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ORIGINAL ARTICLE

Forecasting index changes in the German DAX family

Friedrich-Carl Franz[1]

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Abstract
Combining market data with a publicly available monthly snapshot of Deutsche Börse's index ranking list, I create a model that predicts index changes in the DAX, MDAX, SDAX, and TecDAX from 2010 to 2019 before they are officially announced. Even though I empirically show that index changes are predictable, they still earn sizeable post-announcement 1-day abnormal returns up to 1.42% and − 1.54% for promotions and demotions, respectively. While abnormal returns are larger in smaller stocks, I find no evidence that they are related to funding constraints or additional risk for trading on wrong predictions. A trading strategy that trades according to my model yields an annualized Sharpe ratio of 0.83 while being invested for just 4 days a year.

Keywords Index rebalancing · Passive investment · Index effect · Index investing · Trading strategy

JEL Classification G12 · G14

Introduction

Index-linked or the so-called passive investments are growing steadily every year.[1] One related but unsettled research question is the existence of the index effect, i.e., abnormal returns of additions and deletions around index rebalancings. Recent results in the literature [see e.g., Kappou (2018)] show that abnormal returns are nowadays flat on the rebalancing date and limited to the day following the announcement. This makes exploitation difficult and the market supposedly more efficient. For example, Fig. 1 shows the intraday return chart of two recent DAX pro- and demotions on the day following the respective index change announcement by Deutsche Börse. The opening gap, e.g., up to 4% for Covestro, could only be collected by arbitrageurs if they had known the index changes before their respective announcement.[2] In this paper, I empirically establish that index changes—at least in Germany—are relatively easy to predict making the index effect still exploitable. A trading strategy that trades on the predictions of my model has an annualized Sharpe ratio of 0.83 while being invested for only *four days* a year.

Importantly, I examine index changes within the German DAX family, i.e., the DAX, MDAX, SDAX, and TecDAX, from 2010 to 2019 with respect to their ex-ante predictability and abnormal returns around their announcement. This yields two major contributions to the index effect literature. First, this paper is|to my knowledge|the first paper that empirically demonstrates the predictability of index changes. Fernandes and Mergulhao (2016) create a probit model to predict FTSE 100 changes but focus on the ex-post inherited probabilities and do not discuss the performance of their model with respect to real-world predictions. Although most index methodologies are rule-based and publicly available, forecasting index changes with data that were available to the public at the respective point in time is challenging. For example, to predict German DAX changes one would need to calculate the free float exactly analogous to Deutsche Börse's methodology and keep track of all index-eligible stocks trading on Xetra at every historic rebalancing date. I overcome these difficulties by using the publicly available

✉ Friedrich-Carl Franz
franz@finance.uni-frankfurt.de

[1] Goethe University Frankfurt, House of Finance Room 2.73, Theodor-W.-Adorno Platz 3, 60323 Frankfurt, Germany

[1] For example, see https://www.morningstar.com/blog/2018/03/12/fund-flows-charts.html.

[2] Note that the last DAX changes, which were announced on the September 4, 2019, exhibited the opposite behavior, i.e., the demotion (promotion) Thyssenkrupp (MTU Aerio Engine) was the best (worst) performing stock in their respective index on the following day.

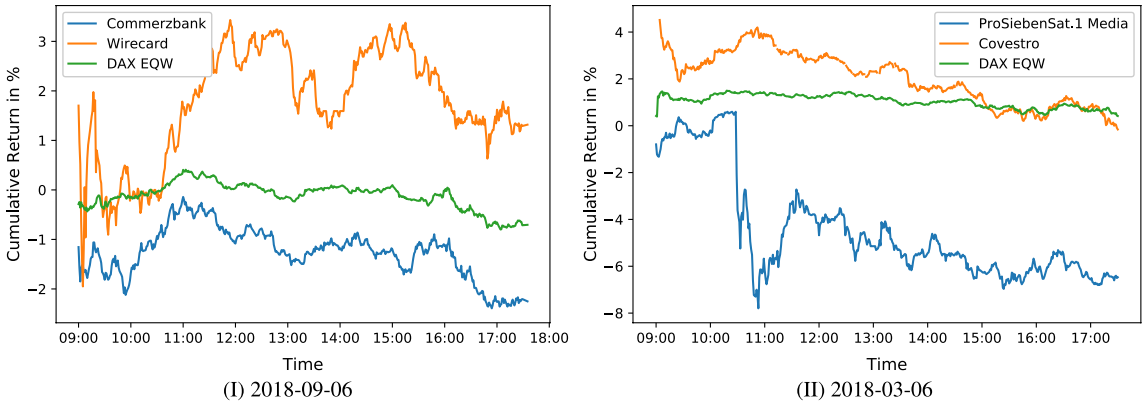


Fig. 1 DAX AD+1—intraday cumulative returns. This figure shows cumulative intraday returns during the AD+1 of the DAX addition (deletion) Commerzbank (Wirecard) on the left and of the DAX addition (deletion) ProSiebenSat.1 Media (Covestro) on the right. DAX EQW refers to an equally weighted portfolio of DAX constituents

ranking lists for the DAX family, which are a monthly snapshot of Deutsche Börse's ranking of the German equity universe according to their data and methodology. This unique service makes the German DAX family the prime habitat for a study on anticipating index changes. Combining the ranking list with standard market data, I create a model that, for example, correctly predicts 71% of DAX changes.

Second, having empirically established that index changes are predictable, I examine abnormal returns conditional to the prediction of my model. The results show that more surprising changes are not related to higher abnormal return as, e.g., argued and shown in the merger market by Song and Walkling (2000). Abnormal returns of changes that were correctly predicted are of similar magnitude compared to abnormal returns of changes that were not predicted. Instead, limits to arbitrage theories (Gromb and Vayanos 2010) or investor (in)attention (Barber and Odean 2008) might help to explain the market inefficiency. That is, larger stocks tend to earn lower abnormal returns. However, even in the large-cap index DAX, correctly predicted demotions earn a 1-day average abnormal return of − 1.63%. Funding constraints do not seem to play a role as abnormal returns seem to be lower when the VDAX is higher. Additionally, arbitrageurs do not face the additional risk of getting it wrong, i.e., the abnormal gains of trading correctly predicted changes are not offset by abnormal losses of trading falsely predicted changes.

The literature on the index effect in the equity markets is extensive, and Afego (2017) offers an excellent survey. Since the first papers on the index effect by Goetzmann and Garry (1986), Shleifer (1986), and Harris and Gurel (1986) abnormal returns have shifted from the rebalancing date to the announcement date. Consequently, Kappou (2018) concludes that market participants are nowadays well prepared for large index flows. Green and Jame (2011) support that by showing that index trackers do not wait until the rebalancing date to implement the announced index changes, but already trade between the announcement and rebalancing date. Therefore, this paper focuses on the announcement day.

Abnormal returns following the index change announcement are also found recently by others, such as Yu et al. (2015) and Biktimirov and Xu (2019) for the USA., and Chen et al. (2016) for the international equity markets. Chen et al. (2004) find higher abnormal returns for additions than for deletions in the S&P 500 and link the difference to a change in investor awareness. My result does not support their conclusion as abnormal returns of pro- and demotions are of similar magnitude. Lee et al. (2008) document significant abnormal returns for S&P 500 additions during the post-trading session after the announcement. Other studies that find abnormal post-announcement returns include Harris and Gurel (1986), Goetzmann and Garry (1986), Shleifer (1986), Jain (1987), and Beneish and Whaley (1996) for the S&P 500, Petajisto (2011) and Chang et al. (2014) for the Russel2000, Deininger et al. (2000) for the German DAX and MDAX, Doeswijk (2005) for the AEX index, Chakrabarti et al. (2005) for international MSCI indices, Liu (2006) and Liu (2011) for the Nikkei225, Mazouz and Saadouni (2007) and Mase (2007) for the FTSE100, Qiu and Pinfold (2007) for the ASX300, and Yun and Kim (2010) for the KOSPI 200. Similar to the German DAX, many of these indices are based on a publicly available rule-based methodology. Therefore, the results in this paper should be generalizable to the aforementioned international indices.

The pre-announcement period has also received attention in the literature. Zdorovtsov et al. (2017) arguelon the example of the Russell 3000lthat speculators do not only trade to gain on price movements but that they actively try to push stocks into indices. Mase (2007) and Fernandes and Mergulhao (2016) find evidence of anticipatory trading in the FTSE 100, which has a very straightforward methodology.

Predicting index changes is also common among practitioners. For example, Serkan Bartir, the head of portfolio management of Blackrock in Germany, states that index changes are no surprise anymore and that forecasts by brokers are released weeks before their announcement.[3] He also says that Blackrock waits until the rebalancing date to implement the changes, which could be explained by the priority of tracking error over outperformance of index fund managers as argued by Blume and Edelen (2004). Nonetheless, arbitrageurs that do not face such constraints should step in and front-run the temporary mispricing in predictable index changes. Consequently, the high abnormal returns found in this paper pose a challenge for efficient markets and support theories from, e.g., Duffie (2010) that arbitrageurs face restrictions, such as slow-moving capital, that forces them to forgo profitable opportunities.

The paper is structured as follows. Section 2 explains the index methodologies, introduces the data, and discusses the prediction model. Section 3 presents and discusses the results. Section 4 concludes.

