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Market efficiency under ad hoc information: evidence from Germany

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Abstract This paper focuses on how ad hoc disclosures affect German stock market efficiency. An event study based on absolute abnormal returns and regression analyses is conducted to investigate markets not only on event day, but also prior to and after the issuance of ad hoc information. Event-day reactions are found to depend on index affiliation, market uncertainty, disclosure periodicity, and the informativeness of the disclosure. Although reacting very efficiently in the post-event period, market prices are subject to adjustment several days after disclosure. The most important finding is that information related to periodic reports diffuses into the market prior to report issuance.

Keywords Market efficiency · Stock price adjustment · Ad hoc disclosure

JEL Classification G14 · G18 · K22

1 Introduction

In an attempt to increase market efficiency and reduce insider conflicts, the German government introduced mandatory disclosure requirements for all publicly traded companies in the country. Thus, ever since 1995, all market participants in Germany have

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been required to immediately publish all information that has the potential to significantly affect the stock market and the confidentiality of which cannot be guaranteed. Although this regulation has been investigated with regard to its general market impact on a daily basis (Oerke 1999; Roeder 2000), as well as with regard to intraday market reactions (Roeder 2002; Muntermann and Guettler 2007), there is to date no comprehensive study of the regulation's impact on market efficiency. Moreover, the extant research focuses entirely on the particular event day, and does not study surrounding intervals. Thus, to provide a more detailed understanding of the market impact of ad hoc disclosures and the efficiency gains induced thereby, this paper leverages a comprehensive sample spanning an 11-year window from 2000 to 2011 and analyzes an interval of 21 days around disclosure publication. Abnormal returns for the event study are calculated on a daily basis using market data from the Frankfurt Stock Exchange (FSE).

The approach distinguishes between all relevant market indices, controls for possible anticipation effects due to ad hoc disclosures issued in the run-up to periodic reports, and clarifies whether disclosures hitting the market intra-daily produce different effects than those issued in off-trading hours. The analysis is expanded to investigate whether reluctant market adjustment is the reason for the generation of economically significant excess returns. A regression model delivers insight into the driving forces of market adjustment and finds it related to market uncertainty and the informativeness of the disclosure. The most important finding is that market prices tend to react prior to the release of expected periodic reports, thus evidencing an information asymmetry that is subsequently smoothed via ad hoc disclosures. These results imply that to work as intended, ad hoc disclosures related to periodic reports would, on average, need to be issued 1 day earlier.

Following a common legal interpretation (the legislation itself does not specify when information is sufficiently important), ad hoc disclosures must be issued when share price changes of 2 % (for DAX companies) and 5 % (for second-tier stocks) are reasonably expected (Oerke 1999; Roeder 2000). These thresholds drove the number of issued disclosures especially in the early 2000s, but even in 2011, companies issued more than 2000 announcements. Aside from requiring the disclosure of significant, relevant, and immediate information, the legislation is vague in terms of form and content. Companies are free to write these disclosures in almost any style, making a reasonable ex ante anticipation of the disclosures' effects impossible. This paper accounts for this by employing the well-established event study methodology first suggested by Fama et al. (1969) adapted according to a suggestion of Carter and Soo (1999), thus allowing joint examination of disclosures containing different information content through the calculation of unsigned abnormal returns. The testable sample, which was obtained from the Deutsche Gesellschaft fuer Ad hoc-Publizitaet (DGAP), even after all refinement measures consists of 4703 disclosures within the FSE Prime Standard segment.[1] Abnormal market reactions are computed by applying daily trad-

[1] The Prime Standard segment contains German market participants that follow international standards. Prime Standard membership is a key requirement for admittance to any of the four prominent indices, DAX, MDAX, SDAX and TecDAX. As the Prime Standard did not exist before January 1, 2003, the Official Market (Amtlicher Markt) is used as its closest equivalent during the period from 2000 to 2002.

ing data obtained from the Karlsruher Kapitalmarktdatenbank, which is Germany's most comprehensive stock market database.

The rest of the paper is structured as follows. Section 2 provides a review of the extant literature and introduces the study's hypotheses. Section 3 contains summary statistics of the sample composition and explains the methodological approaches. Empirical results are discussed in Sect. 4; Sect. 5 concludes.

2 Review of the literature and research hypotheses

There is a great deal of research into the ramifications for market efficiency of mandatory or voluntary announcements. For example, Fama et al. (1969) found that markets rapidly incorporate new information delivered by stock split announcements. Pettit (1972) finds the US market reasonably efficient in reacting to new information provided by dividend announcements. Pettit also reports small anticipation effects but concludes that they are negligible. Aharony and Swary (1980) include earnings announcements in their analysis of dividend announcements and find that both types of announcement enhance market efficiency. Patell and Wolfson (1984) assess intraday stock returns for the US market. Apart from indications of in-advance reactions, they find that most of the price adjustment occurs within the first 5 min after the announcement. Unlagged market response to dividend announcements is also reported by Eades et al. (1985). Jennings and Starks (1985) find significantly different reactions depending on the information content of the disclosure; they find a longer lasting adjustment process for disclosures associated with higher information content. Woodruff and Senchack (1988) find that intra-day price adjustments to earnings announcements, while not instantaneous, are very rapid. However, despite the rapid reaction, new prices are not determined within one trading day.

Gosnell et al. (1996) focus on the effects of dividend announcements on intraday data and find significant reactions in both market prices and traded volume. Tracking differences between positive and negative announcements shows that positive information seems to be anticipated by the market, leading to this sort of information having a weaker market impact than negative surprises. In addition to finding anticipation effects prior to dividend announcements, Bajaj and Vijh (1995) report that stronger price and volume adjustment is negatively related to firm size. Further evidence for the different effects of positive and negative information and their immediate market reactions is provided by Michaely et al. (1995).

The aforementioned studies have studied market efficiency by measuring the price adjustment induced by various types of disclosure instruments (stock split announcements, earnings and dividend announcements, etc.), thereby taking for granted the market relevance of these announcements. In contrast, the US accounting literature scrutinizes the particular characteristics and informativeness of specific publications.

Of those, SEC Form 8-K and the 10-Q and 10-K reports are the closest US equivalent to the German Ad Hoc Disclosure Legislation. Carter and Soo (1999) investigate the daily market price effect induced by a large sample of Form 8-Ks and find only a reluctant response to information arrival, suggesting that there may be more timely sources of information.[2] The report's overall informativeness is related to timeliness, firm size, and index affiliation. Griffin (2003) concentrates on daily market reactions to SEC 10-K and SEC 10-Q forms filed on EDGAR.[3] Stock markets are found to be sensitive to both filing types, albeit they react more abnormally to the annual 10-K. Market reactions do not appear to be completed within 1 day of the disclosure, but remain persistent for at least 2 days after. Notably, markets do not tend to react prior to the event. Furthermore, when compared to pre-EDGAR periods, the electronic filing seems to significantly speed up market adjustment. Asthana and Balsam (2001) compare daily market reactions to pre- and post-EDGAR 10-K filings. They find that the market reacts more strongly to filings in the EDGAR period and conclude that mandatory electronic filings significantly enhance market efficiency. Li and Ramesh (2009) target 10-K and 10-Q EDGAR filings and control for concurrent earnings releases. They find that significant price and volume reactions are observed only when reports include earnings announcements new to the market. Except for 10-K filings, the authors find no significant market reaction to filings that followed an earnings announcement.

In one of the first studies of the German Ad Hoc Disclosure Legislation, Roeder (2000) quantifies the average price reaction attributable to ad hoc disclosures at roughly 2 %. The study concentrates on daily stock returns and contains disclosures from the middle of 1996 to the middle of 1997. Market reactions are found to be significantly stronger for second-tier stocks than for blue chips and seem to be related to information content. In a consecutive intra-day study, Roeder (2002) focuses on distinct information content and index affiliation of ad hoc disclosures and analyzes trading volumes around an event window of 30 min prior and 60 min after the announcement. He finds that stocks react conditional on the respective index and also finds significantly different price effects for positive and negative information content. Guettler (2005) shows that many companies active in the new economy of the early 2000s misused ad hoc disclosures for public relations and advertising, whereas DAX companies met the disclosure requirements in the way intended by the lawmakers. Negative announcements tend to be issued with delay while positive information reaches the public almost instantly. Muntermann and Guettler (2007) employ a sample of 160 ad hoc disclosures and find significantly abnormal returns and trading volume immediately after information dissemination. They do not discover any price reactions prior to the announcements, but cannot definitely rule out that these do occur. Conditional on the index to which the security belongs, their time-dependent assessment finds that the adjustment process is completed after 10 trades or 30 min. They also find supporting evidence for the hypothesis that the larger the company, the less severe the market effect. Baule and Tallau (2012) report significant market reaction to ad hoc disclosures as well as to periodic reports. Ad hoc disclosures seem to provoke a stronger market reaction, but do not completely compensate for periodic reports. The

[2] In 1999, the Form 8-K Report had to be issued within 15 calendar days. In 2004, the SEC tightened the regulation to require disclosures to be issued within 4 days.

[3] 10-K and 10-Q reports deviate from 8-K filings by their periodic character. 10-K filings subsume annual reports, whereas the 10-Q form provides information on a quarterly basis. EDGAR is the electronic data-gathering, analysis, and retrieval system of the SEC, introduced in 1996.

reports still contain market-relevant information even when they are preceded by an ad hoc disclosure.

2.1 Research hypotheses

This paper adds to the body of evidence on the efficiency effects of the German Ad Hoc Disclosure Legislation. Since it is based on the premise that there should be a price change of at least 2 % on the day of publication, the effect should be detectable in the data. The first set of hypotheses, mainly reassessing the evidence produced by Roeder (2000, 2002) and Muntermann and Guettler (2007) on a broader sample basis, is thus as follows:

- $H_0 1a$ The average absolute price change is not above 2 %.
- $H_0 1b$ Market prices do not react abnormally on the day of disclosure.

Further, the study investigates whether the effects of ad hoc disclosures can be differentiated based on the issuing firm being a member of one of the prominent indices (DAX, MDAX, SDAX, or TecDAX), market depth (trading volume), the disclosure being related to a subsequent periodic report (periodically triggered or non-periodically triggered ad hoc disclosures[4]), the disclosure being published intradaily (published from 09:00 to 19:00[5]) or the informativeness of the disclosure (measured as number of trading days between an ad hoc disclosure and the previous ad hoc disclosure issued by the same firm). The corresponding hypothesis is as follows:

- $H_0 1c$ The event-day returns do not depend on index affiliation, market depth, periodicity, disclosure timing, or informativeness.

