN BANK INT.	with KO c.	A*B; B*C	22.47	0.315	yes
	w/o KO c.	A*B*C	0.00	1.000	yes
RHI	with KO c.	A*B; C	20.66	0.542	yes
	w/o KO c.	A*B; C	13.73	0.911	yes
VERBUND	with KO c.	A*B; B*C	20.98	1.000	yes
	w/o KO c.	A*B; B*C	6.80	0.742	yes
VOESTALPINE	with KO c.	A*B; A*C	8.54	0.398	yes
	w/o KO c.	A*B; B*C	4.91	0.147	yes
WIENER BERGER	with KO c.	A*B; C	15.86	0.823	yes
	w/o KO c.	A*B; C	7.26	0.999	yes

Note: This table shows four types of contingency tables with different combinations of the variables number of KO turbos per day (A), price alarm (B) and volume alarm (C). Variable A is given in its two forms: an extended form by counting KO turbos per day (six possible outcomes 0, 1, 2, 3, 4, = 5 KO turbos) and a short form i.e. without counting KO turbos per day (two possible outcomes 0 or =1 KO turbos).

* Significance level 5%

** Significance level 1%

Loglinear model class, likelihood ratio, p value and test of independence for the three-way tables as well as Pearson's Chi-square, Cramer's V, p value and test of independence for two-way tables are all given in Table 2. The association between variables A and B is confirmed by the test of independence, which clearly shows that dependence between these two variables exists for all stocks and is significant at the 1% level. It can be noted that Cramer's V is very

[14]In the loglinear analysis, H0 says that the model fits the data well, whereas H1 says that it does not.

high in the 2×2 tables for the variable combination A*B and that for some stocks it reaches values > 0.55 (e.g. Bwin 0.62, Erste Group Bank 0.56, Raiffeisen Bank Int. 0.59 andVerbund 0.59).

Table 2a: Analysis I: Contingency table combinations for the variables number of KO turbos, price alarm and volume alarm for 12 stocks (II)

		A*B			
		Pearson Chi-square	Cramer's V	p value	Independence at 5% or 1%
ANDRITZ	with KO c.	278.09	0.53	0.000	no**
	w/o KO c.	200.40	0.50	0.000	no**
AUSTRIAN AIRLINES	with KO c.	142.41	0.43	0.000	no**
	w/o KO c.	117.42	0.39	0.000	no**
BWIN	with KO c.	384.86	0.62	0.000	no**
	w/o KO c.	263.33	0.52	0.000	no**
CA IMMOBILIEN ANLAGEN	with KO c.	104.78	0.33	0.000	no**
	w/o KO c.	86.65	0.30	0.000	no**
ERSTE GROUP BANK	with KO c.	309.15	0.56	0.000	no**
	w/o KO c.	206.53	0.46	0.000	no**
INTERCELL	with KO c.	225.16	0.48	0.000	no**
	w/o KO c.	194.34	0.44	0.000	no**
MEINL EUROPEAN LAND	with KO c.	149.88	0.39	0.000	no**
	w/o KO c.	145.70	0.38	0.000	no**
RAIFFEISEN BANK INT.	with KO c.	342.35	0.59	0.000	no**
	w/o KO c.	221.49	0.47	0.000	no**
RHI	with KO c.	257.96	0.51	0.000	no**
	w/o KO c.	238.36	0.49	0.000	no**
VERBUND	with KO c.	345.61	0.59	0.000	no**
	w/o KO c.	228.32	0.48	0.000	no**
VOESTALPINE	with KO c.	178.67	0.42	0.000	no**
	w/o KO c.	148.27	0.39	0.000	no**
WIENER BERGER	with KO c.	263.28	0.51	0.000	no**
	w/o KO c.	205.01	0.45	0.000	no**

Note: This table shows four types of contingency tables with different combinations of the variables number of KO turbos per day (A), price alarm (B) and volume alarm (C). Variable A is given in its two forms: an extended form by counting KO turbos per day (six possible outcomes 0, 1, 2, 3, 4, = 5 KO turbos) and a short form i.e. without counting KO turbos per day (two possible outcomes 0 or =1 KO turbos).

* Significance level 5%

** Significance level 1%

This shows that the interaction between the days when a price alarm is on the down limit and when there is at least oneKO turbo is significantly strong. It is also noted that Cramer's V[15] is always higher when variable A is in its extended version, namely when the days with the number of KO turbos per day are counted. This means that variables A and B are positively associated.

[15]A concise overview of the effect sizes of association measures can be found in Cohen (1998).