Data and methodology

Deutsche Börse decides on index membership within the index-eligible stocks based on free floating market capitalization and turnover.[4] Additional criteria determine whether membership in the DAX family is actually possible. For example, to be able to become a member of the DAX, MDAX, SDAX, or TecDax, a stock must be listed in Deutsche Börse's Prime Standard, be continuously traded on Xetra, and must have its legal or operating headquarter in Germany. Among the index-eligible companies, Deutsche Börse creates a monthly ranking list to determine the respective index membership. For instance, a company is added to the DAX if it ranks below 26 in market capitalization and turnover. Therefore, index membership is completely determined by the ranking list and if an investor can predict the ranking list, she can predict index changes. The list is created upon data from the last trading day of the previous month but published together with the index change announcements after the close of trading on the third trading day of the month. Consequently, arbitrageurs that want to front-run the index change announcements have 3 days between the cutoff for the final data collection and announcement. I call the announcement day (AD) and the trading day after the announcement (AD+1). Note that neither the ranking list nor index changes are available to the public before their announcement.

Since 2010 Deutsche Börse made several changes to their index methodology, such as varying the cutoffs for index changes. For example, in 2018, they increased the number of index constituents from 50 to 60 and from 50 to 70 for the MDAX and SDAX, respectively. This methodology change was announced well in advance,[5] and I exclude these changes from the sample because it is an extraordinary adjustment with many changes that would make the results non-representative of a regular index change. However, all methodology changes are incorporated into the forecasting model. Before September 2016, Deutsche Börse used the so-called soft criteria, such as industry membership, to alter index changes via a discretionary overlay. They switched to a fully transparent methodology because these soft criteria were hardly used and most often the actual changes were identical to the changes derived by the purely rule-driven methodology. Therefore, arbitrageurs can forecast the ranking list and ultimately index changes by recalculating the rankings using the official methodology created upon free floating market capitalization and turnover. Furthermore, arbitrageurs must keep constantly track of new and delisted companies and their potential index eligibility.

Index changes are very sensitive to the data of the complete index universe, i.e., arbitrageurs must get the whole ranking right and not just the data of one potential change. For example, a promotion can be triggered by, e.g., the rise of market capitalization of that promotion or by the decline of market capitalization by another stock that consequently has become a demotion. However, getting the same data that Deutsche Börse uses is not straightforward. For example, the number of eligible shares or the free float in standard databases, such as Bloomberg or Compustat, might be very similar but not identical to the version Deutsche Börse uses. Consequently, I was unable to recreate the ranking list by relying solely on data from Bloomberg and Compustat and instead, use the official ranking list of the previous month and mix it with a custom ranking based upon on publicly available market data.

Specifically, for every last trading day in a month t, I rank the stocks that were part of the official ranking list in the month $t-1$ according to the index methodology based on data from Bloomberg and Compustat. I call these ranks customranks. Then, I calculate the change of these customranks for stock i between the months. As shown in Eq. 1, the difference between the custom ranking between month t and $t-1$, which is based on market data, is then added to the

[3] See p. 40 in the July 2019 edition of the Rendite Magazin of the Börsen-Zeitung.

[4] See https://www.dax-indices.com/document/Resources/Guides/Guide_Equity_Indices.pdf for the detailed up-to-date methodology.

[5] See https://deutsche-boerse.com/dbg-de/media/pressemitteilungen/Deutsche-B-rse-beschlie-t-Regel-nderungen-f-r-Indizes-MDAX-SDAX-und-TecDAX-147700.

official Deutsche Börse rank of the prior month to obtain the final rank that I use to predict index changes.

$$\text{finalrank}_{i,t} = \text{officialrank}_{i,t-1} + (\text{customrank}_{i,t} - \text{customrank}_{i,t-1}) \quad (1)$$

This approach has the advantage that market data must not match Deutsche Börse data exactly in order to make meaningful predictions. For example, if the free float in Bloomberg is different from the free float Deutsche Börse uses, the forecasted ranking would still be accurate as long as the difference stays constant between the months. Furthermore, I do not have to track the whole German stock universe at every rebalancing date because it is given in the ranking list of the previous month.

Fernandes and Mergulhao (2016) use a probit model to forecast FTSE100 changes. I prefer my methodology for the following four reasons. First, the methodology of the FTSE100 is much simpler than the DAX' methodology as it only relies on a ranking of unadjusted market capitalization compared to the many different interdependencies in the DAX' methodology. This eases the regression design and lowers the requirements on data quality significantly. Second, there is only 1 day between the data cutoff and announcement date in the FTSE 100. In contrast, arbitrageurs in the DAX have 3 days between the data cutoff and the announcement date to position for the changes. Consequently, there is no uncertainty with respect to changing prices due to market movements and a probability-driven approach seems unreasonable to me. Third, and in contrast to Fernandes and Mergulhao (2016), I include all changes due to corporate actions to obtain a realistic setup. This is an important distinction because corporate actions can significantly alter the ranking and thus predictions. Fourth, my equity universe is determined ex-ante due to the publicly available ranking list and not constructed ex-post using the actual changes. This makes my setup free of any backward-looking bias.

The historical index constituents and the monthly ranking list are obtained directly from the public section of Deutsche Börse's website.[6] Daily DAX, MDAX, SDAX, and TecDAX index returns and free float for index constituents are obtained from Bloomberg. Daily closing prices and shares outstanding are from Compustat, which is accessed via the Wharton Research Data Services (WRDS). Intraday returns are obtained from the Deutsche Boörse public dataset.[7] I merge Compustat, Deutsche Börse, and Bloomberg data via the stock's ISIN. Total returns are calculated using Compustat's dividend and total return adjustment factors. Table 1 shows the descriptive statistics of the sample at the respective AD for each stock. The total return, i.e., the return before subtracting the benchmark return, is − 0.68% and +0.73% for DAX promotions on the AD and the AD+1, respectively. The mean unadjusted market capitalization ranges from 241 EUR million for demotions from the TecDAX to 13.4 EUR billion for promotions to the DAX. Thus, the separation into the four segments yields insights into the announcement effect with respect to stock size and liquidity.

I do not use a market or multi-factor model, such as the Fama and French (1993) model, to create abnormal returns because oftentimes additions are newly listed companies and hence are not publicly traded long enough to estimate reliable coefficients. Therefore, abnormal returns are calculated as in Eq. 2 whereby R is the total return of stock i at day t and j refers to the respective index of stock i at day t. For example, j would be the DAX if stock i is a pro- or demotion in the DAX.

$$AR_{i,t} = R_{i,t} - R_{j,t} \quad (2)$$

Results and discussion

Table 2 shows the performance of the forecasting model. It correctly predicts about 45% of the actual changes, i.e., 108 out of 228, and 27% of the predicted changes are false positives, i.e., 40 out of 148. The performance is much better in the DAX (71% and 16%) and MDAX (63% and 19%) than in the SDAX (30% and 40%). This is expected because first, the SDAX contains the smallest stocks and hence the data availability and quality are likely to be the poorest. Second, changes due to IPOs or delistings are only predictable if they are already covered in the ranking list of the prior month. That is not always the case and since SDAX constituents are affected most by these corporate actions, predicting them is the most difficult. Fernandes and Mergulhao (2016) arelto the best of my knowledgel the only paper that tries to predict index changes, and the authors focus on an ex-post evaluation. Consequently, there is no benchmark for my model in the literature. Nonetheless, it seems to predict at least the larger index changes reasonably well and thus, empirically establishes that index changes can be predicted before their announcement.

Arbitrageurs who want to profit from a potential announcement effect are likely to trade near the close of the AD because it is closest to the announcement and hence trading on the AD would expose the arbitrageur to less risk than trading before it and holding the potential announcement over several days or even weeks. The cutoff for the data collection to determine index membership is 3 days prior to the announcement and hence abnormal returns on the AD

[6] See https://www.dax-indices.com/ressourcen.

[7] See https://registry.opendata.aws/deutsche-boerse-pds/.