Several studies report pre-event market reactions to, for example, dividend announcements in the United States (Pettit 1972; Bajaj and Vijh 1995) and German ad hoc disclosures related to periodic reports (Baule and Tallau 2012). However, the existing evidence is not consistent and there is no consensus on whether pre-announcement price reactions occur on the German stock market. The sample used in this paper provides a unique opportunity to make a comprehensive analysis of those elusive effects as ad hoc information in its ideal form is by definition unexpected. Hence, there should not be any abnormal price effects before the event day and this should be true even when controlling for index affiliation or disclosure periodicity. It is well established that measuring these phenomena is difficult due to elevated volatility in the disclosure run-up. Research by Beaver (1968), Patell and Wolfson (1979) and Kalay and

[4] In addition to the requirement to issue ad hoc disclosures, companies traded on the German stock market are also mandated to issue periodic financial reports. These periodic reports (e.g., annual and quarterly financial reports, preliminary earnings figures, etc.) are usually published during a fixed and foreseeable period within the respective company's financial year. For instance, for companies whose fiscal year ends in December, the most common time for presenting the annual report is at the end of February/beginning of March in the following year. The completion of such a periodic report usually triggers the issuance of an ad hoc disclosure of the report's most important parts and information. The report itself is then issued in much greater detail during the annual press conference a few hours or days later. In this paper, a disclosure whose issuance has been triggered by an upcoming periodic report is referred to as a "periodic" ad hoc disclosure.

[5] The German market is open from 09:00 to 20:00; however, we exclude the last trading hour from the analysis for methodological reasons.

Loewenstein (1985) shows that market prices are subject to elevated volatility around informative events. We account for this through the specification of a suitable regression model able to control for market uncertainty. In addition, we use the volatility robust Corrado (1989) test statistic to test the results of the event study for statistical significance. The testable pre-event hypothesis is as follows:

- H_0*2a* There is no statistically significant abnormal market behavior in the 10 days pre-event time window, even when controlling for index affiliation and disclosure periodicity.

Depending on the amount of volatility during the disclosure run-up, it may well be that even the Corrado (1989) test statistic (although robust to elevated return variance) falsely supports statistically significant results. If so, the test will capture only return noise and thus not provide any useful information. Therefore, an abnormal return measure calculated for a pre-event period should have no explicative power with respect to event-day returns. A regression calculated with pre-event abnormal returns as the explaining variable for post-event returns thus should not yield significant coefficients, even if the regression controls for elevated return variance. The corresponding hypothesis is as follows:

- H_0*2b* Pre-event abnormal returns have no explicative power for post-event abnormal returns, even when the underlying regression controls for market uncertainty.

The final step of the analysis examines German market efficiency with respect to post-announcement adjustment capability. A semi-efficient market, as defined by Fama (1970), should experience adjustment effects only on the event date, not on the following days. Ideally, new information should be incorporated almost instantaneously. This idea is in conflict with the findings of Woodruff and Senchack (1988), Michaely et al. (1995), Griffin (2003) and also those of Baule and Tallau (2012), all of whom report significant market adjustment days after the informative event. To discover whether there is, and if so, the size of, post-announcement drift on the German market, the testable hypotheses with respect to the post-event markets are as follows:

- H_0*3a* There are no statistically significant abnormal returns in the 10-day post-event time window.

Although their very name suggests the opposite, it is not unthinkable that ad hoc disclosures might be of a periodic nature. Indeed, some ad hoc disclosures typically communicate key figures from upcoming periodic reports a few hours or days in advance of the scheduled reports and, therefore, may be largely anticipated. In such cases, the full periodic report is then delivered and explained in detail, for example, during a press conference. Therefore, it may be hypothesized that the market needs considerably more time to achieve a new market equilibrium in the aftermath of periodically triggered ad hoc disclosures compared to the time required after completely unpredictable announcements. This would be because even though the disclosures foretell the most important information contained in the periodic reports, there is still a great deal of market-relevant information in the reports themselves (as found by Griffin (2003) for the United States and by Baule and Tallau (2012) for Germany). Moreover, index membership may play role in the adjustment speed, as stocks of index constituents are usually more liquid than those of non-constituents. The corresponding hypothesis, therefore, is as follows:

- $H_0 3b$ The length of the adjustment process does not depend on index affiliation.

Standardized mean-corrected absolute abnormal returns are calculated to discover the prevalence of abnormal market reactions. While this measure is perfectly specified to detect market reactions of unknown sign, its interpretation in terms of economic significance is not straightforward. To decide whether statistically significant post-event abnormal returns are also economically significant, buy-and-hold returns for the period after disclosure publication are calculated in addition to the abnormal return measure. Further, it is conceivable that the highest event-day price reactions following disclosures with the highest informational value permit particular economic exploitation. Therefore, the analysis looks into whether the degree of disclosure impact (i.e., the size of the effect on the event day) has any influence on the excess return generation potential. Hence, it is hypothesized:

- $H_0 3c$ There are no economically significant excess return patterns in the 10-day post-event time window even after accounting for index affiliation and disclosure impact on the event day.

3 Data and methodology

The DGAP database provided the initial sample of 11,886 distinct ad hoc disclosures (the full database is larger, containing redundant duplicates in English and other languages). The DGAP is a private company, originally established by Deutsche Boerse Group, Reuters, and VWD. It specializes in the law-conforming dissemination of ad hoc disclosures and is the clear market leader with more than 77.5 % of total disclosures in 2011 issued by it. Covering the period from January 1st 2000 to December 31st 2011, the sample includes a cross section of all companies listed on the German stock market in Frankfurt. The following refinements made the sample appropriate for assessment. As the most prominent German stock market in Frankfurt is the focus of the analysis, disclosures issued by companies not listed on the FSE were dropped from the sample. Second, issuers that at announcement time were not part of the FSE Prime Standard segment were removed from the sample. This measure was necessary because the analysis requires a consistent and clean sample, containing liquid stocks of companies complying with international transparency standards, and is responsible for most exclusions. Then, those disclosures were dropped that had a preceding ad hoc disclosure during a 10-day period before and/or a subsequent one in 10-day period after, as some distance from concurrent events in the 21-day analysis window is required. The last sample refinement was the exclusion of disclosures published between 19:00 and the close of the exchange at 20:00 so as to ensure that no abnormal stock returns are carried over to the following trading day. We exclude only the final hour because Muntermann and Guettler (2007) show that intraday price reactions are, on average, completed within 30 min. These refinements result in a sample of 4703 ad hoc disclosures.

Table 1 provides a comprehensive overview of the composition of the adjusted sample. The table shows the sample composition with respect to the disclosure issuer

Table 1 Total Prime Standard sample by index

Index	# of disclosures
DAX	408
MDAX	514
SDAX	609
TecDAX	469
Total index	2000
Total Non-index	2703
Total Prime Standard	4703

"Index" refers to disclosures issued by companies belonging to one of the four prominent indices of Deutsche Boerse Group: DAX, MDAX, SDAX, and TecDAX. "Non-index" refers to non-constituents within the Prime Standard segment. The DAX includes multinational large caps. The MDAX encompasses mid-sized companies and the SDAX small to medium-sized players. The TecDAX index comprises companies in the technology sector. The TecDAX group also contains ad hoc disclosures issued by companies that made up its predecessor, the Nemax50

Table 2 Total sample by year of issuance

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Index	250	257	102	99	175	214	180	169	164	114	202	71
Non-index	264	630	275	116	163	200	178	202	195	130	254	96
Total	514	887	377	215	338	414	358	371	359	244	456	167

being a constituent of one of the large German stock indices; these form the "Index" group of disclosures. The table also shows that the large majority of disclosures were issued by companies that are not members of an index; these are referred to as the "Non-index" group of disclosures.

The TecDAX segment was not in existence across the entire research horizon. It was created as a substitute for the Nemax50, which used to be the German index for companies in the new economy. In the aftermath of the dot-com bubble, Deutsche Boerse Group re-launched the segment under its new name, the TecDAX; the Nemax50 was discontinued in June 2003. As the TecDAX at its inception consisted of an almost equal portfolio of companies and operated in the same segment, the Nemax50 disclosures were carried over to the TecDAX subsample.

Table 2 shows the ad hoc disclosure sample by year of issuance. The sample mirrors the decreasing frequency of published ad hoc disclosure since the early 2000s. The German government amended the ad hoc disclosure scheme in 2003 to mandate the publication of only sufficiently important information, causing a decline in the total number of publications. Particularly high numbers in 2001, especially for the non-index group, are due to the burst of the dot-com bubble and the subsequent collapse of the new economy segment.

Table 3 Total sample by periodicity and timing

	Periodic	Non-periodic	Intraday	Non-intraday
Index affiliates	1142	858	765	1235
DAX	230	178	171	237
MDAX	229	285	258	256
SDAX	369	240	229	380
TecDAX	314	155	107	362
Non affiliates	1663	1039	1100	1603
Total Prime Standard	2806	1897	1865	2838

"Periodic" refers to ad hoc disclosures issued prior to upcoming periodic reports. "Non-periodic" refers to disclosures not related to periodic financial information. "Intraday" denotes disclosures issued during trading hours, i.e., between 09:00 and 19:00. "Non-intraday" refers to ad hoc disclosures issued off-trading hours

Table 3 shows the majority of disclosures got issued in the run-up to periodic reporting.[6] The periodic character of a disclosure was determined by a search algorithm, which, in a first step, looked for relevant key words in the text of the disclosure and in a second step clarified whether the disclosure stated when the upcoming periodic report would be published. In the event a disclosure fulfilled both criteria (which was true for about half the sample), it was categorized as "periodic". To ensure the algorithm was specified correctly, a sufficiently large portion of the automatically sorted sample (1200 disclosures) was read by a human. If the criteria were not met, the disclosure was read and manually categorized.

3.1 Research method

3.1.1 Standardized mean-corrected absolute abnormal returns

The market model is applied to specify the estimated returns model for the event study, as outlined by Brown and Warner (1980). For an overview of all relevant event study parameter estimations, see Fig. 1. Specifically, a standard regression model is used to estimate $\hat{\alpha}_j$ and $\hat{\beta}_j$:

$$r_{j,t} = \hat{\alpha}_j + \hat{\beta}_j r_{M,t} + \epsilon_{j,t}, \tag{1}$$

where $t \in [-302, \ldots, -11]$ and $E[\epsilon_j] = 0$.

The CDAX composite, which provides a large cross section of the German stock market, serves as reference for the OLS regression model. The market model parameters are computed for a 292-trading day (days are denoted by t) estimation period from t_{-302} to t_{-11} relative to t_0.[7] The exclusion of the 10-day pre-event period from all

[6] All ad hoc disclosures (without exception) related to periodic reports were issued prior to the corresponding report.

[7] The entire study will follow the convention that the letter t denotes days. Days prior to the issuance of ad hoc disclosures on day t_0 are denoted by a negative subscript number, e.g., for the day prior to publication this translates to t_{-1}. Days after t_0 are denoted by unsigned subscripts, e.g., for the day after issuance this leads to t_1.