Table 2b: Analysis I: Contingency table combinations for the variables number of KO turbos, price alarm and volume alarm for 12 stocks (I)					
		A*C			
		Pearson Chi-square	Cramer's V	p value	Independence at 5% or 1%
ANDRITZ	with KO c.	4.25	0.05	0.935	yes
	w/o KO c.	2.35	0.05	0.308	yes
AUSTRIAN AIRLINES	with KO c.	15.09	0.10	0.129	yes
	w/o KO c.	3.00	0.06	0.224	yes
BWIN	with KO c.	33.67	0.13	0.000	no**
	w/o KO c.	8.30	0.09	0.016	no*
CA IMMOBILIEN ANLAGEN	with KO c.	7.63	0.06	0.665	yes
	w/o KO c.	0.45	0.02	0.799	yes
ERSTE GROUP BANK	with KO c.	17.22	0.09	0.070	yes
	w/o KO c.	2.73	0.05	0.255	yes
INTERCELL	with KO c.	94.75	0.22	0.000	no**
	w/o KO c.	12.71	0.11	0.002	no**
MEINL EUROPEAN LAND	with KO c.	30.52	0.12	0.001	no**
	w/o KO c.	18.29	0.14	0.000	no**
RAIFFEISEN BANK INT.	with KO c.	17.89	0.09	0.057	yes
	w/o KO c.	11.22	0.11	0.004	no**
RHI	with KO c.	21.09	0.10	0.020	no*
	w/o KO c.	9.61	0.10	0.008	no**
VERBUND	with KO c.	35.04	0.13	0.000	no**
	w/o KO c.	7.76	0.09	0.021	no*
VOESTALPINE	with KO c.	19.50	0.10	0.034	no*
	w/o KO c.	11.63	0.11	0.003	no**
WIENER BERGER	with KO c.	15.95	0.09	0.101	yes
	w/o KO c.	5.08	0.07	0.079	yes

Note: This table shows four types of contingency tables with different combinations of the variables number of KO turbos per day (A), price alarm (B) and volume alarm (C). Variable A is given in its two forms: an extended form by counting KO turbos per day (six possible outcomes 0, 1, 2, 3, 4, = 5 KO turbos) and a short form i.e. without counting KO turbos per day (two possible outcomes 0 or =1 KO turbos).

* Significance level 5%

** Significance level 1%

As mentioned in Section 3, the most striking results among our seven types of contingency tables were obtained in the 2×2 tables for the A and B variable combination. Therefore, we analyze this type of table in more detail for Bwin. The Chi-square statistics for all stocks in the 2×2 table design are presented in Table 2a and Table 2b. For the 5% and 1% significance levels and 1 df, the theoretical values of the Chi-square distribution are 3.84 and 6.63, respectively, which are both much smaller than the empirical value of 263.33 for Bwin.

Table 3 shows the observed and expected frequencies and their deviation in percentages for the Bwin stock. If we look at the crucial variable combination, namely when the number of KO turbos is at least one and there is a price alarm on the down limit, we notice that the observed frequency is 79, meaning there are 79 days when there is at least oneKO turbo per day and when there is a price alarm on the down limit on the same day.

However, there should be only 19 days in this variable combination, or expressed in percentages, there are 324% more such days than what it should be. This percentage is far higher than it is in other variable combinations, which is an indication that it could not have happened by chance. Our explanation for this result supports the allegation of the concerned investors that the knocking out of KO turbos was performed on purpose by crashing down the prices, which

then triggered an alarm price on the down limit. However, rather than evidence,this is only a strong indication of price manipulation.

Table 2b: Analysis I: Contingency table combinations for the variables number of KO turbos, price alarm and volume alarm for 12 stocks (II)

		B*C			
		Pearson Chi-square	Cramer's V	p value	Independence at 5% or 1%
ANDRITZ	with KO c.				
	w/o KO c.	1.56	0.04	0.458	yes
AUSTRIAN AIRLINES	with KO c.				
	w/o KO c.	3.97	0.07	0.138	yes
BWIN	with KO c.				
	w/o KO c.	3.73	0.06	0.155	yes
CA IMMOBILIEN ANLAGEN	with KO c.				
	w/o KO c.	10.06	0.10	0.007	no**
ERSTE GROUP BANK	with KO c.				
	w/o KO c.	23.15	0.15	0.000	no**
INTERCELL	with KO c.				
	w/o KO c.	10.25	0.10	0.006	no**
MEINL EUROPEAN LAND	with KO c.				
	w/o KO c.	18.61	0.14	0.000	no**
RAIFFEISEN BANK INT.	with KO c.				
	w/o KO c.	13.52	0.12	0.001	no**
RHI	with KO c.				
	w/o KO c.	0.36	0.02	0.834	yes
VERBUND	with KO c.				
	w/o KO c.	12.11	0.11	0.002	no**
VOESTALPINE	with KO c.				
	w/o KO c.	12.00	0.11	0.002	no**
WIENER BERGER	with KO c.				
	w/o KO c.	5.71	0.08	0.058	yes

Note: This table shows four types of contingency tables with different combinations of the variables number of KO turbos per day (A), price alarm (B) and volume alarm (C). Variable A is given in its two forms: an extended form by counting KO turbos per day (six possible outcomes 0, 1, 2, 3, 4, = 5 KO turbos) and a short form i.e. without counting KO turbos per day (two possible outcomes 0 or =1 KO turbos).