Table 1 Descriptive statistics

	Promotion					Demotion				
	Price	Market Cap	Free Float	Return AD	Return AD+1	Price	Market Cap	Free Float	Return AD	Return AD+1
DAX										
Count	7.00	7	7.00	7.00	7.00	7.00	7	7.00	7.00	7.00
Mean	76.56	13465	82.54	− 0.68	0.73	35.23	6573	72.35	0.46	− 0.75
Std	52.09	6120	18.68	3.01	2.16	21.30	3049	30.58	2.32	3.61
Min	29.57	5158	47.20	− 5.75	− 1.27	8.30	2962	24.97	− 2.72	− 6.39
25%	44.69	9101	74.28	− 1.88	− 1.15	22.82	3997	51.77	− 0.91	− 2.87
50%	61.99	13780	93.00	− 1.26	0.23	28.13	6554	79.99	0.20	− 1.15
75%	85.25	17160	94.56	1.33	2.32	46.14	9054	98.97	2.08	2.19
Max	184.50	22798	99.93	3.33	3.81	72.30	10390	100.00	3.42	3.61
Skewness	1.80	0	− 1.27	− 0.39	0.59	0.73	0	− 0.66	0.00	− 0.34
Kurtosis	3.65	− 1	1.19	0.22	− 1.59	0.30	− 2	− 1.27	− 1.14	− 1.03
MDAX										
Count	35.00	34	34.00	35.00	35.00	35.00	34	34.00	35.00	35.00
Mean	48.16	4694	54.82	− 0.03	0.13	60.65	2442	49.97	− 0.39	− 0.80
Std	83.74	4099	24.68	1.77	1.83	100.81	2718	26.18	2.46	2.67
Min	4.17	442	9.36	− 5.45	− 4.43	1.30	130	4.97	− 7.84	− 6.23
25%	17.47	2064	32.26	− 0.61	− 0.74	10.95	945	29.62	− 0.88	− 1.71
50%	30.21	3263	54.65	0.00	0.37	25.20	1551	45.94	− 0.34	− 0.61
75%	44.50	6063	71.23	0.99	1.24	65.88	3088	65.80	0.60	0.50
Max	510.00	17286	100.00	3.35	2.65	542.65	13002	100.00	7.30	4.74
Skewness	5.21	1	0.27	− 1.00	− 0.88	3.64	2	0.45	− 0.35	− 0.22
Kurtosis	29.20	2	− 0.87	2.11	0.41	15.64	7	− 0.69	4.63	0.28
SDAX										
Count	39.00	39	38.00	40.00	39.00	41.00	41	40.00	41.00	41.00
Mean	29.47	1894	58.98	0.01	0.89	22.26	454	61.08	− 1.01	− 0.98
Std	21.78	2725	27.77	2.07	2.49	20.99	593	26.10	7.14	2.88
Min	2.51	118	9.55	− 5.53	− 3.05	0.04	4	14.37	− 43.90	− 15.22
25%	16.32	314	37.92	− 0.82	− 0.22	4.90	170	42.56	− 1.05	− 1.47
50%	24.61	630	61.10	− 0.03	0.34	15.60	272	55.77	− 0.19	− 0.48
75%	33.92	2410	84.34	1.10	1.45	32.62	438	87.81	0.71	0.08
Max	91.50	12965	100.00	5.35	10.03	73.75	3377	100.00	5.37	3.45
Skewness	1.28	3	− 0.07	− 0.08	1.62	1.14	3	0.08	− 5.64	− 3.28
Kurtosis	1.22	7	− 1.20	0.99	4.19	0.49	15	− 1.14	34.65	15.17
TecDAX										
Count	25.00	24	24.00	25.00	25.00	25.00	23	22.00	25.00	25.00
Mean	31.06	2108	65.99	0.79	1.82	28.07	241	77.29	− 0.19	− 1.33
Std	39.00	7223	26.82	2.47	3.19	59.30	201	17.43	3.38	4.13
Min	3.50	132	10.90	− 3.94	− 4.09	0.25	44	45.87	− 8.65	− 12.01
25%	8.81	206	43.58	− 0.70	− 0.02	3.35	125	64.17	− 1.28	− 2.86
50%	16.49	365	71.17	0.78	1.78	7.00	174	78.02	− 0.30	− 0.52
75%	44.80	579	89.83	2.35	3.51	20.61	317	91.30	1.31	0.72
Max	183.40	35500	100.00	5.28	10.22	294.50	947	100.00	7.19	7.19
Skewness	2.81	5	− 0.61	− 0.05	0.68	4.10	2	− 0.18	− 0.26	− 1.00
Kurtosis	9.49	22	− 0.62	− 0.68	0.96	18.45	6	− 1.27	1.18	2.09

This table shows the descriptive statistics of promotions and demotions. Price is in euro, and Market Cap refers to the unadjusted market capitalization in million euro on the respective announcement day of the index constituent change. The free float is in percent, and the return refers to the daily return in percent. The sample period is from 2010 to 2019

Table 2 Actual and predicted changes by category

Index	Actual changes	Correctly predicted	Not predicted	Wrongly predicted
DAX	14	10	4	2
MDAX	70	44	26	10
SDAX	92	28	64	19
TecDAX	52	26	26	9
Total	228	108	120	40

This table shows the number of predictions of pro- and demotions within the DAX family from 2010 to 2019. Predictions are based on a forecast model described in Sect. 2. Correctly predicted changes are true positives, not predicted false negatives, and wrongly predicted changes are false positives

cannot be due to some type of index gaming, i.e., bidding prices up to push a stock in the larger index, as argued in Zdorovtsov et al. (2017) for the Russell indices. Table 3 displays that abnormal returns of the index changes on that day are relatively small. However, promotions and demotions have the expected signs. That is, promotions (demotions) earn a positive (negative) 33bp (25bp) abnormal return on the AD. While only promotions to the MDAX and TecDAX are at most weakly significant, the evidence on the AD indicates that there seems to be at least some pre-announcement speculation by sophisticated investors. Moreover, the magnitude of the abnormal return of changes that have not been predicted by my forecasting model is even larger, which might be due to chance or due to investors having a superior approach compared to my simple model for predicting index changes.

Figure 2 displays abnormal returns on the AD+1. Correctly predicted changes are in green, actual changes that have not been predicted (false negatives) in red, and falsely predicted changes (false positives) in blue. Table 4 shows the corresponding *p* values. The magnitude of abnormal returns is much larger on the AD+1 than on the AD. Combining all actual promotions (demotions) yields a highly significant positive (negative) 82bp (98bp) whereby the strongest moves occur in TecDAX and SDAX changes. Therefore, the announcement effect of index changes seems to still be present in the German equity market, which is consistent with international findings, such as in Kappou (2018) for the S&P 500 or in Biktimirov and Xu (2019) for the NASDAQ-100.

Motivated by Song and Walkling (2000) who link takeover probabilities to abnormal returns, I investigate whether unexpected changes have higher abnormal returns. That is, I would expect the changes that were not predicted by the model to have larger abnormal returns than changes that were predicted. However, Table 5 shows that the average of the differences between correctly and not predicted changes has no clear message. While, for example, TecDAX demotions that are not predicted earn a much larger negative abnormal return that is not true for MDAX demotions and DAX promotions. Therefore, it does not seem that more surprising index changeslat least in comparison with my modell earn higher abnormal returns.

There are at least two rational theories [see, e.g., Gromb and Vayanos (2010)] that might explain these abnormal returns. First, arbitrageurs might be able to collect abnormal returns because they are exposed to additional risk, i.e., they collect a risk premium. Second, real-world limits to arbitrage, such as funding constraints, trading costs, or short-selling restrictions make real-world exploitation impossible or at least unprofitable.

If arbitrageurs were earning a profit in predictable changes, theory would suggest that these profits reflect a risk premium for bearing the risk of falsely predicting changes resulting in a loss. My empirical hypothesis does not support this. As shown in Table 4, wrongly predicted changes are insignificant and of the same sign as actual changes, which indicates that speculators do not take a large hit by falsely predicted changes. That is, a speculator that is long predicted promotions and short predicted demotions would only lose on average 17bp in the falsely predicted changes compared to a gain of 1.8% in the correctly predicted changes.

The second rational explanation argues that the shown abnormal profits are mostly paper gains but hardly exploitable in practice. Abnormal returns for demotions are hardly larger than for promotions, which indicate that short-sell restrictions are not the cause of these returns. However, especially TecDAX changes are rather small with a median unadjusted market capitalization of 365 million euro and 174 million euro for pro-and demotions, respectively (see Table 1). Thus, they are likely to be more illiquid. Indeed, the results in Table 4 show that abnormal returns are the highest in the TecDAX followed by the SDAX, which changes are mostly smaller stocks, too. While the DAX results have to be treated with care due to the small sample, abnormal returns for MDAX changes are present but considerably smaller than in the TecDAX and SDAX.

To test the influence of stock size on abnormal returns, I regress abnormal returns on the AD+1 on market capitalization. Moreover, I include the VDAX in the regression, which is a proxy for tighter funding constraints (see, e.g., Nagel (2012)). That is, a higher VDAX is related to tighter funding and hence less activity of arbitrageurs. Specifically, I use the level of the VDAX at day t to estimate the following regression whereby D_i^{PM} is a 1 if stock i is a promotion at day t and 0 if it is a demotion at day t.

$$\begin{aligned} \text{return}_{i,t} = \alpha &+ \beta_1 D_{i,t}^{PM} + \beta_2 \text{MarketCap}_{i,t} \\ &+ \beta_3 D_{i,t}^{PM} * \text{MarketCap}_{i,t} \\ &+ \beta_4 \text{VDAX}_t + \beta_5 D_{i,t}^{PM} * \text{VDAX}_t + \epsilon_{i,t} \end{aligned} \tag{3}$$

Table 3 Abnormal returns on the AD by category—statistics

	Promotion				Demotion			
	Actual changes	Correctly predicted	Not predicted	Wrongly predicted	Actual changes	Correctly predicted	Not predicted	Wrongly predicted
DAX								
Mean	− 0.90	− 0.80	− 1.15	− 0.04	0.24	0.58	− 0.60	0.28
	(0.25)	(0.44)	(0.54)	(–)	(0.83)	(0.72)	(0.21)	(–)
Median	0.06	0.06	− 1.15	− 0.04	− 0.40	− 0.27	− 0.60	0.28
	(0.50)	(0.69)	(0.65)	(0.32)	(0.87)	(0.69)	(0.18)	(0.32)
N	7	5	2	1	7	5	2	1
MDAX								
Mean	0.52**	0.42	0.70**	0.89	0.17	0.50	− 0.33	− 1.76
	(0.03)	(0.19)	(0.04)	(0.18)	(0.59)	(0.26)	(0.43)	(0.33)
Median	0.36**	0.02	0.98*	1.04	− 0.11	0.13	− 0.14	− 1.12
	(0.04)	(0.35)	(0.06)	(0.14)	(0.92)	(0.50)	(0.51)	(0.25)
N	35	23	12	4	35	21	14	6
SDAX								
Mean	0.22	0.29	0.20	0.13	− 0.83	0.01	− 1.37	− 1.23
	(0.40)	(0.60)	(0.52)	(0.85)	(0.47)	(0.99)	(0.46)	(0.14)
Median	0.13	0.42	0.11	0.44	− 0.43	− 0.52	0.32	− 0.79
	(0.45)	(0.51)	(0.63)	(0.88)	(0.69)	(0.44)	(0.80)	(0.35)
N	40	10	30	10	41	16	25	6
TecDAX								
Mean	0.60	0.16	1.00**	− 1.00	0.00	0.48	− 0.51	0.13
	(0.13)	(0.80)	(0.05)	(0.65)	(1.00)	(0.49)	(0.59)	(0.86)
Median	0.34	0.38	0.34*	− 0.04	0.11	− 0.10	0.15	0.01
	(0.15)	(0.81)	(0.09)	(0.71)	(0.82)	(0.60)	(0.81)	(0.59)
N	25	12	13	4	25	13	12	3
Total								
Mean	0.33**	0.21	0.44**	0.04	− 0.25	0.36	− 0.87	− 1.08
	(0.04)	(0.39)	(0.04)	(0.94)	(0.60)	(0.24)	(0.33)	(0.13)
Median	0.25**	0.19	0.34**	0.40	− 0.14	− 0.27	− 0.11	− 0.49
	(0.04)	(0.38)	(0.05)	(0.52)	(0.92)	(0.75)	(0.71)	(0.16)
N	107	50	57	19	108	55	53	16