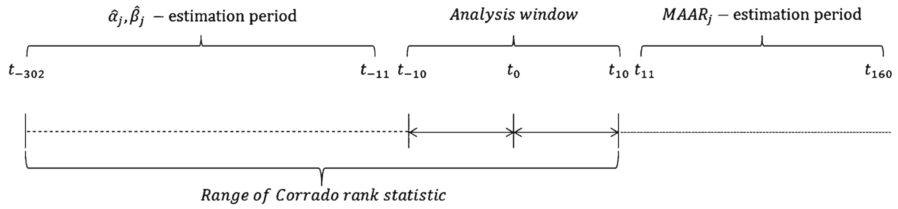

Fig. 1 Event study parameter estimation. Market model parameters $\hat{\alpha}_j$ and $\hat{\beta}_j$ are estimated over a 292 trading day estimation period from t_{-302} to t_{-11}. The mean absolute abnormal return (MAAR$_j$) for security j is calculated for a 150-day period, starting 11 days after the announcement, i.e., t_{11} to t_{160}. The analysis window of the event study, ranging from t_{-10} to t_{10} was not used for parameter estimation and was chosen free from the publication of any concurrent ad hoc disclosure. The Corrado (1989) test is applied to test the abnormal returns in the analysis window for statistical significance. It is common for the Corrado (1989) test to use the entire data range in constructing the Corrado rank statistic, translating to 313 abnormal return ranks taken from the entire data range t_{-302} to t_{10}

parameter estimation operations is for purposes of examining the occurrence of pre-announcement market adjustments. Having estimated the parameters, the abnormal return AR$_{j,t}$ is calculated by subtracting the estimated from the realized return:

$$\text{AR}_{j,t} = r_{j,t} - E[r_{j,t}|r_{M,t}], \tag{2}$$

where $E[r_{j,t}|r_{M,t}] = \hat{\alpha}_j + \hat{\beta}_j r_{M,t}$ and $t \in [-10, \ldots, 0, \ldots, +10]$.

As the disclosures contain many different types of information (making an ex ante anticipation of their effects almost impossible), the mutual cancelation of positive and negative abnormal returns needs to be prevented. The way around this complication is to calculate (unsigned) absolute abnormal returns (AAR$_{j,t}$) instead of just abnormal returns:

$$\text{AAR}_{j,t} = |\text{AR}_{j,t}|. \tag{3}$$

The event study methodology itself is the source of the next problem: when calculating accumulated absolute abnormal returns, it is straightforward that a sum of absolute values almost certainly yields a positive result and will reject the null hypothesis even when there may be no effect at all (Kaserer and Nowak 2001). Carter and Soo (1999) deal with this by a transformation of the absolute residuals by the absolute abnormal returns average obtained from an estimation period. The present analysis follows this approach and calculates the mean absolute abnormal return (MAAR$_j$) for the 150-day period starting 11 days after the announcement:

$$\text{MAAR}_j = \frac{1}{150} \sum_{t_{11}}^{t_{160}} \text{AAR}_t. \tag{4}$$

Transforming the event window absolute abnormal returns by MAAR$_j$ leads to an expected value of exactly zero for the mean of the resulting distribution. Standardizing by the standard deviation of residuals during the MAAR$_j$ estimation period yields the standardized mean-corrected absolute abnormal return AAR$^*_{j,t}$:

$$\mathrm{AAR}^*_{j,t} = \frac{\mathrm{AAR}_{j,t} - \mathrm{MAAR}_j}{\sigma_{j,t_{11},t_{160}}}. \tag{5}$$

The measure is interpreted as an absolute deviation of observed residuals from those of the estimation period mean, standardized by the estimation period standard deviation. To obtain insights into longer periods, cumulative standardized mean-corrected absolute abnormal returns are calculated as follows:

$$\mathrm{CAAR}^*_{j,t_I,t_{II}} = \sum_{t_I}^{t_{II}} \mathrm{AAR}^*_{j,t}. \tag{6}$$

Finally, mean $\mathrm{AAR}^*_{j,t}$, as well as mean $\mathrm{CAAR}^*_{j,t}$ are obtained through aggregation over the total sample of disclosures J and yield $\overline{\mathrm{AAR}}^*_{J,t}$ and $\overline{\mathrm{CAAR}}^*_{J,t_I,t_{II}}$ for every single $t \in [-10, \ldots, 0, \ldots, 10]$.

Statistical significance of the absolute abnormal returns is tested through the application of Corrado (1989)'s test statistic.[8] This test procedure is robust to event-induced volatility and, therefore, better specified under the null hypothesis than common parametric tests like the t test. Moreover, the test is less restrictive when it comes to assumptions about the sample's distribution as it does not require a normally distributed statistic.[9]

3.1.2 Multivariate analysis

The cross-sectional regression analysis is designed to deliver insights into the driving forces of market price adjustment in the aftermath of ad hoc disclosures. The 3-day cumulative mean-corrected absolute abnormal return, $\mathrm{CAAR}^*_{j,t_0,t_2}$, serves as the dependent variable in the regression. The regression is designed to control for all features important in the evaluation of the effects induced by ad hoc disclosures. Specifically, the regression controls for market properties (degree of uncertainty, information leakage), issuer characteristics (mean trading volume, market capitalization, index affiliation), disclosure informativeness (year of issuance, time since the last disclosure), and certain disclosure attributes (publication time, periodicity).

Variable $\hat{\sigma}^2_j$ is designed to capture the degree of market uncertainty at disclosure arrival. It is calculated as the natural logarithm of the 5-day variance of daily returns

[8] The entire sample of standardized mean-corrected absolute abnormal returns is used to create the Corrado (1989) test statistic. $\mathrm{AAR}^*_{j,t}$ are calculated for each single day of the entire research period, i.e., from t_{-302} to t_{10}. Each of the $\mathrm{AAR}^*_{j,t}$ has a return rank assigned, leading to $K_{j,t} = \mathrm{rank}[\mathrm{AAR}^*_{j,t}]$, where $K_{j,t}$ is the return rank of $\mathrm{AAR}^*_{j,t}$ and $K_{j,t} \in [1, \ldots, 313]$. The rank statistic of the daily $\mathrm{AAR}^*_{j,t}$, under the 313-day analysis window, follows $T_{\mathrm{AAR}^*} = \frac{\frac{1}{N}\sum_1^N (K_{j,t} - 156.5)}{\sigma_{K_{\mathrm{AAR}^*}}}$, whereas $\sigma_{K_{\mathrm{AAR}^*}} = \sqrt{\frac{1}{313}\sum_{t-302}^{t+10}(\frac{1}{N}\sum_1^N K_{j,t} - 156.5)^2}$. Under the H_0, T_{AAR^*} follows $\sim N(0, 1)$.

[9] An earlier version of the paper applied the Wilcoxon–Mann–Whitney U statistic to test the abnormal returns for statistic significance. While the Corrado (1989) test is preferable due to allowing for a less restrictive sample selection technique, the former test design was capable of producing robust and significant results not different from those reported here.

for the period t_{-5} to t_{-1} prior to disclosure publication, divided by the 20-day variance, calculated for the period from t_{-30} to t_{-11}:

$$\hat{\sigma}_j^2 = ln \left[\frac{\sigma^2_{t_{-5},t_{-1}}}{\sigma^2_{t_{-30},t_{-11}}} \right]. \tag{7}$$

The variable measures the relation between daily return variance prior to disclosure and that of a period free from any systematic disturbances. The ratio should be indicative of the presence of higher-than-average volatility due to the direct link between return variance and uncertainty.

The second variable in the regression is the weekly $\mathrm{AAR}^*_{j,w_{-01}}$ (where subscript w denotes weeks), calculated for the trading week prior to disclosure, based on the convention $r_{j,w_{-01}} = \frac{p_{j,t_{-5}}}{p_{j,t_{-1}}} - 1$, where $p_{j,t}$ denotes the price of stock j at day t and $r_{j,w_{-01}}$ is the normal return of security j. Calculation of the weekly $\mathrm{AAR}^*_{j,w}$ follows the same procedure as for calculating the daily $\mathrm{AAR}^*_{j,t}$ only applying weekly returns instead of daily returns.[10] The variable investigates whether pre-event abnormal price adjustment can explain event-day abnormal returns. If so, it would point toward the existence of information leakage and in-advance price adjustment. Weekly returns are chosen because of their higher robustness to potential variance hikes during the disclosure run-up.

To adjust for liquidity and market depth, the MV_j variable captures the natural logarithm of the average trading volume of disclosure j's corresponding stock, during a 150-day estimation period from t_{-160} to t_{-11}. The MCAP_j variable is the natural logarithm of the issuing firm's market capitalization at the beginning of the year of disclosure and controls for size effects.

The following two variables are designed to capture the degree of disclosure informativeness. The YEAR_j variable increases gradually as years pass. For each additional year, the variable increases by one 11th, leading to the following rule:

$$\mathrm{YEAR}_j = a_{j,\mathrm{year}} \cdot \frac{1}{11} \tag{8}$$

whereas $a_{j,2000} = 1, \ldots, a_{j,2011} = 11$.

The rationale for this variable is the assumption that disclosure informativeness increased, on average, over time, as the 2003 amendment of the German Securities Trading Act required that only sufficiently important information be issued via the ad hoc channel. The LAST_j variable measures the natural logarithm of the number

[10] The same periods as for the daily returns are used to derive the parameters, reducing data points by a factor of five. Assuming a stable variance–covariance matrix for the market regression, we use the same market model parameters as for the daily returns to calculate the expected returns model. For the week prior to the event Eq. (2) changes to $\mathrm{AR}_{j,w_{-1}} = r_{j,w_{-1}} - E[r_{j,w_{-1}}|r_{M,w_{-1}}]$, where $\mathrm{AR}_{j,w_{-1}}$ is the abnormal return in the week prior to the event in t_0, $r_{j,w_{-1}}$ is the realized return of security j and $E[r_{j,w_{-1}}|r_{M,w_{-1}}]$ is the expected return in week w_{-1} according to the market model. The weekly MAAR_j-estimation is carried out for 30 weekly returns, still corresponding to the period from t_{11} to t_{160}. The weekly equivalent of Equation [4] is $\mathrm{MAAR}_j = \frac{1}{30}\sum_{w_3}^{w_{32}} \mathrm{AAR}_w$, ranging from week 3 to week 32.

of days between the current and the previous ad hoc disclosure issued by the same company. The implicit assumption is that the longer the time between disclosures, the more valuable the information contained in a disclosure.

Finally, a set of dummy variables probes particular disclosure attributes. The PER_j variable controls for disclosure periodicity. It is set to 1 if the disclosure was triggered by an upcoming periodic report; 0 otherwise. The ITD_j variable is set to 1 if the disclosure hit the market between 09:00 and 19:00 to capture effects induced by intraday issuance. IND_j controls for effects due to the underlying company being listed on one of the prominent indices (DAX, MDAX, SDAX, or TecDAX). These variables translate into the following regression model, ϵ_j being the error term, assumed to be independent and identically normally distributed:

$$\begin{aligned}\mathrm{CAAR}^*_{j,t_0,t_2} = \alpha &+ \beta_0 \cdot \hat{\sigma}_j^2 + \beta_1 \cdot \mathrm{AAR}^*_{j,w_{-01}} + \beta_2 \cdot \mathrm{MV}_j + \beta_3 \cdot \mathrm{MCAP}_j \\ &+ \beta_4 \cdot \mathrm{YEAR}_j + \beta_5 \cdot \mathrm{LAST}_j + \beta_6 \cdot \mathrm{PER}_j + \beta_7 \cdot \mathrm{ITD}_j \\ &+ \beta_8 \cdot \mathrm{IND}_j + \epsilon_j. \end{aligned} \tag{9}$$

3.1.3 Buy-and-hold returns

The analysis of post-announcement abnormal returns is extended by the generation of buy-and-hold excess returns. The $\mathrm{AAR}^*_{j,t}$ measure is designed to deliver insights into the statistical significance of abnormal stock returns, but it is not appropriate for discovering the economic significance of the effects observed. This problem is further corroborated through application of the Corrado (1989) test statistic, which is not suitable for analyzing cumulative abnormal returns. While the standardized mean-corrected absolute abnormal returns reveal the existence of an effect with high reliability, the buy-and-hold excess returns permit an additional direct observation of the economic impact of ad hoc disclosures. To obtain the upper bound of the potential excess return attainable on the German market, the following conventions apply:

1. The sign of the return on the day of publication is taken as an estimate for the character of the news (positive or negative) provided by the ad hoc disclosure.
2. If the ad hoc disclosure triggered a positive (negative) reaction on announcement day, the strategy is to go long (short) in the stock and short (long) in the market on the following days.