* Significance level 5%

** Significance level 1%

Table 3: Two-way table for Bwin

	Number of KO turbos	Price alarm down limit: no	Price alarm down limit: yes	Sum
Observed Frequencies	0	800	46	846
	= 1	69	79	148
	SUM	869	125	994
Expected Frequencies	0	740	106	846
	= 1	129	19	148
	SUM	869	125	994
Deviation	0	8%	-57%	-0.49
	= 1	-47%	324%	2.78
	SUM	-39%	268%	2.29

Note: Two-way contingency table showing observed and expected frequencies for the variable combination A* B as well as their deviations and total sums for Bw

Further, variable C has to be analyzed with variables A and B separately. Regarding the interaction between variables A and C, the test of independence shows that these two variables are statistically dependent only in some cases. Very often,Cramer's V stays low, mostly around 0.1, meaning that the interaction between variables A and C is weak. Moreover, for the variable combination B*C, Cramer's Valsoremains very low, mostly < 0.2, which denotes that price and volume alarms are also weakly associated, although the test of independence does show statistical significance at 1% for some stocks. Since variable C is not a key variable in connection with variable A, it is excluded from Analyses II and III.

Table 4: Conditional probability and z test (I)

Underlying	KO turbo: no		KO turbo: yes		Sum
	Price	Price	Price	Price	
	alarm	alarm	alarm	alarm	
	down	down	down	down	
	limit: no	limit: yes	limit: no	limit: yes	
ANDRITZ	783	33	107	71	994
AUSTRIAN AIRLINES	641	67	24	35	767
BWIN	800	46	69	79	994
CA IMMOBILIEN ANLAGEN	841	84	37	32	994
ERSTE GROUP BANK	737	24	147	86	994
INTERCELL	805	71	53	65	994
MEINL EUROPEAN LAND	814	127	12	41	994
RAIFFEISEN BANK INT.	713	28	151	102	994
RHI	822	72	36	64	994
VERBUND	799	66	70	59	994
VOESTALPINE	733	21	148	92	994
WIENERBERGER	754	47	106	87	994
AVERAGE					

Table 4: Conditional probability and z test (II)

Underlying	Conditional	z	p value	Significance	
	probability			level = 5%	
	P(Alarm/KO)				
				H0:	H1:
				p1 = p2	p1 < p2
ANDRITZ	39.89%	1.684	0.046		x
AUSTRIAN AIRLINES	59.32%	2.112	0.983	x	
BWIN	53.38%	1.919	0.972	x	
CA IMMOBILIEN ANLAGEN	46.38%	0.089	0.535	x	
ERSTE GROUP BANK	36.91%	2.940	0.002		x
INTERCELL	55.08%	2.083	0.981	x	
MEINL EUROPEAN LAND	77.36%	4.673	1.000	x	
RAIFFEISEN BANK INT.	40.32%	1.909	0.028		x
RHI	64.00%	3.749	1.000	x	
VERBUND	45.74%	0.028	0.489	x	
VOESTALPINE	38.33%	2.515	0.006		x
WIENERBERGER	45.08%	0.229	0.409	x	
AVERAGE	45.85%				

Note: This table shows the P(Alarm/KO) for each stock, z test of equality between the two proportions, p values and results about the hypotheses. Stocks whose p1 is bigger than p2 have a higher possibility of having been manipulated since their P(Alarm/KO) is higher than the P(Alarm/KO) of the rest of the stocks in the group.

4.2. **Searching for Manipulated Stocks.** The results of the z test of equality between the two proportions are shown in Table 4. The null hypothesis asserts that the conditional probability (P(Alarm/KO)) of a stock p1 is higher than the P(Alarm/KO) of the rest of the stocks p2 and is accepted by the following stocks Austrian Airlines, Bwin, CA Immobilien Anlagen, Intercell, Meinl European Land, RHI, Verbund and Wienerberger. We define these stocks as manipulated stocks in the period 2nd January 2007 until 31st December 2010 on the Vienna Stock Exchange. Manipulated stocks are signaled by bold letters. However, we must emphasize that these results are not evidence of manipulation but rather an indication.