This table shows mean and median abnormal returns of pro- and demotions within the DAX family from 2010 to 2019 on the announcement date. Actual changes refer to all actual index changes, correctly predicted changes refer to actual changes that were predicted by the forecasting model described in Sect. 2, not predicted refer to actual changes that were not predicted, and wrongly predicted refers to predicted changes that were not actual changes. The abnormal return is the total return of a stock minus its respective index total return. The numbers in brackets refer to the *p* value of a two-sided *t* test for the mean and the Wilcoxon (1945) *p* value for the median

*Signals significance at the 10%-level, **at the 5%-level, and ***at the 1%-level

The constant and the promotion dummy in Table 6 are statistically significant and have the expected signs, i.e., demotions (promotions) earn a negative (positive) abnormal return. Market capitalization and its interaction terms with the promotion dummy are statistically insignificant but have the expected signs, too. That is, larger stocks tend to have smaller abnormal returns. This could be due to market frictions, such as illiquidity or due to behavioral biases, such as the lack of investor attention (see Barber and Odean (2008) or Da et al. (2011)) as larger stocks are more likely to receive investor's attention. Since Table 6 also shows that a higher VDAX is related to smaller abnormal returns, funding constraints do not seem to drive the results.

Although the results indicate that abnormal returns are partly driven by size, it does not make them unexploitable for the following reasons. First, although smaller in magnitude, abnormal returns are still present in the larger DAX and MDAX indices. Second, index trackers are likely to already hold demotions before their announcement and buy promotions after their announcement. Since they implement the index changes regardless of stock size, they should consider shifting their trading

Table 4 Abnormal returns on the AD+1 by category—statistics

	Promotion				Demotion			
	Actual changes	Correctly predicted	Not predicted	Wrongly predicted	Actual changes	Correctly predicted	Not predicted	Wrongly predicted
DAX								
Mean	0.33	0.49	− 0.07	1.24	− 1.15	− 1.63	0.06	0.63
	(0.53)	(0.51)	(0.91)	(–)	(0.29)	(0.29)	(0.94)	(–)
Median	0.41	0.90	− 0.07	1.24	− 0.77	− 0.93	0.06	0.63
	(0.40)	(0.35)	(0.65)	(0.32)	(0.31)	(0.35)	(0.65)	(0.32)
N	7	5	2	1	7	5	2	1
MDAX								
Mean	0.27	0.31	0.19	− 2.17	− 0.66*	− 0.10	− 1.50**	1.34
	(0.31)	(0.33)	(0.71)	(0.15)	(0.08)	(0.84)	(0.01)	(0.34)
Median	0.36	0.36	0.58	− 2.06*	− 0.77*	− 0.56	− 0.91***	0.95
	(0.16)	(0.20)	(0.43)	(0.07)	(0.08)	(0.85)	(0.01)	(0.25)
N	35	23	12	4	35	21	14	6
SDAX								
Mean	1.00**	0.94	1.03*	0.27	− 0.87*	− 0.74	− 0.95	0.52
	(0.02)	(0.14)	(0.07)	(0.44)	(0.06)	(0.15)	(0.18)	(0.43)
Median	0.35***	1.14	0.32**	0.19	− 0.41**	− 0.29	− 0.85*	0.08
	(0.01)	(0.14)	(0.04)	(0.39)	(0.02)	(0.15)	(0.09)	(0.75)
N	39	10	29	10	41	16	25	6
TecDAX								
mean	1.42**	0.54	2.24**	3.68	− 1.54**	− 3.17**	0.22	− 0.23
	(0.02)	(0.39)	(0.03)	(0.18)	(0.04)	(0.01)	(0.78)	(0.38)
median	1.06**	0.01	2.65**	2.08*	− 0.89**	− 1.93**	− 0.22	− 0.20
	(0.03)	(0.53)	(0.04)	(0.07)	(0.04)	(0.01)	(1.00)	(0.29)
N	25	12	13	4	25	13	12	3
Total								
Mean	0.82***	0.51**	1.09***	0.52	− 0.98***	− 1.15***	− 0.79**	0.69
	(0.00)	(0.04)	(0.01)	(0.44)	(0.00)	(0.00)	(0.05)	(0.20)
Median	0.50***	0.50**	0.53***	0.33	− 0.73***	− 0.77***	− 0.56***	0.17
	(0.00)	(0.03)	(0.00)	(0.38)	(0.00)	(0.01)	(0.00)	(0.20)
N	106	50	56	19	108	55	53	16

This table shows mean and median abnormal returns of pro- and demotions within the DAX family from 2010 to 2019 on the day after the AD+1. Actual changes refer to all actual index changes, correctly predicted changes refer to actual changes that were predicted by the forecasting model described in Sect. 2, not predicted refer to actual changes that were not predicted, and wrongly predicted refers to predicted changes that were not actual changes. The abnormal return is the total return of a stock minus its respective index total return. The numbers in brackets refer to the *p* value of a two-sided *t* test for the mean and the Wilcoxon (1945) *p* value for the median

*Signals significance at the 10%-level, **at the 5%-level, and ***at the 1%-level

partly before the announcement date. Instead, Green and Jame (2011) show that they primarily trade after the announcement to avoid tracking error risk (Blume and Edelen 2004). Therefore, it seems rational for risk-averse index trackers to avoid profitable pre-announcement trading to minimize the tracking error. Nonetheless, in an efficient market, arbitrageurs that are not constrained by tracking error should step in and collect these profitable opportunities.

Finally, I show that my results are also economically meaningful. A trading strategy that could 100% correctly predict index changes in the DAX family and equally weighting longs (shorts) promotions (demotions) at the closing price on the AD and closes the position at the closing price on the AD+1 would have yielded a cumulative return of 72.35% during 2010 to 2019. Figure 3 shows that the return comes primarily from the long side with very little drawdowns, yielding an annualized

Table 5 Correctly predicted vs. not predicted changes on the AD+1

	DAX promotions	DAX demotions	MDAX promotions	MDAX demotions
Mean	0.56	− 1.69	0.12	1.41*
	(0.54)	(0.31)	(0.85)	(0.06)
Median	0.97	− 0.99	− 0.22	0.35
	(0.44)	(0.25)	(0.94)	(0.11)
	SDAX promotions	SDAX demotions	TecDAX promotions	TecDAX demotions
Mean	− 0.09	0.21	− 1.70	− 3.38**
	(0.91)	(0.81)	(0.14)	(0.02)
Median	0.82	0.56	− 2.63	− 1.72**
	(0.44)	(0.67)	(0.14)	(0.02)

This table shows mean and median of the difference between abnormal returns of actual changes that were correctly predicted and abnormal returns of actual changes that were not predicted by my model. The changes refer to index changes within the DAX family from 2010 to 2019. The abnormal return is the total return of a stock minus its respective index total return on the AD+1. The numbers in brackets refer to the *p* value of a Welch (1938) test for the mean and the Mann-Whitney test *p* value for the median

*Signals significance at the 10%-level, **at the 5%-level, and ***at the 1%-level

Table 6 Cross-sectional regression

	(I)	(II)	(III)
Constant	− 1.02***	− 1.00***	− 1.00***
	(0.00)	(0.00)	(0.00)
D^{PM}	1.85***	1.87***	1.87***
	(0.00)	(0.00)	(0.00)
Market Cap		0.02	0.02
		(0.86)	(0.84)
D^{PM}*Market Cap		− 0.06	− 0.03
		(0.62)	(0.62)
VDAX			0.01
			(0.51)
D^{PM}*VDAX			− 0.03
			(0.62)
N	209	209	209
Adj. R^2	0.106	0.1	0.096

This table shows the results of the regression in Eq. 3. The dependent variable is the abnormal return in percent of stock *i* at the AD+1 *t* and Market Cap is the unadjusted market capitalization in billion euro. Market Cap and VDAX are centered. Standard errors are clustered by date, and *p* values are given in brackets.

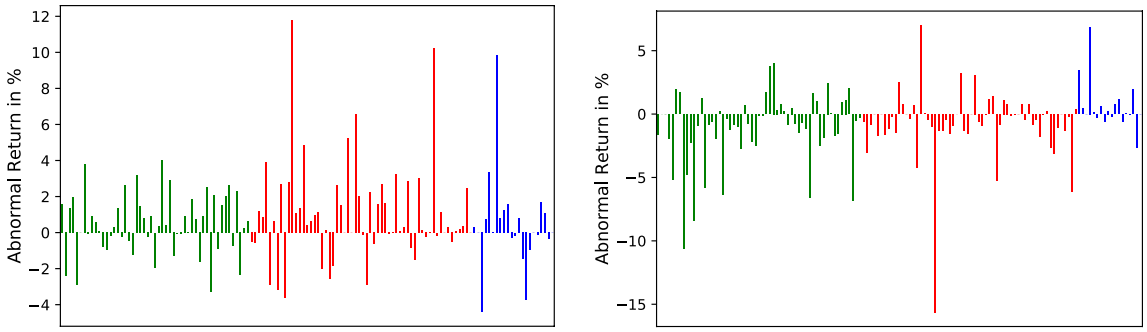
*Signals significance at the 10%-level, **at the 5%-level, and ***at the 1%-level

Sharpe ratio of 1.10. Figure 4 shows the performance of the strategy if predictions have not been made with perfect foresight but according to my model, which is free of any backward-looking bias and thus approximates the real world. The strategy would have yielded a yearly arithmetic average return of 5.61% with a Sharpe ratio of 0.83. It is important to understand that this return is achieved by being invested only four times a year. If an investor had the opportunity to invest in such a strategy during ever trading day in a year, she would earn a Sharpe ratio of 6.59.