According to this scheme, the geometric return is calculated for each of the ad hoc disclosures, formally translating to:

$$\mathrm{ER}_{j,t} = [s|r_{j,t_0}] \cdot \prod_1^t \cdot (1 + r_{j,t}) - [s|r_{j,t_0}] \cdot \prod_1^t \cdot (1 + r_{M,t}) \tag{10}$$

where $\mathrm{ER}_{j,t}$ is the excess return triggered by ad hoc disclosure j from day t_1 to day t. $[s|r_{j,t_0}]$ is set to $+1$ for $r_{j,t_0} > 0$ and -1 for $r_{j,t_0} < 0$. $r_{j,t}$ is the corresponding stock return, $r_{M,t}$ is the return of the market.

4 Empirical results

4.1 Daily market price adjustment

Table 4 sets out the mean AAR^*_t to the arrival of ad hoc information on the day of issuance and the t_{-5} to t_5 time window. Figure 2 provides a graphic interpretation of the results of the event study. As expected, the event day shows a striking amplitude, being indicative of a substantial price adjustment. Figure 2 also shows that the $\overline{\text{AAR}^*_{J,t}}$ fluctuate around zero when no systematic informational events occur and the AAR^*_t-measure is correctly specified. In line with results by Roeder (2000), Muntermann and Guettler (2007) and Baule and Tallau (2012), the event-day adjustment has a size of more than one standard deviation of estimation period absolute abnormal returns (i.e., 1.1665) for the entire sample, translating to roughly 2.5 % of average absolute return induced by the 4703 disclosures,[11] which means that $H_0 1a$, stating that the market reaction to the arrival of ad hoc disclosures is below 2 % on average, is not supported. The result does support the idea that the Ad Hoc Legislation does indeed trigger the publication of sufficiently important information and, on average, works as intended. Table 4 reveals the strongest statistical significance of the average $\text{AAR}^*_{t_0}$ for the entire sample, as well as for every subsample, found by applying the Corrado (1989) test statistic. A slightly different technique, using the Wilcoxon–Mann–Whitney U test statistic on standardized median-corrected absolute abnormal returns obtained essentially the same results.[12] Therefore, $H_0 1b$, stating that no statistically significant $\overline{\text{AAR}^*_{J,t_0}}$ are detectable, may also be rejected.

While these findings tend to validate the results of earlier research, the focus of this paper is on the days surrounding the event at t_0. It is striking that prices already tend to react significantly abnormally before the arrival of ad hoc disclosures. The effect emerges at t_{-1} and can be detected for the entire sample of 4703 events with very high statistical significance. The corresponding value of the Corrado (1989) test statistic reaches 3.44. The effect can be observed in all large subgroups of the sample, except for the non-periodic part. We, therefore, conclude that the in-advance market reaction appears to be driven by disclosures related to upcoming periodic reports. The results for this subsample are highly significant and the value of the Corrado test statistic is the highest among all t_{-1} values and also the AAR^*_{t-1} of 0.1357 standard deviations is considerable (translating to an average absolute abnormal return of roughly 0.4 %). Baule and Tallau (2012) report very similar findings, also demonstrating that the market reacts 1 day prior to the issuance of ad hoc disclosures related to periodic reports. However, this somewhat contravenes the results of Griffin (2003) who found that the US market reacted only after report filing. Baule and Tallau (2012) do not assess whether in-advance price reactions are a feature of the entire population of ad hoc disclosures or unique to the periodically triggered subsample. Focusing on both types of ad hoc disclosures, our results demonstrate that in-advance market reactions are most pronounced for the periodically triggered portion. Cumulative abnormal

[11] The $\overline{\text{AAR}^*_{J,t}}$ as well as $\overline{\text{AR}_{J,t}}$ and $\overline{R_{J,t}}$ of the entire 21 days observation window from t_{-10} to t_{10} are shown in the "Appendix".

[12] The results are not reported.

Table 4 Standardized mean-corrected absolute abnormal returns (t_{-5} to t_5)

Day	t_{-5}	t_{-4}	t_{-3}	t_{-2}	t_{-1}	t_0	t_1	t_2	t_3	t_4	t_5
Total N	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703
$\overline{\mathrm{AAR}}^*_{J,t}$	0.0194	0.0193	0.0210	0.0358	0.0808***	1.1665***	0.3155***	0.1155***	0.0333*	0.0238	0.0353
Corrado TS	−0.95	−0.41	−0.09	0.59	3.44	38.63	15.75	7.89	2.48	1.31	1.86
Index N	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
$\overline{\mathrm{AAR}}^*_{J,t}$	0.0117	0.0127	0.0324	0.0370	0.0752	1.1264***	0.2885***	0.1100***	0.0279	0.0212	0.0463
Corrado TS	−0.88	0.27	0.10	0.49	1.95	24.32	8.76	4.05	1.16	0.22	1.41
Non-index N	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703
$\overline{\mathrm{AAR}}^*_{J,t}$	0.0251	0.0242	0.0125	0.0349	0.0850**	1.1962***	0.3354***	0.1196***	0.0373*	0.0257	0.0272
Corrado TS	−0.50	−0.77	−0.20	0.36	2.86	30.04	13.29	6.92	2.27	1.55	1.24
Periodic N	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806
$\overline{\mathrm{AAR}}^*_{J,t}$	0.0058	0.0306	0.0133	0.0541	0.1190***	1.2323***	0.3364***	0.1186***	0.0295*	0.0311	0.0268
Corrado TS	−1.07	−0.22	−0.37	0.93	4.10	33.84	13.27	6.35	1.98	1.19	1.16
Non-periodic N	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897
$\overline{\mathrm{AAR}}^*_{J,t}$	0.0395	0.0026	0.0323	0.0088	0.0244	1.0691***	0.2845***	0.1110***	0.0389	0.0129	0.0479
Corrado TS	−0.20	−0.38	0.32	−0.19	0.40	19.96	8.67	4.71	1.50	0.63	1.52
DAX N	408	408	408	408	408	408	408	408	408	408	408
$\overline{\mathrm{AAR}}^*_{J,t}$	0.0317	0.1088	0.0289	0.0980	0.0990	1.4608***	0.3281***	0.0981	0.0404	−0.0264	0.0862
Corrado TS	0.12	1.42	0.36	1.78	1.36	12.77	5.11	1.84	1.18	−0.25	1.48
MDAX N	514	514	514	514	514	514	514	514	514	514	514
$\overline{\mathrm{AAR}}^*_{J,t}$	0.0788	0.0121	0.0457	0.0039	0.1105	1.2138***	0.3219***	0.0973	0.0258	−0.0271	0.0591
Corrado TS	0.59	0.16	0.43	−0.78	1.15	12.65	3.95	1.10	−0.16	−0.84	0.34

Table 4 continued

Day	t_{-5}	t_{-4}	t_{-3}	t_{-2}	t_{-1}	t_0	t_1	t_2	t_3	t_4	t_5
SDAX N	609	609	609	609	609	609	609	609	609	609	609
$\overline{\mathrm{AAR}^*_{J,t}}$	−0.0650	−0.0586	0.0035	−0.0092	0.0405	0.8476***	0.2258***	0.1142**	0.0271	0.0499	−0.0152
Corrado TS	−1.43	−1.31	−0.09	−1.34	0.80	11.77	3.78	2.80	1.33	0.79	0.15
TecDAX N	469	469	469	469	469	469	469	469	469	469	469
$\overline{\mathrm{AAR}^*_{J,t}}$	0.0203	0.0225	0.0585	0.0806	0.0607	1.1016***	0.2990***	0.1288*	0.0206	0.0783	0.0776
Corrado TS	−0.96	0.54	−0.46	1.77	0.64	11.65	4.93	2.34	−0.02	0.65	0.99

The values shown are the respective $\overline{\mathrm{AAR}^*_{J,t}}$, as well as the corresponding values of the Corrado (1989) test statistic (Corrado TS) for the t_{-5} to t_5 period relative to the event day at t_0. The periods from t_{-10} to t_{-6} and t_6 to t_{10} are shown in Table 8 in the "Appendix"
The significance codes are derived as follows: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

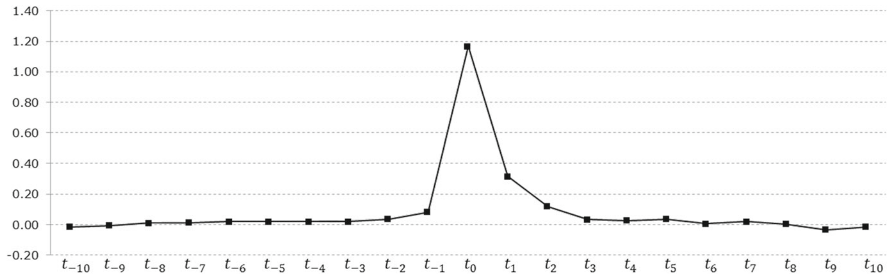

Fig. 2 Total sample daily $\overline{\text{AAR}}_t^*$. The *y*-axis of the graph shows daily $\overline{\text{AAR}}_t^*$ for the total sample of 4703 disclosures on each relevant day during the observation period from t_{-10} to t_{10}. The corresponding values for the entire period shown by the *graph* are contained in Table 8 in the "Appendix". Table 4 shows the values for the period from t_{-5} to t_5

returns for the pre-announcement period suggest that a comparable run-up is also detectable for the non-periodic part, but individual daily abnormal returns stay well below the significance threshold. As our methodology does not allow for reliable testing of accumulated abnormal returns, the true size of the effect for the non-periodic subsample cannot be evaluated.