4.3. **Searching for Suspicious Issuers.** In this subsection, we summarize the results of Analysis II and Analysis III in order to ascertain conclusive results regarding suspicious issuers for Bwin. The results for other suspicious underlyings are presented at the end of this subsection.

Before beginning with the numerical analysis of each suspicious issuer, we look at the graphical presentation of the average mean reversion rate of all KO turbos with minimal barriers for all issuers together on days when a price alarm is on the down limit. At first glance, the mean reversion rate in the period three hours after the KO event reaches the same level as it had three hours before, which is an indication that price manipulation happened. Moreover, the lower part of the Figure 2 shows that the KO event was triggered by very small order sizes, whereas in the time interval three hours before and three hours after order sizes were much higher, which shows that price manipulation was mostly performed with very small orders.

At this point, we also look at the histograms containing the exact KO time of death. According to the concerned investors, KO events used to happen at particular times of the day. However, the Kolmogorov–Smirnoff test does not show any significant difference in the distribution of the KO times of death. This is due to the very small samples s1 of a particular issuer. Becausethe Kolmogorov–Smirnoff or any other statistical test loses test power, it is not possible to examine the KO times of death. However,a visual inspection of the histograms (Figure 3) shows that on days when a price alarm is on the down limit there is a larger accumulation of KO turbos at the beginning of the day from 9:15 until 9:45 a.m. and at the end of the working day from 4:45 until 5 p.m.

Table 5a contains the observed and expected frequencies and elimination measures,while Table 5b contains the Chi-squares statistics and critical values at a 95% confidence level. The Chi-square statistics for the Bwin stock is 46.14, whereas the critical value is 36.42, meaning that the table is heterogeneous. Issuers under the codes 432, 581, 803 and 525 have positive elimination measures,which defines them as suspicious issuers in the first step of the analysis.

Table 5a: Observed and expected frequencies (I)

BWIN	Observed					Elimination Measure:
	Price alarm down limit: no		Price alarm down limit: yes			Deviation in %
Issuers	Min Barrier: no	Min Barrier: yes	Min Barrier: no	Min Barrier: yes	Sum	
225	8	10	19	7	44	-26%
371	8	1	12	5	26	-10%
432	3	1	8	7	19	72%
438	0	0	3	1	4	
525	24	35	20	25	104	12%
581	5	2	10	7	24	36%
584	2	0	0	0	2	
613	13	9	21	6	49	-43%
803	9	5	19	13	46	32%
901	7	17	8	5	37	-37%
Sum	79	80	120	76	355	

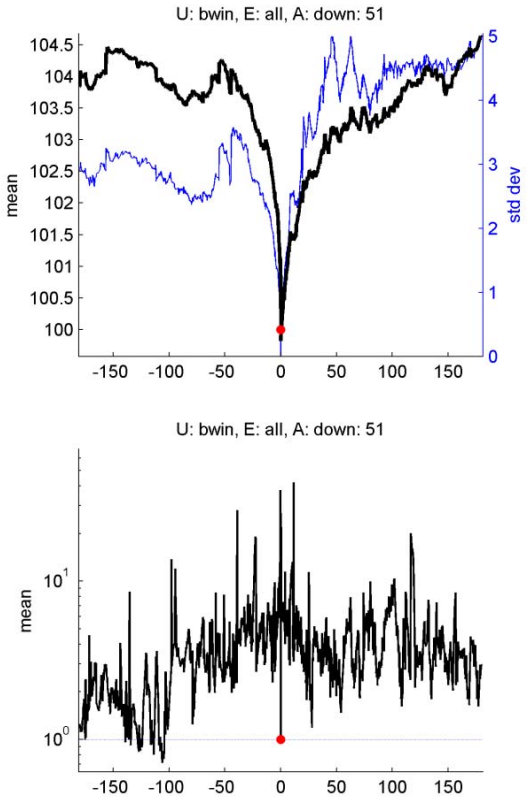

FIGURE 2. Aggregation of KO turbos, all issuers together, price alarm days.

Note: The first row of this figure shows the aggregated price indices for days when a price alarm is on the down limit. The left axis measures the mean (bold black line) and the right axis measures the standard deviation (thin blue line) of these price indices. The red point signifies the KO event for all KO turbos with the minimal barrier of the day, normalized at the price of 100 EUR and at 0 as the exact KO time of death. The upper part shows the mean reversion of 104.5 EUR, whereas the lower part shows the standardized volume. The red point signifies the standardized KO Order Size byKO Second.