Table 7 displays the performance of trading on predictions by AD+1. It shows that in March 2014, the strategy made a particularly large gain of 10.71% by wrongly predicting the promotion of Software AG into the TecDAX and thus buying it and 5.51% by correctly predicting the demotion of ADVA AG and thus shorting. However, apart from this event, the magnitude of the trade is relatively homogeneous and hence the mean and median by date and overall are relatively similar, i.e., for the long–short strategy 1.73% and 1.74% per announcement date.

Conclusion

I show that index changes are predictable and still deliver sizeable abnormal returns. The abnormal returns for index changes following their announcement are large, not related to funding constraints, and even present in the largest stocks and most recent index changes. Considering that similar announcement effects are also found internationally (see Kappou et al. (2010) or Biktimirov and Xu (2019)), most index methodologies are rule-based, and index



(I) Promotions (II) Demotions

Fig. 2 Abnormal returns on the AD+1 by category. This figure shows abnormal returns of promotions and demotions within the DAX Index family from 2010 to 2019. Green refers to promotions that have been predicted correctly (true positives) by the forecasting model described in Sect. 2, in red are actual changes that have not been predicted (false negatives) and in blue are changes that have been wrongly predicted to be changes (false positives)

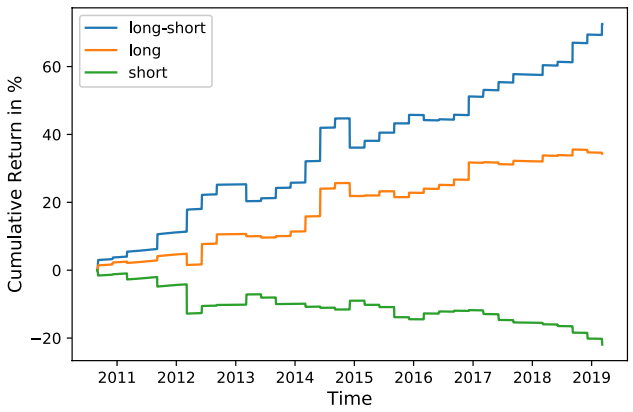


Fig. 3 Cumulative return of actual changes. This table shows the cumulative total return of an investment strategy that longs (shorts) actual DAX, MDAX, SDAX, and TecDax promotions (demotions) on the close of the AD and closes the position at the close of the AD+1. The strategy creates equally weighted portfolios of all the index changes per AD . The sample period is 2010 to 2019

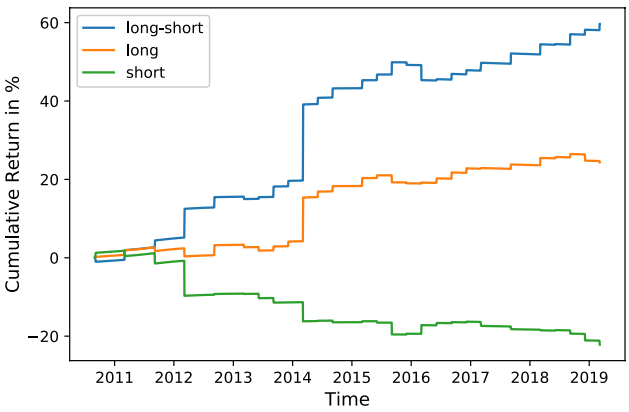


Fig. 4 Cumulative return of predicted changes. This table shows the cumulative total return of an investment strategy that longs (shorts) predicted DAX, MDAX, SDAX, and TecDax promotions (demotions) on the close of the AD and closes the position at the close of the AD+1. The strategy creates equally weighted portfolios of all the index changes per AD. Predictions are made based on a forecast model described in Sect. 2, and the sample period is 2010 to 2019

announcements happen on different dates, a strategy that trades on predicted index changes globally is likely to earn high abnormal returns. This supports theories that arbitrageurs might forgo profitable opportunities due to, for example, slow-moving capital restrictions (see Duffie (2010)).

My results also have implications for practitioners. Index funds usually implement index changes after the announcement (Green and Jame 2011) because front-running announcements expose them to great tracking error risk (Blume and Edelen 2004). However, trading especially smaller changes earlier might protect their shareholders from earning negative abnormal returns in demotions and missing out on positive abnormal returns of promotions, which ultimately resembles a hidden cost for passive investors (Petajisto 2011) and causes underperformance (Gastineau 2004).

Table 7 Return of predicted changes by announcement date + 1

AD+1	Mean			Median		
	Promotions	Demotions	Long–short	Promotions	Demotions	Long–short
2010-09-06	0.23	1.26	− 1.04	1.01	1.26	− 0.25
2011-03-04	1.13	− 1.34	2.47	1.13	− 1.34	2.47
2011-09-06	− 0.92	− 2.60	1.68	0.06	− 2.75	2.81
2012-03-06	− 2.02	− 9.00	6.99	− 2.02	− 9.00	6.99
2012-09-06	2.55	0.21	2.34	2.65	1.97	0.68
2013-03-07	− 0.63	− 0.10	− 0.53	− 0.63	− 0.10	− 0.53
2013-06-06	− 0.87	− 1.24	0.37	− 0.87	− 1.24	0.37
2013-09-05	0.98	− 1.31	2.29	0.98	− 1.31	2.29
2013-12-05	1.17	0.00	1.17	1.17	0.00	1.17
2014-03-06	10.71	− 5.51	16.22	10.71	− 5.51	16.22
2014-06-05	1.22	0.08	1.13	1.22	0.08	1.13
2014-09-04	1.14	− 0.51	1.66	0.37	− 0.52	0.88
2015-03-05	1.71	0.29	1.42	2.24	0.58	1.66
2015-06-04	0.58	− 0.43	1.00	0.58	− 0.43	1.00
2015-09-04	− 1.48	− 3.61	2.13	− 1.38	− 3.98	2.60
2015-12-04	− 0.19	0.25	− 0.44	0.02	− 0.11	0.13
2016-03-04	0.19	2.75	− 2.57	− 0.11	2.41	− 2.53
2016-06-06	0.97	0.74	0.23	0.97	0.74	0.23
2016-09-06	1.33	0.33	1.00	1.33	0.33	1.00
2016-12-06	0.94	0.21	0.72	0.94	0.21	0.72
2017-03-06	0.14	− 1.22	1.36	0.14	− 1.22	1.36
2017-09-06	0.91	− 0.84	1.75	0.91	− 0.84	1.75
2018-03-06	1.51	− 0.20	1.71	1.73	0.46	1.26
2018-06-06	0.27	0.16	0.12	0.72	0.13	0.60
2018-09-06	0.69	− 1.03	1.72	1.32	− 0.44	1.76
2018-12-06	− 1.26	− 2.07	0.81	− 1.26	− 2.07	0.81
2019-03-06	− 0.26	− 1.27	1.01	− 0.28	− 0.70	0.42
Total Mean	0.77	− 0.96	1.73	0.88	− 0.87	1.74
Total Median	0.73	− 0.47	1.27	0.89	− 0.43	1.07

This table shows the mean and median total returns of an investment strategy that longs (shorts) predicted DAX, MDAX, SDAX, and TecDax promotions (demotions) on the close of the AD and closes the position at the close of the AD+1. Predictions are made based on a forecast model described in Sect. 2

Acknowledgments Open Access funding provided by Projekt DEAL.

Appendix

See Tables 8, 9, 10, 11, 12, and 13

Table 8 Changes by Date (I)