The finding that periodic information tends to diffuse into market prices prior to report publication is important because it supports the necessity and viability of the Ad Hoc Disclosure Legislation. The finding also provides evidence of systematic pre-announcement information leakage exactly where one would expect it. Many people, over a considerable amount of time, are involved in generating periodic reports that trigger ad hoc disclosures. Moreover, the entire market is aware that information is about to arrive because the reports are issued at a fixed date in the fiscal year and Prime Standard companies are mandated to disclose in advance when the publication will be made. This is less likely for ad hoc disclosures dealing with other than periodic financial information (e.g., changes in the management board, M&A news, etc.). However, the fact that the arrival of information is foreseeable may also increase market uncertainty and cause higher-than-average volatility. In fact, tests for homogeneity of pre-event variances show that return volatility increases considerably in the run-up to periodic reporting.[13] Though the Corrado test is not susceptible to errors due to increased return variance, it cannot be ruled out that this phenomenon has been captured by the $\overline{\text{AAR}}_{t-1}^*$. The issue of increased short-term return variance becomes less severe the longer the return horizon. The model, therefore, questions (among other things) whether the weekly standardized mean-corrected absolute abnormal return in the week prior to disclosure, while at the same time controlling for market uncertainty (through variable $\hat{\sigma}_j^2$), is capable of explaining a significant part of the abnormal market behavior, starting at t_0.

4.2 Multivariate analysis

Table 5 shows the results of the regression analysis. The regression was computed for the entire cross section of 4703 ad hoc disclosures and pooled for the index constituents,

[13] The tests are not reported.

Table 5 Multivariate analysis

Variable	α	$\hat{\sigma}_i^2$	$\mathrm{AAR}^*_{j,w_{-1}}$	MV_j	MCAP_j	LAST_j	YEAR_j	PER_j	ITD_j	IND_j	R^2
Total											
Coefficient	−2.1821*	0.1445***	0.07656***	0.9062*	−0.0327	0.2790***	0.0325	0.5205***	0.3220**	−0.0693	0.0249
T value	−2.3570	4.2500	4.7830	2.3490	−1.0250	4.6060	0.4990	5.1790	3.0440	−0.5550	
Index											
Coefficient	−3.3294*	0.2092***	0.0574*	1.4663*	−0.0289	0.3268***	0.2149*	0.5329**	−0.0981		0.0305
T value	−1.9870	3.5400	2.0380	1.9810	−0.5180	3.5130	2.0810	3.2900	−0.5740		
Non-index											
Coefficient	−1.8024	0.1383**	0.0894***	0.5029	−0.0401	0.4591***	−0.1262	0.3235*	0.4243**		0.0239
T value	−1.3230	2.9100	3.9880	0.9290	−0.7900	4.9720	−1.2430	2.1960	2.7370		
DAX											
Coefficient	14.629*	0.3825*	−0.0860	−5.2499*	−0.1092	0.4303	−0.5740	−0.0091	−0.0397		0.0501
T value	2.4380	1.9830	−0.9700	−2.1460	−0.5230	1.6540	−1.6270	−0.0220	−0.0910		

Regression variable $\hat{\sigma}_j^2$ controls for the degree of market uncertainty. $\mathrm{AAR}^*_{j,w_{-1}}$ captures pre-event abnormal price adjustment. MV_j is the respective stock's average trading volume; MCAP_j is its market capitalization. YEAR_j controls for increased information value in later years. LAST_j measures the number of days between the current and the previous ad hoc disclosure. Dummy variables control for disclosure periodicity, PER_j, for intraday issuance, ITD_j, and index constituents, IND_j. The dependent variables in the regression models are the corresponding 3-day cumulative mean-corrected absolute abnormal returns, $\mathrm{CAAR}^*_{J,t_0,t_2}$, $\mathrm{CAAR}^*_{\mathrm{Index},t_0,t_2}$, $\mathrm{CAAR}^*_{\mathrm{Non-Index},t_0,t_2}$, $\mathrm{CAAR}^*_{\mathrm{DAX},t_0,t_2}$. The period from t_0 to t_2 has been chosen, as the event study suggests that the price adjustment process for the entirety of disclosures takes at least until t_2. Data have been trimmed at a 0.99 interval to control for outliers. The results are not sensitive to the trimming and would not change qualitatively if the sample had not been trimmed

The significance codes are derived as follows: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

the non-index group, and the DAX. Data plots suggest that the sample variance is stable and thus not harming the regression analysis.

The $\hat{\sigma}_j^2$-variable, which controls for market uncertainty, is highly significant for the entire cross section, as well as in the pooled analyses, indicating the higher the uncertainty in the market during the disclosure run-up, the higher the informative value of an ad hoc disclosure. All t values for the $\hat{\sigma}_j^2$ coefficient have a high magnitude (except for the DAX-focused regression, all are close to or above 3), indicating that the variable explains a large part of the abnormal stock return around the event. Except for the DAX group, the $\text{AAR}^*_{w_{-01}}$ has forecasting power with respect to $\text{CAAR}^*_{j,t_0,t_2}$ in every single regression model. The higher the pre-event weekly $\text{AAR}^*_{w_{-01}}$, the stronger the resulting post-event reaction. The size of the effect is small in terms of the entire sample, as it ranges from 0.0574 to 0.0894. We believe this is plausible: the effect has to be small, on average, because it largely escapes the attention of market participants. The results suggest that the evidence provided by the regression, as well as that of the event study, support the notion of pre-announcement leakage. Consequently, $H_0 2a$, stating that there are no statistically significant abnormal returns in the pre-event period, as well as $H_0 2b$, stating that pre-event abnormal behavior cannot forecast post-event returns, are rejected.

Furthermore, the regression implies that several other variables are influential in the determination of post-event abnormal returns. The variable controlling for average trading volume, MV_j is near 1 for the total sample. The negative sign of the coefficient for the DAX regression is as expected, suggesting that the information contained in an ad hoc disclosure tends to be less important for frequently traded and heavily monitored stocks. Fama and French (1992) demonstrate that size is an important determinant of stock returns. Therefore, it may be surprising that our size-related variables (MV_j and MCAP_j) capture far less variance than those employed in Muntermann and Guettler (2007)'s intraday analysis. MCAP_j shows no sign of statistical significance at all. However, our analysis is only partially comparable to that of Muntermann and Guettler (2007). First, intraday reaction speed depends to greater extent on size factors than do daily returns. If the ad hoc regulation works as intended, size cannot be expected to yield substantial explanatory power because the law specifies a clear significance threshold for disclosures that has nothing to do with the firm's size. The LAST_j variable is significant for the entire cross section as well as for each pooled regression model and indicates that the longer the period between ad hoc disclosures, the higher their value in terms of abnormal market reaction. Guettler (2005) shows that not all disclosures contain valuable information but market participants do not appear to think that there too many disclosures are being issued. Our results do not contradict this idea, but they imply, in contrast to Guettler (2005)'s findings, a negative relation between frequency and importance. The Year_j variable is insignificant except for the entire portion of index constituents, supporting the notion that ad hoc disclosures have increased in importance over time and possibly reflecting the change in legislation that now requires the disclosure of only sufficiently important information.

The coefficient of the PER_j dummy variable, controlling for disclosure periodicity, shows that disclosures related to periodic reports provoke a stronger average market reaction than the rest of the sample and is in line with Roeder (2000). The ITD_j which captures the effect of disclosure while the market is open, indicates that there is a tendency to publish more important news during trading hours. However, the effect can be documented only for the subgroup of companies not listed on one of the prominent indices. Finally, the IND_j dummy indicates that the event-induced reaction is, on average, less pronounced for index constituents. This is also in line with common expectations, as the market reaction for less prominent stocks toward ad hoc disclosures should be stronger.

4.3 Cumulative post-event price adjustment

$\mathrm{CAAR}^*_{j,t_I,t_{II}}$ lend themselves to the analysis of post-event market adjustment. However, the measure is accompanied by two difficulties. First, the Corrado test is not suitable for testing accumulated abnormal returns for statistical significance because it needs an entire (and sufficiently large) rank statistic consisting of corresponding $\mathrm{CAAR}^*_{j,t_I,t_{II}}$ for each accumulation period. Second, the AAR^*_{j,t_0} is designed to capture abnormal market reaction of different signs, meaning that abnormal price increases as well as abnormal decreases are summed. Therefore, it may well be that observed post-event reactions are the absolute sum of counteracting market movements. Thus, the only certain inference that can be drawn from positive post-event $\mathrm{CAAR}^*_{j,t_I,t_{II}}$ is that the market underwent some kind of price adjustment.

That being said, Table 6 shows the daily $\overline{\mathrm{CAAR}^*_{t_0,t}}$ for the t_0 to t_{10} and Fig. 3 provides the corresponding interpretation. Both show that the market adjustment takes considerably longer and is not limited to the day of disclosure, further supporting the findings obtained by the daily $\mathrm{AAR}^*_{j,t}$ analysis. This, and Table 4, revealing that the daily $\overline{\mathrm{AAR}^*_t}$ from t_1 to t_2 are all significant for the entire sample and across all disclosure groups (only the DAX and MDAX have their statistically significant adjustment completed by t_1) leads to rejection of $H_0 3a$, stating that there are no statistically significant post-event abnormal returns after t_0. Using a slightly different technique, Griffin (2003) and Baule and Tallau (2012) come to the same conclusion. Though not supported by statistical testing, the $\overline{\mathrm{CAAR}^*_{J,t_0,t}}$ at least suggests that the market adjustment does not appear to have been completed until t_7/t_8.[14]

To conclude, the evidence provided by the daily $\mathrm{AAR}^*_{j,t}$ analysis and the regression suggests that the market adjustment in the shortest term, i.e., t_0 to t_2, after disclosure depends on index affiliation and disclosure periodicity. Thus, $H_0 3b$, which states the opposite, is rejected. However, the analysis of $\mathrm{CAAR}^*_{j,t_0,t}$ at least suggests that achievement of a new market equilibrium takes considerably longer than 2–3 days after disclosure. After that, the entire sample as well as the sub-samples show the lateral movement one would expect under the absence of systematic information events.

[14] Tests using the Wilcoxon–Mann–Whitney U test on a smaller sample (2813 disclosures) of standardized median-corrected absolute abnormal returns statistically confirm market adjustments for t_7/t_8. The results are not reported.