Table 5a: Observed and expected frequencies (II)

BWIN	Expected					Elimination Measure:
	Price alarm down limit: no		Price alarm down limit: yes			Deviation in %
Issuers	Min Barrier: no	Min Barrier: yes	Min Barrier: no	Min Barrier: yes	Sum	
225	10	10	15	9	44	-26%
371	6	6	9	6	26	-10%
432	4	4	6	4	19	72%
438	1	1	1	1	4	
525	23	23	35	22	104	12%
581	5	5	8	5	24	36%
584	0	0	1	0	2	
613	11	11	17	10	49	-43%
803	10	10	16	10	46	32%
901	8	8	13	8	37	-37%
Sum	79	80	120	76	355	

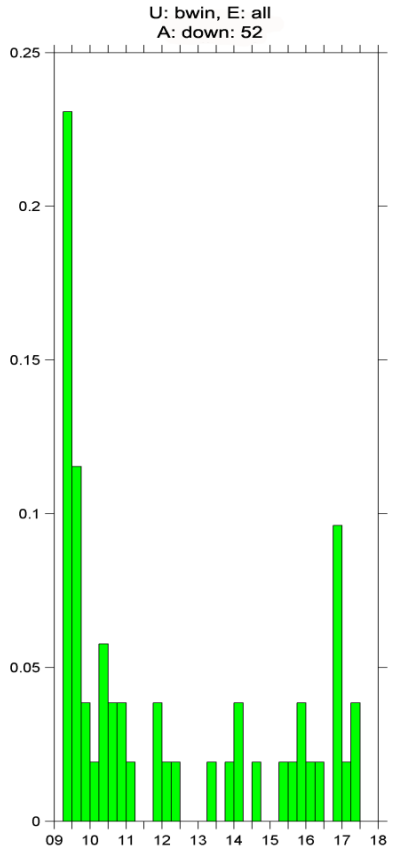

FIGURE 3. Relative frequencies of the KO times of death between 9 a.m. and 6 p.m. on the Bwin stock, all issuers, price alarm days

Note: The elimination measure represents positive deviations in terms of the percentage between the observed and expected frequencies if the expected frequency in the variable combination with a price alarm on the down limit (yes) and min barrier (yes) is bigger than three. Issuers with positive elimination measures are defined as suspicious (signaled in gray).

Table 5b: Chi-square statistics for Bwin

BWIN	Chi-square value	Critical Value at 95%	Homogeneous yes/no
all issuers	49.94	34.41	no
w/o 432	43.56	32.67	no
w/o 581	38.80	28.87	no
w/o 803	30.36	25.00	no
w/o 525	19.06	21.03	yes

Note: This table shows the Chi-square statistics at the beginning of the elimination process for all issuers together as well as its values after the stepwise elimination of each suspicious issuer and the critical values until the table reaches homogeneity.

Issuer 432: has the highest elimination measure, i.e. a positive deviation of 72%, and thus it is first to be eliminated from Table 5a. In other words, the number of KO turbos in the variable combination a price alarm on the down limit (yes) and KO turbo is the turbo with the minimal barrier on theKO turbo day (yes) for issuer 432 is 7 even though it should only be 4[16]. After the elimination of issuer 432, the Chi-square statistics declines to 43.56 (Table 5b),

[16]The expected frequencies of KO turbos are always rounded up to the nearest integer since the turbo certificate cannot be in a decimal form.

but this is still not enough for the table to reach homogeneity because the critical value fell to 32.67[17]. The next step is to see whether the Bwin stock has a significant mean reversion rate. Table 6 contains the average values of the mean reversion rates for all KO turbos with minimal barriers issued by one specific issuer and the p values resulting from Welch's test combinations. Issuer 432 also has a very high mean reversion rate of 7.16% on KO turbo days when a price alarm is on the down limit. Although this is not significantly different from the average mean reversion rate of the remaining issuers, it is much higher than the average mean reversion rate of all issuers together (4.75%). This issuer is also twice a single outlier (Table 7) with 16.1% and 10.2% single mean reversion rates. Owing to the highest elimination measure, a very high average mean reversion rate on KO turbo days when a price alarm is on the down limitand two outliers in Table 7, we define issuer 432 as highly suspicious.