Announcement date	Index	Stock	ISIN	Result
2018-09-05	DAX	WIRECARD AG	DE0007472060	Correctly predicted
2018-09-05	DAX	COMMERZBANK AG KONV.	DE000CBK1001	Correctly predicted
2018-03-05	DAX	COVESTRO AG O.N.	DE0006062144	Correctly predicted
2018-03-05	DAX	PROSIEBENSAT.1 NA O.N.	DE000PSM7770	Correctly predicted
2016-03-03	DAX	PROSIEBENSAT.1 NA O.N.	DE000PSM7770	Correctly predicted
2016-03-03	DAX	K+S AG NA O.N.	DE000KSAG888	Correctly predicted
2015-09-03	DAX	DT.ANNINGTON IMM.SE	DE000A1ML7J1	Correctly predicted
2015-09-03	DAX	LANXESS AG	DE0005470405	Correctly predicted
2015-03-04	DAX	PROSIEBENSAT.1 NA O.N.	DE000PSM7770	Wrongly predicted
2015-03-04	DAX	LANXESS AG	DE0005470405	Wrongly predicted
2012-09-05	DAX	CONTINENTAL AG O.N.	DE0005439004	Correctly predicted
2012-09-05	DAX	LANXESS AG	DE0005470405	Not predicted
2012-09-05	DAX	MAN SE ST O.N.	DE0005937007	Correctly predicted
2012-09-05	DAX	METRO AG ST O.N.	DE0007257503	Not predicted
2010-06-04	DAX	HEIDELBERGCEMENT AG O.N.	DE0006047004	Not predicted
2010-06-04	DAX	SALZGITTER AG O.N.	DE0006202005	Not predicted
2019-03-05	MDAX	KNORR-BREMSE AG INH O.N.	DE000KBX1006	Correctly predicted
2019-03-05	MDAX	DIALOG SEMICOND. LS-,10	GB0059822006	Correctly predicted
2019-03-05	MDAX	GRENKE AG NA O.N.	DE000A161N30	Wrongly predicted
2019-03-05	MDAX	SALZGITTER AG O.N.	DE0006202005	Correctly predicted
2019-03-05	MDAX	SCHAEFFLER AG INH. VZO	DE000SHA0159	Not predicted
2019-03-05	MDAX	WACKER CHEMIE O.N.	DE000WCH8881	Wrongly predicted
2019-03-05	MDAX	NORMA GROUP SE NA O.N.	DE000A1H8BV3	Wrongly predicted
2018-12-05	MDAX	CARL-ZEISS MEDITEC AG	DE0005313704	Correctly predicted
2018-12-05	MDAX	CTS EVENTIM AG	DE0005470306	Correctly predicted
2018-09-05	MDAX	ALSTRIA OFFICE REIT-AG	DE000A0LD2U1	Wrongly predicted
2018-09-05	MDAX	CECONOMY AG ST O.N.	DE0007257503	Wrongly predicted
2018-06-05	MDAX	PUMA AG	DE0006969603	Correctly predicted
2018-06-05	MDAX	DELIVERY HERO AG NA O.N.	DE000A2E4K43	Correctly predicted
2018-06-05	MDAX	SCOUT24 AG NA	DE000A12DM80	Correctly predicted
2018-06-05	MDAX	ALSTRIA OFFICE REIT AG	DE000A0LD2U1	Correctly predicted
2018-06-05	MDAX	KRONES AG O.N.	DE0006335003	Correctly predicted
2018-06-05	MDAX	STADA ARZNEIMITT.VNA O.N.	DE0007251803	Not predicted
2018-06-05	MDAX	CECONOMY AG ST O.N.	DE0007257503	Wrongly predicted
2018-03-05	MDAX	ROCKET INTERNET SE	DE000A12UKK6	Correctly predicted
2018-03-05	MDAX	AROUNDTOWN EO-,01	LU1673108939	Correctly predicted
2018-03-05	MDAX	SUEDZUCKER MA./OCHS. O.N.	DE0007297004	Correctly predicted
2018-03-05	MDAX	STEINHOFF INT.HLDG.EO-,50	NL0011375019	Correctly predicted
2017-09-05	MDAX	GRAND CITY PROPERT.EO-,10	LU0775917882	Correctly predicted
2017-09-05	MDAX	METRO WHOLE.FOOD ST O.N.	DE000BFB0019	Not predicted
2017-09-05	MDAX	BILFINGER BERGER AG	DE0005909006	Correctly predicted
2017-09-05	MDAX	RATIONAL AG	DE0007010803	Not predicted
2016-12-05	MDAX	UNIPER SE NA.	DE000UNSE018	Correctly predicted
2016-12-05	MDAX	INNOGY SE INH. O.N.	DE000A2AADD2	Not predicted
2016-12-05	MDAX	GILDEMEISTER AG O.N.	DE0005878003	Correctly predicted
2016-12-05	MDAX	RHOEN-KLINIKUM O.N.	DE0007042301	Not predicted
2016-06-03	MDAX	SCHAEFFLER AG INH. VZO	DE000SHA0159	Correctly predicted
2016-06-03	MDAX	WINCOR NIXDORF O.N.	DE000A0CAYB2	Correctly predicted
2016-03-03	MDAX	ALSTRIA OFFICE REIT AG	DE000A0LD2U1	Correctly predicted
2016-03-03	MDAX	STEINHOFF INT.HLDG.EO-,50	NL0011375019	Not predicted
2016-03-03	MDAX	SCHAEFFLER AG INH. VZO	DE000SHA0159	Wrongly predicted
2016-03-03	MDAX	ELRINGKLINGER AG NA O.N.	DE0007856023	Correctly predicted
2016-03-03	MDAX	KLOECKNER + CO SE NA	DE000KC01000	Correctly predicted

This table shows actual and predicted pro- and demotions within the DAX family. Correctly predicted changes refer to actual changes that were predicted by the forecasting model described in Sect. 2, not predicted refer to actual changes that were not predicted, and wrongly predicted refers to predicted changes that were not actual changes

Table 9 Changes by Date (II)

Announcement date	Index	Stock	ISIN	Result
2015-12-03	MDAX	STROEER OUT-OF-H.AG	DE0007493991	Correctly predicted
2015-12-03	MDAX	COVESTRO AG O.N.	DE0006062144	Not predicted
2015-12-03	MDAX	KABEL DT. HOLDING AG O.N.	DE000KD88880	Not predicted
2015-12-03	MDAX	MAN SE ST O.N.	DE0005937007	Not predicted
2015-12-03	MDAX	ELRINGKLINGER AG NA O.N.	DE0007856023	Wrongly predicted
2015-09-03	MDAX	HELLA KGAA HUECK+CO. O.N.	DE000A13SX22	Correctly predicted
2015-09-03	MDAX	DT.PFANDBRIEFBK AG	DE0008019001	Not predicted
2015-09-03	MDAX	GERRY WEBER INTERNAT.O.N.	DE0003304101	Correctly predicted
2015-09-03	MDAX	CELESIO AG NAM. O.N.	DE000CLS1001	Not predicted
2015-06-03	MDAX	ZALANDO SE	DE000ZAL1111	Not predicted
2015-06-03	MDAX	BERTRANDT AG O.N.	DE0005232805	Not predicted
2014-09-03	MDAX	DT.ANNINGTON IMM.SE	DE000A1ML7J1	Correctly predicted
2014-09-03	MDAX	KION GROUP AG	DE000KGX8881	Not predicted
2014-09-03	MDAX	RATIONAL AG	DE0007010803	Correctly predicted
2014-09-03	MDAX	SGL CARBON SE O.N.	DE0007235301	Not predicted
2013-09-04	MDAX	EVONIK INDUSTRIES AG	DE000EVNK013	Correctly predicted
2013-09-04	MDAX	OSRAM LICHT AG NA O.N.	DE000LED4000	Not predicted
2013-09-04	MDAX	RTL GROUP	LU0061462528	Not predicted
2013-09-04	MDAX	BAYWA AG VINK.NA. O.N.	DE0005194062	Correctly predicted
2013-09-04	MDAX	PUMA AG	DE0006969603	Not predicted
2013-09-04	MDAX	SGL CARBON SE O.N.	DE0007235301	Not predicted
2013-06-05	MDAX	LEG IMMOBILIEN AG	DE000LEG1110	Correctly predicted
2013-06-05	MDAX	HAMBURG.HAFEN U.LOG.A-SP	DE000A0S8488	Correctly predicted
2013-03-06	MDAX	NORMA GROUP AG NA O.N.	DE000A1H8BV3	Correctly predicted
2013-03-06	MDAX	VOSSLOH AG O.N.	DE0007667107	Correctly predicted
2012-09-05	MDAX	TAG IMMOBILIEN AG	DE0008303504	Correctly predicted
2012-09-05	MDAX	DEUTZ AG O.N.	DE0006305006	Correctly predicted
2012-03-05	MDAX	DUERR AG O.N.	DE0005565204	Correctly predicted
2012-03-05	MDAX	HEIDELBERG.DRUCKMA.O.N.	DE0007314007	Correctly predicted
2011-09-05	MDAX	GSW IMMOBILIEN AG	DE000GSW1111	Correctly predicted
2011-09-05	MDAX	KUKA AG	DE0006204407	Correctly predicted
2011-09-05	MDAX	DEUTZ AG O.N.	DE0006305006	Not predicted
2011-09-05	MDAX	ALSTRIA OFFICE REIT AG	DE000A0LD2U1	Wrongly predicted
2011-09-05	MDAX	PRAKTIKER BAU-U.H.HLDG ON	DE000A0F6MD5	Correctly predicted
2011-09-05	MDAX	DEMAG CRANES AG	DE000DCAG010	Correctly predicted
2011-09-05	MDAX	IVG IMMOBILIEN AG O.N.	DE0006205701	Not predicted
2011-09-05	MDAX	GAGFAH S.A. NOM. EO 1,25	LU0269583422	Wrongly predicted
2010-09-03	MDAX	A.SPRINGER AG VNA	DE0005501357	Correctly predicted
2010-09-03	MDAX	BAUER AG	DE0005168108	Correctly predicted
2010-06-04	MDAX	BRENNTAG AG	DE000A1DAHH0	Not predicted
2010-06-04	MDAX	KABEL DT. HOLDING AG O.N.	DE000KD88880	Not predicted
2010-06-04	MDAX	PFLEIDERER AG	DE0006764749	Not predicted
2010-06-04	MDAX	MLP AG	DE0006569908	Not predicted
2019-03-05	SDAX	AMADEUS FIRE AG	DE0005093108	Correctly predicted
2019-03-05	SDAX	ADVA AG OPT.NETW.O.N.	DE0005103006	Correctly predicted
2019-03-05	SDAX	VARTA AG O.N.	DE000A0TGJ55	Correctly predicted
2019-03-05	SDAX	BAYWA AG NA.	DE0005194005	Not predicted
2019-03-05	SDAX	MEDIGENE AG NA O.N.	DE000A1X3W00	Correctly predicted
2019-03-05	SDAX	TELE COLUMBUS AG	DE000TCAG172	Correctly predicted
2019-03-05	SDAX	GILDEMEISTER AG O.N.	DE0005878003	Correctly predicted
2019-03-05	SDAX	VTG AG O.N.	DE000VTG9999	Not predicted