Table 6 Daily post-event $\overline{\text{CAAR}}^{*}_{t_0,t_{11}}$

$\text{CAAR}^{*}_{j,t_0,t_{11}}$	t_0	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}
Total	1.167	1.482	1.598	1.631	1.655	1.690	1.695	1.716	1.717	1.683	1.668
Index	1.126	1.415	1.525	1.553	1.574	1.621	1.605	1.605	1.594	1.540	1.519
Non-index	1.196	1.532	1.651	1.689	1.714	1.742	1.762	1.798	1.809	1.789	1.778
Periodic	1.232	1.569	1.687	1.717	1.748	1.775	1.762	1.787	1.779	1.752	1.736
Non-periodic	1.069	1.354	1.465	1.504	1.517	1.565	1.597	1.609	1.626	1.580	1.568
DAX	1.461	1.789	1.887	1.928	1.901	1.987	1.990	2.054	2.053	1.972	1.949
MDAX	1.214	1.536	1.633	1.659	1.632	1.691	1.677	1.714	1.743	1.724	1.738
SDAX	0.848	1.074	1.188	1.215	1.265	1.250	1.247	1.201	1.185	1.143	1.111
TecDAX	1.102	1.401	1.530	1.550	1.629	1.706	1.655	1.618	1.561	1.478	1.436

$\overline{\text{CAAR}}^{*}_{t_0,t}$ for the post-event period were not tested for statistical significance in their own right, as the Corrado test statistic is not suitable for testing cumulative abnormal returns. However, calculated for the non-cumulative single-day returns, significance can be established at least until t_3 for the total sample J. The Corrado p values, contained in Table 8 in the Appendix, show that the following days also come close to being statistically significant (e.g., a p value of 0.063 on t_5) Additional tests based on a smaller sample using the Wilcoxon–Mann–Whitney U test also yield statistically significant results for the relevant days

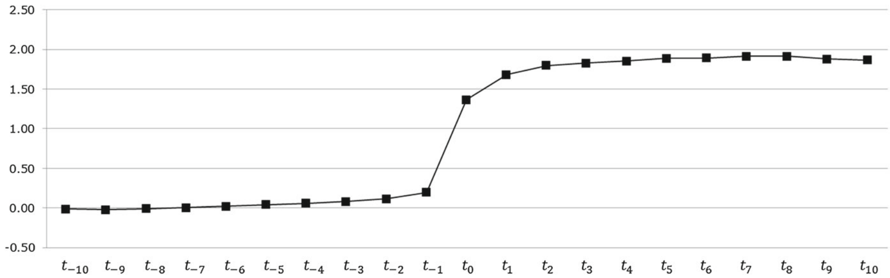

Fig. 3 Total sample daily $\overline{\text{CAAR}}^*_{J,t_{-10},t}$. The y-axis of the graph shows daily $\overline{\text{CAAR}}^*_{J,t_{-10},t}$ for the total sample, J, of 4703 ad hoc disclosures on each relevant day for the period from t_{-10} to t_{-10}. Abnormal return accumulation starts at t_{-10}

4.4 Buy-and-hold return potential

The long-lasting adjustment process, being statistically significant at least for the t_1 to t_3 horizon, says little about the economic significance of the documented market inefficiencies. Though the market is constantly adjusting, the $\text{CAAR}^*_{j,t_0,t_2}$ as well as the daily $\text{AAR}^*_{j,t}$ do not reveal whether the adjustment process is indeed additive or whether positive and negative abnormal returns actually lead to mutual cancelation. Furthermore, the effects may be extremely tiny; for example, the total sample's $\overline{\text{AAR}}^*_{t_3}$ of 0.0333 standard deviations, given an $\overline{\sigma}_{t_{11},t_{170}}$ of 0.02601, translates to an average absolute abnormal return of merely 0.0009 (9 basis points, bp) on day t_3. To evaluate the economic significance of the documented long-lasting market adjustment, buy-and-hold excess returns (instead of signed abnormal returns) are calculated to estimate the true (maximum) return prospects of an investment strategy taking advantage of the inefficiencies discovered.

The results of the buy-and-hold strategy are shown in Table 7 and Fig. 4 and lead to conclusions supporting both that the adjustment process lasts longer than 1 day and that the German stock market is nonetheless highly efficient. The excess returns generated for the entire Prime Standard sample are consistently positive, but statistically insignificant. Furthermore, they never rise above 73 bp, rendering them also economically insignificant. The subsample of disclosures associated with periodic reports produces a statistically insignificant and negative $\overline{ER}_{j,t}$ of up to −49 bp on average. The subsample affiliated with an index and the group of non-periodic disclosures trigger statistically significant excess returns, but as they are always below 50 bp, they, too, have no economic impact. DAX and MDAX do not show any substantial excess return potential either. Moreover, the results for the quantiles formed with respect to t_0 abnormal return size show that the German stock market evaluates information uniformly and market adjustment capability is not related to the importance of the news hitting the market. Things are slightly different if one focuses on the SDAX and TecDAX. The SDAX allows for an considerable excess return of roughly 80 bp in the days following an ad hoc disclosure. The TecDAX appears to generate up to 141 bp, on average, on day t_7 after disclosure, falling again in the following days.

Table 7 Post-event mean excess returns, $\overline{ER}_{j,t}$

Days	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}
Total $\overline{ER}_t$	0.0073	0.0005	0.0007	0.0011	0.0021	0.0021	0.0013	0.0009	0.0014	0.0008
T value	0.7670	0.7594	1.0393	1.7735	1.6815	0.9590	0.6497	0.8911	0.5383	0.1939
Index $\overline{ER}_t$	0.0026**	0.0026***	0.0038**	0.0037**	0.0046**	0.0045**	0.0049**	0.0050*	0.0045	0.0032
T value	3.0218	3.3706	2.7913	3.2554	2.8170	2.9269	2.8356	2.4438	1.6702	1.6177
Non-index $\overline{ER}_t$	0.0107	−0.0009	−0.0015	−0.0007	0.0001	0.0004	−0.0013	−0.0020	−0.0008	−0.0009
T value	−0.8561	−1.1262	−0.4732	0.1114	0.2255	−0.6397	−0.8709	−0.3539	−0.3680	−0.7610
Periodic $\overline{ER}_t$	0.0049	−0.0002	−0.0012	−0.0022	−0.0018	−0.0013	−0.0034	−0.0033	−0.0026	−0.0039
T value	−0.1806	−0.8160	−1.2157	−0.9576	−0.6139	−1.4784	−1.3593	−0.9565	−1.3923	−1.3205
Non-periodic $\overline{ER}_t$	0.0021	0.0011	0.0020*	0.0034**	0.0047**	0.0045**	0.0046*	0.0039*	0.0042*	0.0041
T value	1.2573	1.7722	2.5586	3.1703	2.8201	2.6772	2.0110	2.1714	2.0738	1.4958
DAX $\overline{ER}_t$	0.0038	0.0020	0.0027	0.0027	0.0031	0.0014	0.0018	0.0030	0.0023	0.0008
T value	1.7995	1.6214	1.4196	1.5231	0.6637	0.7976	1.2080	0.8564	0.2916	0.1222
MDAX $\overline{ER}_t$	0.0012	−0.0009	−0.0004	−0.0009	−0.0016	−0.0042	−0.0044	−0.0019	−0.0019	−0.0031
T value	−0.5103	−0.2146	−0.3869	−0.6103	−1.4446	−1.4634	−0.6194	−0.5466	−0.8413	−0.4030
SDAX $\overline{ER}_t$	0.0065*	0.0032*	0.0045*	0.0050**	0.0066**	0.0080**	0.0079*	0.0069*	0.0076*	0.0072*
T value	2.3308	2.4265	2.3397	2.7375	3.0421	2.7926	2.3632	2.4880	2.2645	2.3075
TecDAX $\overline{ER}_t$	−0.0020**	0.0061**	0.0085*	0.0080**	0.0104**	0.0121**	0.0141*	0.0120	0.0097	0.0073
T value	2.6563	2.8292	2.1038	2.6308	2.6718	2.9646	2.3803	1.8879	1.3229	0.9543
$\text{AAR}^*_{Q90/100,t_0}$ $\overline{ER}_t$	0.0412	−0.0023	−0.0026	−0.0033	0.0008	0.0025	0.0022	0.0021	0.0006	−0.0005
T value	−0.7174	−0.7391	−0.8355	0.2208	0.5619	0.4552	0.4371	0.1148	−0.0956	−0.4095
$\text{AAR}^*_{Q80/90,t_0}$ $\overline{ER}_t$	0.0116	0.0006	0.0025	0.0065	0.0060	0.0042	0.0018	0.0009	−0.0004	0.0027
T value	0.2657	0.7249	1.6248	1.2843	0.9311	0.4150	0.2005	−0.0805	0.4582	0.1085

The table shows $\overline{\text{ER}}_t$ for the total sample J and all relevant sub-samples, as well as for the group of disclosures causing the highest 20 % of t_0 market adjustment denoted by $\text{AAR}^*_{Q90/100,t_0}$ for the highest $\text{AAR}^*_{t_0}$ return decile and $\text{AAR}^*_{Q80/90,t_0}$ for the second highest

Two-tailed t tests test the excess returns for statistical significance, the codes are derived as follows: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

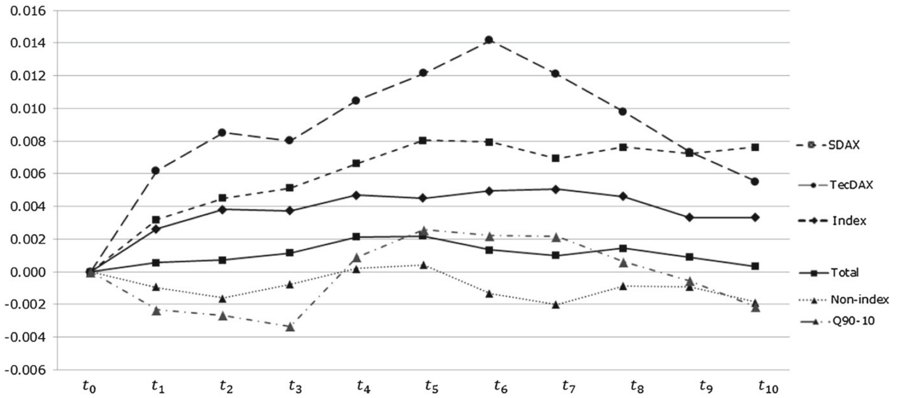

Fig. 4 Excess returns by total sample and relevant sub-samples. The y-axis of the graph show daily $\overline{ER}_t$ calculated according to Eq. (10) for the period from t_0 to t_{10}. The calculation of geometric excess returns starts at t_1

In sum, these findings support the notion that the German stock market takes considerably longer than just 1 day to adjust to information provided in ad hoc disclosures and confirm the analysis based on abnormal returns. Hence, $H_0 2b$, stating that the adjustment process does not depend on index affiliation, disclosure periodicity, or degree of information is rejected. Hypothesis $H_0 3c$ stating that no economically significant $\mathrm{ER}_{j,t}$ can be generated after disclosure is confirmed, despite the fact that excess returns for some niches could come close to being relevant in a statistic and economic sense.

5 Conclusion

This paper's primary goal is to provide comprehensive understanding of the efficiency of the German stock market with respect to ad hoc information. The analysis confirms the regulation's effectiveness in triggering the issuance of only relevant information within a corridor of 2–3 % on average. The market's strong adjustment in the aftermath of disclosure leads to the conclusion that ad hoc disclosures are an effective means of improving market efficiency. Furthermore, the results suggest that ad hoc disclosures can be categorized based on information content and disclosure importance.

Periodic financial information is of particular value for market participants as the average periodic disclosure causes a substantially larger market adjustment than disclosures not containing this kind of information. Similarly, the results show that disclosure informativeness depends on the degree of novelty of the published news. The exact timing of a disclosure is less influential on average, albeit there is a tendency for more important information to be released intradaily.