Table 6: Mean reversion for Bwin

BWIN	Issuers	Price alarm down limit: no		Price alarm down limit: yes		Welch's test
Key Figure		Mean	Welch's test against all other issuers	Mean	Welch's test against all other issuers	price alarm no vs. yes
			p value		p value	
Mean Reversion	225	2.28%	0.594	5.77%	0.419	0.040*
	371	n.a.	n.a.	5.62%	0.809	n.a.
	432	n.a.	n.a.	7.16%	0.276	n.a.
	525	2.37%	0.718	4.18%	0.586	0.216
	581	n.a.	n.a.	2.48%	0.001**	n.a.
	613	5.05%	0.010**	7.25%	0.338	0.434
	803	1.80%	0.464	3.64%	0.161	0.166
	all	2.52%		4.75%		

Note: n.a. stands for those situations when there is only one KO turbo in a sample, meaning that Welch's test statistics could not be calculated. The dark shadowed cells show that the mean of the corresponding issuer is significantly bigger than the mean of the rest of the issuers in the group, whereas the light shadowed cells show the opposite.

* Significant at 5% ** Significant at 1%

Table 7: Top Ten for Bwin

Issuer	KO Day	KO Time	Price Alarm Down Limit	KO Order Size/ Average Order Size of the Day	Low Price/ Min Barrier	Mean Reversion
525	Feb.28, 2007	09:27:49	Yes	38,0%	96,1%	18,5%
613	Jan.22, 2008	09:23:37	Yes	7,0%	100,0%	16,1%
371	Jan.22, 2008	09:23:37	Yes	7,0%	100,0%	16,1%
432	Jan.22, 2008	09:23:37	Yes	7,0%	100,0%	16,1%
525	Aug.08, 2007	10:17:26	Yes	4,0%	99,0%	11,9%
432	Oct.08, 2008	10:07:22	Yes	458,0%	100,0%	10,2%
803	Jul.03, 2008	14:31:07	Yes	14,0%	99,6%	8,3%
225	Aug.21, 2008	09:33:37	Yes	9,0%	99,7%	7,5%
803	Nov.22, 2007	10:21:56	Yes	1,0%	99,8%	7,3%
613	Mar.14, 2007	09:22:50	Yes	2651,0%	92,7%	6,9%

Note: This table contains the 10 turbo certificates with the highest mean reversion rates after the KO event. It includes the coded issuer, date and exact time of the KO turbo and whether there is a price alarm on that KO turbo day or not as well as two other key figures: KO Order Size/Average Order Size of the Day and Low Price/Min Barrier.

Following the numerical part of the analysis for issuer 432, we present a graphical presentation (Figure 4) of the average mean reversion rate and standard deviation for KO turbos with minimal barriers on days when a price alarm is on the down limit.

[17]After the elimination of an issuer, the df of the table change because each issuer represents one row in the contingency table. In order not to lose possible suspicious issuers, we state that the expected frequency in each cell must be larger than 3 ($f_e > 3$) in order to be accountable in the Chi-square test calculation.

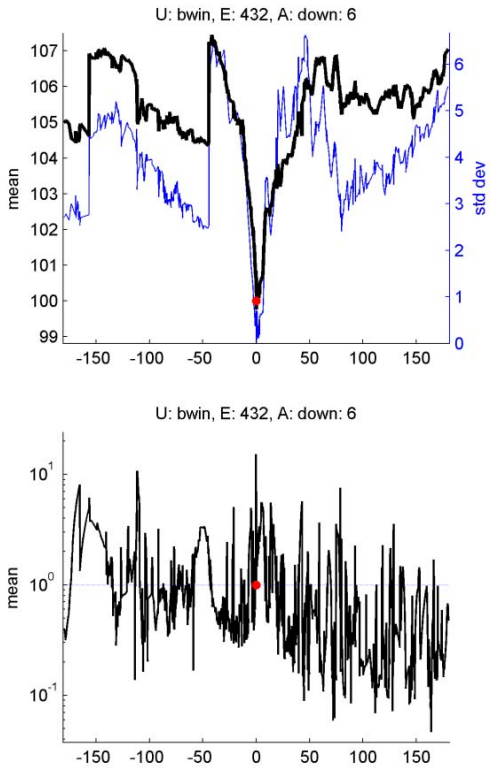

FIGURE 4. KO turbos on Bwin, issuer 432, price alarm days. Note: The upper part of this figure shows the average mean reversion rate of KO turbos with the minimal barrier of the day issued by issuer 432. Although this issuer has the highest mean reversion rate among all issuers on the Bwin stock (at the point +3h, it reaches almost 107 EUR), its volume pattern is not that clear and thus we cannot conclude that issuer 432 performed manipulation by very small order sizes.