This table shows actual and predicted pro- and demotions within the DAX family. Correctly predicted changes refer to actual changes that were predicted by the forecasting model described in Sect. 2, not predicted refer to actual changes that were not predicted, and wrongly predicted refers to predicted changes that were not actual changes

Table 10 Changes by Date (III)

Announcement date	Index	Stock	ISIN	Result
2018-12-05	SDAX	KNORR-BREMSE AG INH O.N.	DE000KBX1006	Not predicted
2018-12-05	SDAX	ADVA OPT.NETW.SE O.N.	DE0005103006	Wrongly predicted
2018-12-05	SDAX	BAYWA AG VINK.NA. O.N.	DE0005194062	Correctly predicted
2018-09-05	SDAX	BEFESA S.A.ORD.REG. EO 1	LU1704650164	Wrongly predicted
2018-09-05	SDAX	ELRINGKLINGER AG NA O.N.	DE0007856023	Wrongly predicted
2018-06-05	SDAX	DWS GROUP GMBH+CO.KGAA ON	DE000DWS1007	Not predicted
2018-06-05	SDAX	HELLOFRESH SE INH O.N.	DE000A161408	Not predicted
2018-06-05	SDAX	AUMANN AG	DE000A2DAM03	Not predicted
2018-06-05	SDAX	DIEBOLD INC. DL 1,25	US2536511031	Not predicted
2018-06-05	SDAX	BET-AT-HOME.COM AG O.N.	DE000A0DNAY5	Not predicted
2018-03-05	SDAX	CORESTATE CAPITAL HLDG	LU1296758029	Correctly predicted
2018-03-05	SDAX	JOST WERKE AG INH. O.N.	DE000JST4000	Not predicted
2018-03-05	SDAX	GERRY WEBER INTERNAT.O.N.	DE0003304101	Correctly predicted
2018-03-05	SDAX	MLP AG	DE0006569908	Not predicted
2017-09-05	SDAX	AROUNDTOWN EO-,01	LU1673108939	Not predicted
2017-09-05	SDAX	DELIVERY HERO AG NA O.N.	DE000A2E4K43	Not predicted
2017-09-05	SDAX	AROUNDTOWN PROP.HD.EO-,01	CY0105562116	Wrongly predicted
2017-09-05	SDAX	AMADEUS FIRE AG	DE0005093108	Correctly predicted
2017-09-05	SDAX	WCM BET.GRD.AG O.N.	DE000A1X3X33	Not predicted
2017-09-05	SDAX	BAYWA AG NA.	DE0005194005	Not predicted
2017-06-06	SDAX	GRAND CITY PROPERT.EO-,10	LU0775917882	Not predicted
2017-06-06	SDAX	TIPP24 SE EO 1	GB00BHD66J44	Not predicted
2016-12-05	SDAX	LEIFHEIT AG O.N.	DE0006464506	Not predicted
2016-12-05	SDAX	FERRATUM FINLAND OY	FI4000106299	Not predicted
2016-09-05	SDAX	LEIFHEIT AG O.N.	DE0006464506	Correctly predicted
2016-09-05	SDAX	COMDIRECT BANK AG	DE0005428007	Correctly predicted
2016-03-03	SDAX	WUESTENROT+WUERTT.AG O.N.	DE0008051004	Not predicted
2016-03-03	SDAX	HAPAG-LLOYD NA. O.N.	DE000HLAG475	Not predicted
2016-03-03	SDAX	WASHTEC AG O.N.	DE0007507501	Not predicted
2016-03-03	SDAX	MLP AG	DE0006569908	Correctly predicted
2016-03-03	SDAX	SIXT AG VZO O.N.	DE0007231334	Not predicted
2016-03-03	SDAX	HORNBACH HOLD.ST O.N.	DE0006083405	Not predicted
2016-03-03	SDAX	SCHALTBAU HOLDING O.N	DE0007170300	Not predicted
2015-12-03	SDAX	WCM BET.GRD.AG O.N.	DE000A1X3X33	Correctly predicted
2015-12-03	SDAX	SCOUT24 AG NA	DE000A12DM80	Not predicted
2015-12-03	SDAX	SCHAEFFLER AG INH. VZO	DE000SHA0159	Not predicted
2015-12-03	SDAX	HYPOPORT AG	DE0005493365	Not predicted
2015-12-03	SDAX	WASHTEC AG O.N.	DE0007507501	Wrongly predicted
2015-12-03	SDAX	GESCO AG NA O.N.	DE000A1K0201	Correctly predicted
2015-12-03	SDAX	TOM TAILOR HOLDG.AG	DE000A0STST2	Correctly predicted
2015-12-03	SDAX	SHW AG	DE000A1JBPV9	Not predicted
2015-09-03	SDAX	SIXT AG VZO O.N.	DE0007231334	Not predicted
2015-09-03	SDAX	SIXT LEASING O.N.	DE000A0DPRE6	Wrongly predicted

Table 10 (continued)

Announcement date	Index	Stock	ISIN	Result
2015-09-03	SDAX	VILLEROY + BOCH AG VZ	DE0007657231	Correctly predicted
2015-06-03	SDAX	TELE COLUMBUS AG	DE000TCAG172	Correctly predicted
2015-06-03	SDAX	ADLER REAL ESTATE AG	DE0005008007	Not predicted
2015-06-03	SDAX	KOENIG + BAUER AG ST O.N.	DE0007193500	Not predicted
2015-06-03	SDAX	LEIFHEIT AG O.N.	DE0006464506	Wrongly predicted
2015-06-03	SDAX	SURTECO SE	DE0005176903	Correctly predicted
2015-06-03	SDAX	DELTICOM AG	DE0005146807	Not predicted
2015-06-03	SDAX	BAUER AG	DE0005168108	Not predicted
2015-06-03	SDAX	DO DT.OFFICE AG O.N.	DE000PRME020	Wrongly predicted
2015-03-04	SDAX	WESTGRUND AG	DE000A0HN4T3	Wrongly predicted
2015-03-04	SDAX	SURTECO SE	DE0005176903	Wrongly predicted

This table shows actual and predicted pro- and demotions within the DAX family. Correctly predicted changes refer to actual changes that were predicted by the forecasting model described in Sect. 2, not predicted refer to actual changes that were not predicted, and wrongly predicted refers to predicted changes that were not actual changes

Table 11 Changes by Date (IV)

Announcement date	Index	Stock	ISIN	Result
2014-12-03	SDAX	ZALANDO SE	DE000ZAL1111	Not predicted
2014-12-03	SDAX	CENTROTEC SUSTAINABLE O.N	DE0005407506	Not predicted
2014-09-03	SDAX	STABILUS S.A. INH. EO-,01	LU1066226637	Correctly predicted
2014-09-03	SDAX	BRAAS MONIER BD.GR.EO-,01	LU1075065190	Not predicted
2014-09-03	SDAX	HAWESKO HOLDING AG SVG	DE0006042708	Correctly predicted
2014-09-03	SDAX	BALDA AG O.N.	DE0005215107	Not predicted
2014-06-04	SDAX	HORNBACH HOLD.VZO O.N.	DE0006083439	Not predicted
2014-06-04	SDAX	BORUSSIA DORTMUND	DE0005493092	Not predicted
2014-06-04	SDAX	VTG AG O.N.	DE000VTG9999	Wrongly predicted
2014-06-04	SDAX	KOENIG + BAUER AG ST O.N.	DE0007193500	Correctly predicted
2014-06-04	SDAX	AIR BERLIN PLC EO -,25	GB00B128C026	Not predicted
2014-03-05	SDAX	SURTECO SE	DE0005176903	Not predicted
2014-03-05	SDAX	CAPITAL STAGE AG	DE0006095003	Not predicted
2014-03-05	SDAX	H+R WASAG AG	DE0007757007	Not predicted
2014-03-05	SDAX	VTG AG O.N.	DE000VTG9999	Not predicted
2013-12-04	SDAX	SHW AG	DE000A1JBPV9	Correctly predicted
2013-12-04	SDAX	MVV ENERGIE AG O.N.	DE000A0H52F5	Correctly predicted
2013-09-04	SDAX	KION GROUP AG	DE000KGX8881	Not predicted
2013-09-04	SDAX	DT.ANNINGTON IMM.SE	DE000A1ML7J1	Not predicted
2013-09-04	SDAX	PRAKTIKER BAU-U.H.HLDG ON	DE000A0F6MD5	Not predicted
2013-09-04	SDAX	HIGHLIGHT CMNCTS INH.SF 1	CH0006539198	Not predicted
2013-09-04	SDAX	SMT SCHARF AG	DE0005751986	Not predicted
2013-09-04	SDAX	R. STAHL AG NA O.N.	DE000A1PHBB5	Not predicted
2013-06-05	SDAX	RTL GROUP	LU0061462528	Not predicted
2013-06-05	SDAX	R. STAHL AG NA O.N.	DE000A1PHBB5	Wrongly predicted
2013-06-05	SDAX	CONSTANTIN MEDIEN AG O.N.	DE0009147207	Not predicted
2013-06-05	SDAX	IVG IMMOBILIEN AG O.N.	DE0006205701	Wrongly predicted
2011-09-05	SDAX	SCHALTBAU HOLDING O.N	DE0007170300	Correctly predicted
2011-09-05	SDAX	DERBY CYCLE AG O.N.	DE000A1H6HN1	Not predicted
2011-09-05	SDAX	PRIME OFFICE REIT-AG O.N.	DE000PRME012	Not predicted
2011-09-05	SDAX	ELEXIS AG O.N.	DE0005085005	Correctly predicted
2011-09-05	SDAX	MEDION AG O.N.	DE0006605009	Not predicted
2011-03-03	SDAX	HAMBORNER REIT AG O.N.	DE0006013006	Correctly predicted
2011-03-03	SDAX	PFLEIDERER AG	DE0006764749	Not predicted
2011-03-03	SDAX	COLON.REAL ESTATE AG	DE0006338007	Wrongly predicted
2010-12-03	SDAX	SAF HOLLAND S.A. EO-,01	LU0307018795	Not predicted
2010-12-03	SDAX	HAWESKO HOLDING AG SVG	DE0006042708	Not predicted
2010-12-03	SDAX	TELEPLAN INT. NV EO-25	NL0000229458	Not predicted
2010-09-03	SDAX	STROEER OUT-OF-H.AG	DE0007493991	Not predicted
2010-09-03	SDAX	SAF HOLLAND S.A. EO-,01	LU0307018795	Wrongly predicted
2010-09-03	SDAX	LOEWE AG O.N.	DE0006494107	Correctly predicted
2010-09-03	SDAX	LOEWE AG O.N.	DE000A1X3W34	Wrongly predicted
2010-06-04	SDAX	TOM TAILOR HOLDG.AG	DE000A0STST2	Not predicted
2010-06-04	SDAX	DYCKERHOFF ST O.N.	DE0005591002	Not predicted
2010-06-04	SDAX	VILLEROY + BOCH AG VZ	DE0007657231	Not predicted
2010-06-04	SDAX	VBH HOLDING AG O.N.	DE0007600702	Not predicted
2010-06-04	SDAX	ZOOPLUS AG	DE0005111702	Wrongly predicted
2010-06-04	SDAX	COLON.REAL ESTATE AG	DE0006338007	Wrongly predicted