These results are evidence of a highly efficient stock market and are in line with general expectations. The evidence generated for the pre-event period is especially corroborative of this as it shows the tendency of not yet published information to diffuse into market prices and cause in-advance adjustment. This result supports the notion of an even higher than second-degree efficient market. Pre-announcement price reactions are detectable only for the sample of disclosures related to periodic reporting and indicative of a prevalent information asymmetry. On the one hand, this reinforces the necessity and viability of the Ad Hoc Legislation. At the same time, however, the findings suggest that ad hoc disclosures do not prevent information asymmetries from evolving and that the average periodically triggered ad hoc disclosure is "late" by at least 1 day. Thus, the results also call into question the effectiveness of the German legislation and whether the average periodically triggered ad hoc disclosure is "ad hoc enough". Part of the pre-event abnormal returns are attributable to increased volatility. But this explanation cannot account for all the findings, as evidence for anticipation effects was discovered in both the event study, which applied the volatility robust Corrado test, and in the regression analyses, which controlled for elevated return variance.[15]

The general post-announcement adjustment process includes at least the 2 days following disclosure. Analyses of cumulative abnormal returns suggest that the total market adjustment process could take as long as 7–8 days after disclosure. An investor taking advantage of this situation could achieve excess returns of up to 141 bp, pointing toward a market that is in that sense less than semi-strong efficient. Yet, most deviations from ideal semi-strong form efficiency are small and taking advantage of them is not a realistic option. Therefore, we conclude that the German market—in the sense intended by Grossman and Stiglitz (1980)—is as close to efficiency as possible.

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Appendix

[15] A possible way was to analyze subgroups of ad hoc disclosures that contain information from which it would be possible to make an ex ante assumption about the expected sign of the price effects and see whether the results are consistent with those of this paper. A robustness check applied a standard event study methodology to a much smaller sample of ad hoc disclosures announcing future dividends. The results are consistent as they show the same anticipative market reaction in t_{-1}.

Table 8 Standardized mean-corrected absolute abnormal returns (t_{-10} to t_{10})

Day	t_{-10}	t_{-9}	t_{-8}	t_{-7}	t_{-6}	t_{-5}	t_{-4}	t_{-3}	t_{-2}	t_{-1}	t_0	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}
Total N	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703
Mean AAR	−0.0160	−0.0052	0.0096	0.0126	0.0193	0.0194	0.0193	0.0210	0.0358	0.0808	1.1665	0.3155	0.1155	0.0333	0.0238	0.0353	0.0051	0.0202	0.0017	−0.0342	−0.0148
Corrado TS	−2.12	−2.03	−0.26	−1.00	−0.73	−0.95	−0.41	−0.09	0.59	3.44	38.63	15.75	7.89	2.48	1.31	1.86	−0.36	0.88	−0.50	−2.59	−0.80
Corrado P	0.034	0.042	0.792	0.315	0.462	0.341	0.680	0.931	0.555	0.001	0.000	0.000	0.000	0.013	0.190	0.063	0.715	0.382	0.617	0.010	0.423
Corrado mean	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Index	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Mean AAR	−0.0139	−0.0046	9.3953	0.0246	0.0432	0.0117	0.0127	0.0324	0.0370	0.0752	1.1264	0.2885	0.1100	0.0279	0.0212	0.0463	−0.0157	−0.0003	−0.0108	−0.0536	−0.0207
Corrado TS	−2.86	−2.55	−1.05	−0.83	0.22	−0.88	0.27	0.10	0.49	1.95	24.32	8.76	4.05	1.16	0.22	1.41	−1.75	−0.47	−0.90	−2.85	−0.92
Corrado P	0.004	0.011	0.292	0.407	0.823	0.380	0.790	0.918	0.627	0.051	0.000	0.000	0.000	0.248	0.829	0.159	0.080	0.636	0.370	0.004	0.359
Corrado mean	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Non-index	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703
Mean AAR	−0.0176	−0.0056	0.0167	0.0038	0.0015	0.0251	0.0242	0.0125	0.0349	0.0850	1.1962	0.3354	0.1196	0.0373	0.0257	0.0272	0.0205	0.0354	0.0110	−0.0198	−0.0105
Corrado TS	−0.33	−0.47	0.55	−0.61	−1.17	−0.50	−0.77	−0.20	0.36	2.86	30.04	13.29	6.92	2.27	1.55	1.24	1.02	1.55	0.10	−0.97	−0.27
Corrado P	0.744	0.638	0.581	0.542	0.242	0.617	0.442	0.840	0.719	0.004	0.000	0.000	0.000	0.023	0.122	0.215	0.307	0.121	0.922	0.330	0.790
Corrado mean	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 8 continued

Day	t_{-10}	t_{-9}	t_{-8}	t_{-7}	t_{-6}	t_{-5}	t_{-4}	t_{-3}	t_{-2}	t_{-1}	t_0	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}
Periodic	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806
Mean AAR	−0.0219	0.0017	−0.0024	0.0092	0.0165	0.0058	0.0306	0.0133	0.0541	0.1190	1.2323	0.3364	0.1186	0.0295	0.0311	0.0268	−0.0131	0.0253	−0.0083	−0.0264	−0.0163
Corrado TS	−2.20	−2.16	−0.46	−1.49	0.06	−1.07	−0.22	−0.37	0.93	4.10	33.84	13.27	6.35	1.98	1.19	1.16	−1.18	1.04	−1.12	−1.88	−0.91
Corrado P	0.028	0.031	0.644	0.137	0.954	0.284	0.825	0.711	0.354	0.000	0.000	0.000	0.000	0.048	0.236	0.248	0.240	0.298	0.262	0.060	0.364
Corrado mean	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Non-periodic	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897
Mean AAR	−0.0073	−0.0156	0.0275	0.0177	0.0234	0.0395	0.0026	0.0323	0.0088	0.0244	1.0691	0.2845	0.1110	0.0389	0.0129	0.0479	0.0321	0.0126	0.0167	−0.0457	−0.0126
Corrado TS	−0.68	−0.56	0.14	0.23	−1.22	−0.20	−0.38	0.32	−0.19	0.40	19.96	8.67	4.71	1.50	0.63	1.52	0.85	0.11	0.57	−1.79	−0.16
Corrado P	0.499	0.578	0.890	0.818	0.222	0.842	0.705	0.751	0.847	0.686	0.000	0.000	0.000	0.134	0.530	0.130	0.394	0.913	0.567	0.073	0.874
Corrado mean	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DAX	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408
Mean AAR	−0.0316	−0.0335	0.0625	0.0361	0.0832	0.0317	0.1088	0.0289	0.0980	0.0990	1.4608	0.3281	0.0981	0.0404	−0.0264	0.0862	0.0029	0.0639	−0.0011	−0.0808	−0.0234
Corrado TS	−0.37	−0.93	1.48	0.00	0.26	0.12	1.42	0.36	1.78	1.36	12.77	5.11	1.84	1.18	−0.25	1.48	−1.04	1.05	−0.11	−1.10	−0.29
Corrado P	0.713	0.355	0.141	0.999	0.795	0.904	0.158	0.717	0.076	0.175	0.000	0.000	0.066	0.241	0.804	0.139	0.299	0.296	0.912	0.272	0.769
Corrado mean	0.0000	−0.0001	0.0002	0.0000	0.0000	0.0000	0.0002	0.0000	0.0002	0.0002	0.0017	0.0006	0.0002	0.0001	0.0000	0.0002	−0.0001	0.0001	0.0000	−0.0001	0.0000

Table 8 continued

Day	t_{-10}	t_{-9}	t_{-8}	t_{-7}	t_{-6}	t_{-5}	t_{-4}	t_{-3}	t_{-2}	t_{-1}	t_0	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}
MDAX	514	514	514	514	514	514	514	514	514	514	514	514	514	514	514	514	514	514	514	514	514
Mean AAR	0.0010	−0.0652	−0.0406	0.0182	0.0337	0.0788	0.0121	0.0457	0.0039	0.1105	1.2138	0.3219	0.0973	0.0258	−0.0271	0.0591	−0.0140	0.0371	0.0289	−0.0192	0.0139
Corrado TS	−1.31	−2.00	−1.42	−1.19	0.34	0.59	0.16	0.43	−0.78	1.15	12.65	3.95	1.10	−0.16	−0.84	0.34	−1.28	0.39	0.19	−1.16	−0.22
Corrado P	0.192	0.046	0.157	0.234	0.731	0.557	0.870	0.668	0.438	0.251	0.000	0.000	0.270	0.872	0.403	0.732	0.203	0.697	0.847	0.248	0.828
Corrado mean	−0.0001	−0.0002	−0.0001	−0.0001	0.0000	0.0001	0.0000	0.0000	−0.0001	0.0001	0.0012	0.0004	0.0001	0.0000	−0.0001	0.0000	−0.0001	0.0000	0.0000	−0.0001	0.0000
SDAX	609	609	609	609	609	609	609	609	609	609	609	609	609	609	609	609	609	609	609	609	609
Mean AAR	−0.0444	−0.0493	0.0246	0.0072	0.0327	−0.0650	−0.0586	0.0035	−0.0092	0.0405	0.8476	0.2258	0.1142	0.0271	0.0499	−0.0152	−0.0026	−0.0463	−0.0156	−0.0415	−0.0324
Corrado TS	−2.94	−1.85	−0.39	−0.85	−0.33	−1.43	−1.31	−0.09	−1.34	0.80	11.77	3.78	2.80	1.33	0.79	0.15	0.09	−1.27	−1.13	−1.26	−0.05
Corrado P	0.003	0.065	0.697	0.397	0.743	0.153	0.192	0.928	0.182	0.423	0.000	0.000	0.005	0.184	0.427	0.881	0.925	0.206	0.258	0.207	0.959
Corrado mean	−0.0002	−0.0001	0.0000	−0.0001	0.0000	−0.0001	−0.0001	0.0000	−0.0001	0.0001	0.0008	0.0003	0.0002	0.0001	0.0001	0.0000	0.0000	−0.0001	−0.0001	−0.0001	0.0000
TecDAX	469	469	469	469	469	469	469	469	469	469	469	469	469	469	469	469	469	469	469	469	469
Mean AAR	0.0246	0.1452	−0.0419	0.0441	0.0325	0.0203	0.0225	0.0585	0.0806	0.0607	1.1016	0.2990	0.1288	0.0206	0.0783	0.0776	−0.0510	−0.0374	−0.0567	−0.0834	−0.0412
Corrado TS	−0.82	−0.22	−1.64	0.50	0.25	−0.96	0.54	−0.46	1.77	0.64	11.65	4.93	2.34	−0.02	0.65	0.99	−1.41	−0.99	−0.69	−2.23	−1.31
Corrado P	0.412	0.826	0.101	0.617	0.801	0.336	0.589	0.645	0.077	0.521	0.000	0.000	0.020	0.983	0.516	0.323	0.161	0.324	0.489	0.026	0.190
Corrado mean	−0.0001	0.0000	−0.0002	0.0000	0.0000	−0.0001	0.0001	0.0000	0.0002	0.0001	0.0012	0.0005	0.0002	0.0000	0.0001	0.0001	−0.0001	−0.0001	−0.0001	−0.0002	−0.0001

The values shown are the respective $\overline{\text{AAR}}_t^*$, as well as the corresponding values of the Corrado (1989) test statistic (Corrado TS) for the t_{-10} to t_{10} period relative to the event day at t_0

The significance codes correspond to the respective values of the two-tailed Corrado test statistic, hypothesizing that the mean Corrado value is zero and are derived as follows: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