Issuer 581: In the next step, issuer 581 has to be eliminated because it has the second highest elimination measure of 36%. The observed number of KO turbos in the above-mentioned variable combination is 7, whereas the expected number of KO turbos is only 5. The Chi-square statistics declines to 38.80, but the table has still not reached homogeneity because the critical value is 28.86. The second suspicious issuer from Analysis II is issuer 581. However, this issuer does not have significant average mean reversion rates nor are those rates higher than the average mean reversion rates of all issuers together. Further, it has no KO turbo outlier in Table 7. Therefore, we define issuer 581 as rather unsuspicious.

Issuer 803:Further, we eliminate the issuer with the third highest elimination measure of 32%, i.e. issuer 803. This issuer has mean reversion rates of 1.80% on days when there is no price alarm and of 3.64% on days when there is a price alarm. These are both lower than the average mean reversion rates on these days (2.52% and 4.75%, respectively). However, this issuer appears twice in Table 7 with 8.3% and 7.3% single outlier rates. According to these facts, we define issuer 803 as moderately suspicious. Further, after the elimination of issuer 803, the Chi-square statistics of the table falls to 30.36, which is still not enough to reach homogeneity because the critical value is now only 25.00, implying that the elimination process has to be continued.Although the results of the Kolmogorov–Smirnoff test did not reach statistical significance, some patterns in the distribution of the KO times of death can

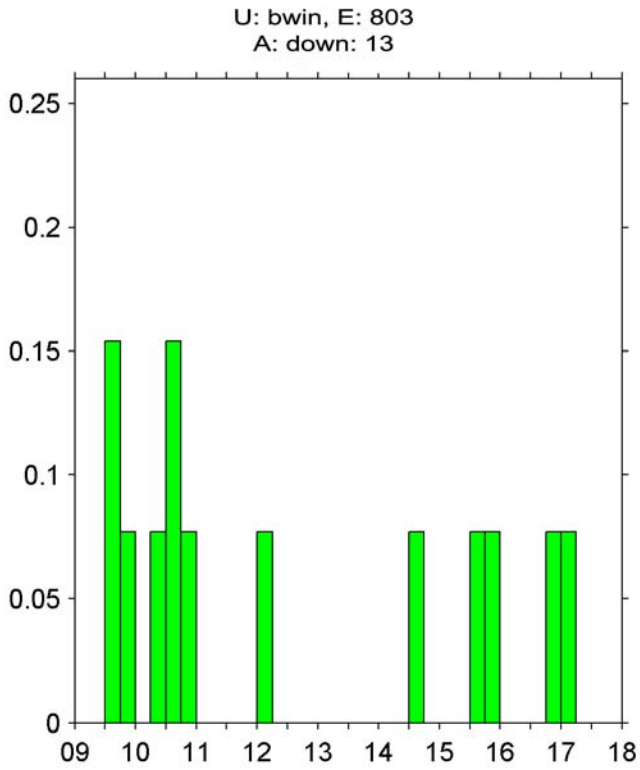

FIGURE 5. Relative frequencies of the KO times of death between 9 a.m. and 6 p.m. on the Bwin stock, issuer 803, price alarm days

be noted. For issuer 803, most knockouts happened in the periods 9:30–9:45 a.m. and 10:30–l 10:45 a.m.,while about 15% happened in the periods 3:30–4 p.m. and about 7.5% in 4:45–5:15 p.m., which is more than in the same time periods for all issuers together (Figure 5). With the exception of the beginning of the day, where the percentage of the KO times of death reaches about 23% until 9:45 a.m., the KO times of death remain equally distributed during the rest of the day with a percentage of about 4% in almost each quarter of an hour.

Issuer 525: We are now left with the last suspicious issuer from Analysis II, namely issuer 525, which has the fourth highest elimination measure. Similar to issuer 803, this issuer has no statistically significant mean reversion rates, having 2.37% on KO turbo days when there is no price alarm and 4.18% on KO turbo days when there is a price alarm (these are lower than the average mean reversion rates for the group of 2.52% and 4.75%). Issuer 525 also appears twice in Table 7 with 18.5% and 11.9% single mean reversion rates. Accordingly, we classify issuer 525 as moderately suspicious.However, we must make a slight distinction between issuers 803 and 525. Although they both have similar general characteristics, issuer 525 has higher mean reversion rates (2.37% and 4.18%) than issuer 803 (1.80% and 3.64%). The same pattern can be noted in Table 7, where issuer 525 has much higher single outliers (18.5% and 11.9%) than issuer 803 (8.3% and 7.3%). Owing to these differences between issuers 803 and 525, we characterize issuer 525 as more suspicious than issuer 803, although both of them are moderately suspicious. Finally, after the elimination of issuer 525 from Table 5a, the table reaches homogeneity with

the Chi-square statistics of 19.06 and a critical value of 21.07. Thus, since the table has reached homogeneity, we stop the elimination process.