This table shows actual and predicted pro- and demotions within the DAX family. Correctly predicted changes refer to actual changes that were predicted by the forecasting model described in Sect. 2, not predicted refer to actual changes that were not predicted, and wrongly predicted refers to predicted changes that were not actual changes

Table 12 Changes by Date (V)

Announcement date	Index	Stock	ISIN	Result
2018-06-05	TECDAX	SIEMENS HEALTH.AG NA O.N.	DE000SHL1006	Correctly predicted
2018-06-05	TECDAX	MEDIGENE AG NA O.N.	DE000A1X3W00	Wrongly predicted
2018-03-05	TECDAX	ISRA VISION O.N.	DE0005488100	Correctly predicted
2018-03-05	TECDAX	AUMANN AG	DE000A2DAM03	Correctly predicted
2018-03-05	TECDAX	ADVA AG OPT.NETW.O.N.	DE0005103006	Correctly predicted
2018-03-05	TECDAX	GFT TECHNOLOGIES AG	DE0005800601	Correctly predicted
2017-03-03	TECDAX	AIXTRON AG NA O.N.	DE000A0WMPJ6	Correctly predicted
2017-03-03	TECDAX	STRATEC BIOMEDICAL NAM.ON	DE000STRA555	Correctly predicted
2016-12-05	TECDAX	MEDIGENE AG NA O.N.	DE000A1X3W00	Not predicted
2016-12-05	TECDAX	AIXTRON AG NA O.N.	DE000A0WMPJ6	Not predicted
2016-09-05	TECDAX	QUANMAX AG (Z.REG.MKT.Z.)	AT0000A0E9W5	Correctly predicted
2016-09-05	TECDAX	SUESS MICROTEC NA O.N.	DE000A1K0235	Correctly predicted
2016-03-03	TECDAX	SLM SOLUTIONS GRP AG	DE000A111338	Correctly predicted
2016-03-03	TECDAX	SUESS MICROTEC NA O.N.	DE000A1K0235	Not predicted
2016-03-03	TECDAX	QSC AG NA O.N.	DE0005137004	Correctly predicted
2016-03-03	TECDAX	LPKF LASER+ELECTRON.	DE0006450000	Not predicted
2015-12-03	TECDAX	SILTRONIC AG NA O.N.	DE000WAF3001	Not predicted
2015-12-03	TECDAX	MANZ AUTOMATION AG	DE000A0JQ5U3	Not predicted
2015-09-03	TECDAX	SILTRONIC AG NA O.N.	DE000WAF3001	Wrongly predicted
2015-09-03	TECDAX	QSC AG NA O.N.	DE0005137004	Wrongly predicted
2015-06-03	TECDAX	ADVA AG OPT.NETW.O.N.	DE0005103006	Not predicted
2015-06-03	TECDAX	BB BIOTECH NAM. SF 1	CH0038389992	Not predicted
2015-03-04	TECDAX	GFT TECHNOLOGIES AG	DE0005800601	Correctly predicted
2015-03-04	TECDAX	KONTRON AG O.N.	DE0006053952	Correctly predicted
2014-09-03	TECDAX	RIB SOFTWARE AG NA	DE000A0Z2XN6	Correctly predicted
2014-09-03	TECDAX	PSI AG F.PR.U.SYS. NA	DE000A0Z1JH9	Correctly predicted
2014-03-05	TECDAX	MANZ AUTOMATION AG	DE000A0JQ5U3	Not predicted

This table shows actual and predicted pro- and demotions within the DAX family. Correctly predicted changes refer to actual changes that were predicted by the forecasting model described in Sect. 2, not predicted refer to actual changes that were not predicted, and wrongly predicted refers to predicted changes that were not actual changes

Table 13 Changes by Date (IV)

Announcement date	Index	Stock	ISIN	Result
2014-03-05	TECDAX	SOLARWORLD AG O.N.	DE000A1YCMM2	Wrongly predicted
2014-03-05	TECDAX	ADVA AG OPT.NETW.O.N.	DE0005103006	Correctly predicted
2013-09-04	TECDAX	NEMETSCHEK AG O.N.	DE0006452907	Not predicted
2013-09-04	TECDAX	COMPUGROUP HOL.AG O.N.	DE0005437305	Not predicted
2013-09-04	TECDAX	SUESS MICROTEC NA O.N.	DE000A1K0235	Not predicted
2013-09-04	TECDAX	EUROMICRON AG NA O.N.	DE000A1K0300	Not predicted
2013-03-06	TECDAX	TELEFONICA DTLD HLDG AG	DE000A1J5RX9	Correctly predicted
2013-03-06	TECDAX	SOLARWORLD AG O.N. KONV.	DE000A1YCMM2	Not predicted
2013-03-06	TECDAX	XING AG	DE000XNG8888	Wrongly predicted
2012-09-05	TECDAX	LPKF LASER+ELECTRON.	DE0006450000	Correctly predicted
2012-09-05	TECDAX	BB BIOTECH NAM. SF 1	CH0038389992	Not predicted
2012-09-05	TECDAX	ARQUES INDUSTRIES AG	DE0005156004	Correctly predicted
2012-09-05	TECDAX	SINGULUS TECHNOL. EO 1	DE000A1681X5	Not predicted
2012-06-05	TECDAX	SARTORIUS AG O.N.	DE0007165607	Not predicted
2012-06-05	TECDAX	CANCOM IT SYSTEME AG	DE0005419105	Not predicted
2012-06-05	TECDAX	CENTROTHERM PHOTOVOLT.	DE000A0JMMN2	Not predicted
2012-06-05	TECDAX	BB BIOTECH NAM. SF 1	CH0038389992	Not predicted
2012-03-05	TECDAX	EUROMICRON AG NA O.N.	DE000A1K0300	Not predicted
2012-03-05	TECDAX	SARTORIUS AG VZO O.N.	DE0007165631	Wrongly predicted
2012-03-05	TECDAX	Q-CELLS SE	DE0005558662	Correctly predicted
2011-09-05	TECDAX	XING AG	DE000XNG8888	Correctly predicted
2011-09-05	TECDAX	PSI AG F.PR.U.SYS. NA	DE000A0Z1JH9	Wrongly predicted
2011-09-05	TECDAX	PHOENIX SOLAR AG O.N.	DE000A0BVU93	Correctly predicted
2011-09-05	TECDAX	ROTH + RAU O.N.	DE000A0JCZ51	Correctly predicted
2011-03-03	TECDAX	SUESS MICROTEC NA O.N.	DE000A1K0235	Not predicted
2011-03-03	TECDAX	ARQUES INDUSTRIES AG	DE0005156004	Not predicted
2011-03-03	TECDAX	SUESS MICROTEC O.N.	DE0007226706	Wrongly predicted
2011-03-03	TECDAX	CONERGY AG O.N. KONV.	DE000A1KRCK4	Correctly predicted
2011-03-03	TECDAX	MANZ AUTOMATION AG	DE000A0JQ5U3	Not predicted
2011-03-03	TECDAX	CONERGY AG O.N.	DE0006040025	Wrongly predicted
2010-09-03	TECDAX	ADVA AG OPT.NETW.O.N.	DE0005103006	Correctly predicted
2010-09-03	TECDAX	MEDIGENE NA O.N.	DE0005020903	Correctly predicted

This table shows actual and predicted pro- and demotions within the DAX family. Correctly predicted changes refer to actual changes that were predicted by the forecasting model described in Sect. 2, not predicted refer to actual changes that were not predicted, and wrongly predicted refers to predicted changes that were not actual changes

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Friedrich-Carl Franz graduated with a master's degree in finance from the University of Mannheim and is now a Ph.D. candidate in finance at the University of Frankfurt. Before starting his Ph.D., he worked as a portfolio manager for a large Swiss asset manager.