Table 9 Absolute returns (t_{-10} to t_{10})

Day	t_{-10}	t_{-9}	t_{-8}	t_{-7}	t_{-6}	t_{-5}	t_{-4}	t_{-3}	t_{-2}	t_{-1}	t_0	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}
Total N	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703
Mean	0.0243	0.0243	0.0245	0.0245	0.0246	0.0249	0.0247	0.0248	0.0252	0.0266	0.0512	0.0314	0.0273	0.0255	0.0252	0.0247	0.0249	0.0247	0.0249	0.0238	0.0242
Median	0.0146	0.0147	0.0149	0.0147	0.0147	0.0148	0.0148	0.0150	0.0151	0.0156	0.0300	0.0189	0.0169	0.0154	0.0154	0.0149	0.0148	0.0146	0.0146	0.0144	0.0149
Index	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Mean	0.0205	0.0208	0.0206	0.0207	0.0212	0.0209	0.0209	0.0212	0.0209	0.0218	0.0394	0.0250	0.0226	0.0213	0.0211	0.0214	0.0199	0.0203	0.0204	0.0196	0.0205
Median	0.0121	0.0125	0.0127	0.0129	0.0130	0.0128	0.0129	0.0131	0.0132	0.0128	0.0254	0.0154	0.0142	0.0125	0.0133	0.0126	0.0124	0.0124	0.0128	0.0125	0.0129
Non-index	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703
Mean	0.0270	0.0269	0.0275	0.0272	0.0271	0.0278	0.0275	0.0275	0.0283	0.0301	0.0599	0.0361	0.0307	0.0285	0.0282	0.0272	0.0286	0.0278	0.0283	0.0269	0.0269
Median	0.0168	0.0167	0.0165	0.0162	0.0164	0.0166	0.0164	0.0169	0.0170	0.0181	0.0349	0.0220	0.0194	0.0175	0.0172	0.0170	0.0172	0.0167	0.0166	0.0164	0.0169
Periodic	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806
Mean	0.0236	0.0240	0.0235	0.0239	0.0241	0.0242	0.0242	0.0245	0.0250	0.0273	0.0517	0.0305	0.0267	0.0249	0.0249	0.0243	0.0239	0.0244	0.0237	0.0229	0.0235
Median	0.0146	0.0147	0.0149	0.0144	0.0147	0.0150	0.0149	0.0153	0.0156	0.0167	0.0334	0.0194	0.0174	0.0159	0.0156	0.0152	0.0149	0.0154	0.0146	0.0148	0.0153
Non-periodic	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897
Mean	0.0252	0.0247	0.0260	0.0253	0.0253	0.0259	0.0255	0.0254	0.0253	0.0256	0.0504	0.0327	0.0280	0.0263	0.0255	0.0254	0.0264	0.0250	0.0268	0.0250	0.0251
Median	0.0147	0.0147	0.0148	0.0151	0.0148	0.0145	0.0144	0.0146	0.0143	0.0144	0.0253	0.0182	0.0162	0.0145	0.0150	0.0145	0.0146	0.0134	0.0146	0.0141	0.0144
DAX	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408
Mean	0.0180	0.0155	0.0157	0.0158	0.0155	0.0161	0.0168	0.0169	0.0170	0.0163	0.0340	0.0183	0.0170	0.0164	0.0167	0.0167	0.0165	0.0165	0.0168	0.0153	0.0154
Median	0.0111	0.0100	0.0109	0.0110	0.0105	0.0115	0.0115	0.0115	0.0117	0.0102	0.0238	0.0125	0.0111	0.0107	0.0108	0.0104	0.0113	0.0109	0.0129	0.0107	0.0108
MDAX	514	514	514	514	514	514	514	514	514	514	514	514	514	514	514	514	514	514	514	514	514
Mean	0.0181	0.0170	0.0184	0.0178	0.0192	0.0193	0.0194	0.0181	0.0174	0.0210	0.0373	0.0239	0.0201	0.0182	0.0173	0.0185	0.0174	0.0193	0.0187	0.0183	0.0188
Median	0.0120	0.0116	0.0118	0.0116	0.0120	0.0119	0.0128	0.0121	0.0124	0.0120	0.0245	0.0145	0.0135	0.0114	0.0110	0.0112	0.0098	0.0120	0.0098	0.0124	0.0119
SDAX	609	609	609	609	609	609	609	609	609	609	609	609	609	609	609	609	609	609	609	609	609
Mean	0.0173	0.0171	0.0187	0.0188	0.0194	0.0175	0.0181	0.0180	0.0187	0.0196	0.0336	0.0225	0.0210	0.0199	0.0192	0.0188	0.0178	0.0175	0.0184	0.0172	0.0183
Median	0.0103	0.0107	0.0111	0.0118	0.0124	0.0102	0.0112	0.0113	0.0108	0.0122	0.0224	0.0137	0.0134	0.0121	0.0133	0.0118	0.0115	0.0105	0.0113	0.0110	0.0121
TecDAX	469	469	469	469	469	469	469	469	469	469	469	469	469	469	469	469	469	469	469	469	469
Mean	0.0296	0.0343	0.0296	0.0308	0.0307	0.0311	0.0297	0.0326	0.0309	0.0305	0.0540	0.0353	0.0325	0.0309	0.0314	0.0318	0.0283	0.0285	0.0282	0.0278	0.0296
Median	0.0186	0.0203	0.0187	0.0211	0.0198	0.0204	0.0188	0.0203	0.0214	0.0211	0.0362	0.0233	0.0217	0.0191	0.0215	0.0191	0.0189	0.0186	0.0172	0.0172	0.0194

The values shown are the respective $\overline{\mathrm{AR}_t}$, as well as median AR_t for the t_{-10} to t_{10} period relative to the event day at t_0

Table 10 Normal returns (t_{-10} to t_{10})

Day	t_{-10}	t_{-9}	t_{-8}	t_{-7}	t_{-6}	t_{-5}	t_{-4}	t_{-3}	t_{-2}	t_{-1}
Total N	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703
Mean	−0.0012	−0.0006	−0.0013	−0.0005	−0.0011	0.0000	0.0007	0.0004	0.0009	0.0021
Median	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Index	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Mean	0.0011	0.0000	−0.0003	−0.0011	−0.0017	−0.0004	−0.0002	0.0001	0.0002	0.0007
Median	0.0000	0.0000	0.0000	0.0000	−0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
Non-index	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703
Mean	−0.0029	−0.0011	−0.0021	0.0000	−0.0007	0.0003	0.0013	0.0006	0.0014	0.0031
Median	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Periodic	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806
Mean	−0.0004	−0.0012	−0.0019	0.0001	−0.0007	−0.0002	0.0010	0.0003	0.0017	0.0034
Median	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Non-periodic	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897
Mean	−0.0024	0.0003	−0.0005	−0.0013	−0.0017	0.0003	0.0001	0.0004	−0.0003	0.0002
Median	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DAX	408	408	408	408	408	408	408	408	408	408
Mean	−0.0013	−0.0002	0.0003	−0.0001	0.0005	0.0004	−0.0014	−0.0027	0.0000	0.0010
Median	0.0000	0.0004	0.0005	0.0000	0.0007	0.0015	−0.0004	−0.0009	0.0008	0.0015
MDAX	514	514	514	514	514	514	514	514	514	514
Mean	0.0019	−0.0009	0.0016	0.0010	−0.0011	0.0004	0.0037	−0.0016	0.0011	0.0028
Median	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009	0.0000	0.0000	0.0000

Table 10 continued

Day	t_{-10}	t_{-9}	t_{-8}	t_{-7}	t_{-6}	t_{-5}	t_{-4}	t_{-3}	t_{-2}	t_{-1}	
SDAX	609	609	609	609	609	609	609	609	609	609	
Mean	0.0020	0.0011	−0.0003	−0.0010	−0.0012	−0.0005	−0.0002	0.0001	0.0008	0.0008	
Median	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
TecDAX	469	469	469	469	469	469	469	469	469	469	
Mean	0.0009	−0.0002	−0.0028	−0.0044	−0.0051	−0.0019	−0.0034	0.0044	−0.0015	−0.0019	
Median	−0.0012	−0.0019	−0.0011	−0.0062	−0.0049	−0.0031	−0.0029	−0.0012	−0.0011	−0.0004	
Total N	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703	4703
Mean	0.0073	−0.0051	−0.0027	−0.0012	−0.0013	−0.0001	−0.0002	0.0004	0.0000	−0.0003	−0.0014
Median	0.0047	−0.0020	−0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Index	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Mean	0.0026	−0.0024	−0.0022	−0.0003	−0.0009	0.0010	−0.0006	−0.0007	0.0002	−0.0009	−0.0012
Median	0.0031	−0.0001	−0.0013	0.0000	−0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	−0.0007
Non-Index	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703	2703
Mean	0.0108	−0.0070	−0.0031	−0.0019	−0.0016	−0.0009	0.0001	0.0013	−0.0001	0.0000	−0.0015
Median	0.0064	−0.0037	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Periodic	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806
Mean	0.0021	−0.0062	−0.0031	−0.0007	−0.0008	0.0001	−0.0008	0.0002	−0.0002	−0.0008	−0.0016
Median	0.0030	−0.0022	−0.0011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	−0.0004
Non-periodic	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897	1897
Mean	0.0150	−0.0034	−0.0021	−0.0019	−0.0021	−0.0003	0.0006	0.0009	0.0003	0.0004	−0.0011
Median	0.0064	−0.0014	0.0000	0.0000	−0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DAX	408	408	408	408	408	408	408	408	408	408	408
Mean	0.0038	−0.0023	−0.0005	0.0008	−0.0007	−0.0023	0.0001	0.0010	−0.0019	−0.0005	0.0017
Median	0.0031	−0.0005	−0.0011	0.0002	−0.0006	−0.0023	0.0000	0.0000	−0.0028	0.0006	0.0010

Table 10 continued

Day	t_0	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}
MDAX	514	514	514	514	514	514	514	514	514	514	514
Mean	0.0013	−0.0007	−0.0028	−0.0015	0.0018	0.0034	−0.0010	0.0020	0.0001	−0.0015	−0.0016
Median	0.0031	0.0000	−0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	−0.0015
SDAX	609	609	609	609	609	609	609	609	609	609	609
Mean	0.0066	0.0021	−0.0004	0.0002	−0.0003	−0.0002	−0.0009	−0.0020	0.0020	0.0002	−0.0017
Median	0.0051	0.0000	−0.0008	0.0000	0.0000	0.0000	0.0000	−0.0008	0.0000	0.0000	0.0000
TecDAX	469	469	469	469	469	469	469	469	469	469	469
Mean	−0.0020	−0.0102	−0.0055	−0.0003	−0.0050	0.0030	−0.0006	−0.0033	−0.0003	−0.0018	−0.0028
Median	0.0000	−0.0071	−0.0031	−0.0019	−0.0055	−0.0008	−0.0027	−0.0013	0.0000	−0.0025	−0.0039

The values shown are the respective average normal returns, $\overline{\mathrm{NR}}_t$, as well as median NR_t for the t_{-10} to t_{10} period relative to the event day at t_0

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