Issuer 613: Although issuer 613 was not found to be suspicious in Analysis II, it has however the highest mean reversion rates among all issuers (5.05% on KO turbo days when there is no price alarm on the down limit and 7.25% on KO turbo days when there is a price alarm on the down limit). The rate of 5.05% is significantly different at the 5% significance level from the mean reversion rate of the rest of the issuers in the group on days when there is no price alarm. Issuer 613 also has one outlier in Table 7 of 6.9%. These characteristics define issuer 613 as moderately suspicious.

To summarize, the suspicious issuers from Analyses II and III are 432, which we find to be highly suspicious, and 525, 803 and 613, which are moderately suspicious. Issuer 581 is rather unsuspicious. Regarding the rest of the issuers 225, 371, 438, 584 and 901, we conclude that they are not suspicious because they show no suspicion in Analyses II and III.

The same procedure was carried out for the other eight stocks. The results are shown in Table 8. It is clear that some issuers show up as more suspicious than others. Issuer 225 is recognized as highly suspicious twice, as moderately suspicious three times and as rather unsuspiciousonce. Issuer 432 is rated as highly suspicious,moderately suspicious and rather unsuspicious twice each. Issuer 581 issuspicious and highly suspicious once each and rather unsuspicious three times. Further, issuer 371 is classified as being highly suspiciousonce, moderatelysuspicious once and less suspicious twice. Issuers 803, 525 and 613 are classified as moderately suspicious as their highest levels of suspiciousness. Issuer 803 shows up as rather unsuspicious once. Issuer 525 is rated as moderately suspicious, less suspicious and rather unsuspicious twice each. Furthermore, issuer 613 is classified as moderately suspicious once and rather unsuspicious twice. Finally, issuer 438 is found to be less suspicious once and rather unsuspicious twice.

Table 8: Classification of all issuers

Underlying	Suspiciousness Rating				Unrated due to the low
	Highly	Moderately	Less	Rather	number of KO turbos
	suspicious	suspicious	suspicious	unsuspicious	
AUSTRIAN AIRLINES	225		525, 371		432, 438, 581, 613, 803
BWIN	432	803, 525, 613		581	225, 371, 438
CA IMMOBILIEN ANLAGEN			525, 371	432, 803	225, 438, 581, 613
INTERCELL	581	803, 432, 225		371	525, 438, 613
MEINL EUROPEAN LAND	225			438, 432	371, 525, 581, 613, 803
RHI		371, 525, 225			225, 432, 438 581, 613
VERBUND	432	225		581, 371, 438, 525, 613	803
WIENERBERGER	371	432	438	581, 225, 525, 613	803

Note: This table shows the results for the eight stocks that were analyzed in all the research. Issuers for which we could not specify the level of suspiciousness by certain stocks due to the low number of KO turbos are listed in last column. For the stock Meinl European Land, the conclusive results are carried out only according to Analysis II because of missing tick data.

5. Conclusion

Based upon the asserted turbo scandal case at the Vienna Stock Exchange, we set up and test models and hypotheses using different mathematical and statistical methods. We divide our research into three parts: two daily analyses and one intraday analysis. First, we investigate which variables are crucial for the research and find out that a KO event is connected to a price alarm, whereas a volume alarm, in most cases, is irrelevant. Further, the second analysis incorporates the search for actually manipulated stocks. By applying the z test of equality between two proportions, we find that eight out of 12 stocks mentioned in the statement of the Vereinfur Finanzmarktausgleich were indeed manipulated. In the second analysis, we use the Chi-square test of homogeneity in combination with an elimination measure to detect suspicious

issuers from contingency tables. Moreover, the intraday analysis shows the investigation of price and volume indices upon which we construct key figures. The most striking results are derived by the key figure maximal mean reversion rate in the period three hours after the KO event. Another important key figure, which also supported detecting suspicious issuers, is the proportion of KO Order Size to the Average Order Size of the Day.For some stocks, especially for particular issuers, this figure fully supports the rumors that turbo certificates have been knocked out by very small order sizes. However, we do not find either evidence or indications thatknocking out was performed atspecific times of the day.

Our results deliver strong indications that there exists reasonable suspiciousness that in the period 2nd January 2007 until 31st December 2010 on the Vienna Stock Exchange price manipulation was performed on certain stocks by crashing down their prices in order to knock out turbo certificates. Further, this research makes two important contributions. The first one is to the scientific literature because papers on price manipulation based on empirical cases are rare and tend to tackle the problem of price manipulation using different methodologies. The second one is to the financial market authorities because the methodology we suggest in our work for detecting manipulated underlyings and supposed manipulators isadjustable to all financial markets.

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