Forecasting index changes in the German DAX family

Friedrich-Carl Franz

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

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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.
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) argue on the example of the Russell 3000 that 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 Meghalo (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. 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. 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, 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

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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-resse-beschli-e-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. 

\[
\text{finalrank}_{it} = \text{officialrank}_{i,t-1} + (\text{customrank}_{ij,t} - \text{customrank}_{ij,t-1})
\]

(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 Mergulhão (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 for the changes. Consequently, there is no uncertainty with respect to changing prices due to corporate actions and a probability-driven approach seems unreasonable to me. Third, and in contrast to Fernandes and Mergulhão (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. 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 Börse 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.

\[
AR_{i,t} = R_{i,t} - R_{j,t}
\]

(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 Mergulhão (2016) are to the best of my knowledge 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
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       | 7.00     | 7          | 7.00       | 7.00       | 7.00       | 7.00     | 7          | 7.00       | 7.00       | 7.00       |
| Count     | Mean     | Std        | Min        | 25%        | 50%        | 75%      | Max       | Skewness   | Kurtosis   | Skewness   |
|           | 76.56    | 52.09      | 29.57      | 44.69      | 61.99      | 85.25    | 184.50    | 1.80       | 3.65       | -1.27      |
|           | 13465    | 6120       | 5158       | 9101       | 13780      | 17160    | 22798     | 0          | -1.27      | -0.39      |
|           | 82.54    | 18.68      | 74.28      | 79.28      | 93.00      | 94.56    | 99.93     | -1.27      | 1.19       | 0.22       |
|           | 0.73     | 2.16       | 1.27       | -1.15      | 0.23       | 3.33     | 3.33      | -0.39      | -1.59      | -1.59      |
|           | 0.46     | 30.58      | 8.30       | 51.77      | 28.13      | 46.14    | 72.30     | 0.00       | 0.22       | 0.22       |
|           | -0.75    | 2.32       | 30.58      | -0.91      | -0.75      | 2.19     | 3.61      | -0.34      | -1.14      | -0.34      |

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.
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.

Equation (3)

\[
\text{return}_{i,t} = \alpha + \beta_1 D_{i,t}^{PM} + \beta_2 \text{MarketCap}_{i,t} + \beta_3 D_{i,t}^{PM} \times \text{MarketCap}_{i,t} + \beta_4 \text{VDAX}_{i,t} + \beta_5 D_{i,t}^{PM} \times \text{VDAX}_{i,t} + \epsilon_{i,t}
\]

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.

| 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               |

Table 2 Actual and predicted changes by category

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 \(D_{i,t}^{PM}\) is a 1 if stock \(i\) is a promotion at day \(t\) and 0 if it is a demotion at day \(t\).

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 \(D_{i,t}^{PM}\) is a 1 if stock \(i\) is a promotion at day \(t\) and 0 if it is a demotion at day \(t\).

\[
\text{return}_{i,t} = \alpha + \beta_1 D_{i,t}^{PM} + \beta_2 \text{MarketCap}_{i,t} + \beta_3 D_{i,t}^{PM} \times \text{MarketCap}_{i,t} + \beta_4 \text{VDAX}_{i,t} + \beta_5 D_{i,t}^{PM} \times \text{VDAX}_{i,t} + \epsilon_{i,t}
\]
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 large 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.
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 4 Abnormal returns on the AD+1 by category—statistics

|               | Promotion Actual changes | Correctly predicted | Not predicted | Wrongly predicted | Demotion 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             |
| Median       | 0.41                     | 0.90                | −0.07        | 1.24             | −0.77                    | −0.93                | 0.06         | 0.63             |
| 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             |
| Median       | 0.36                     | 0.58                | −2.06*       | 0.09             | −0.77*                   | −0.56                | −0.91***     | 0.95             |
| N            | 35                       | 23                  | 12           | 4                | 35                       | 21                  | 14           | 6                |
| **SDAX**     |                          |                     |              |                  |                          |                     |              |                  |
| Mean         | 1.00**                   | 1.03*               | 0.27         | −0.87*           | −0.95                    | 0.52                 |             |                  |
| Median       | 0.35***                  | 0.32**              | 0.19         | −0.41**          | −0.85*                   | 0.08                 |             |                  |
| N            | 39                       | 29                  | 10           | 10               | 41                       | 16                  | 25           | 6                |
| **TecDAX**   |                          |                     |              |                  |                          |                     |              |                  |
| Mean         | 1.42**                   | 2.24**              | 3.68         | −1.54**          | −3.17**                  | 0.22                 | −0.23        |                  |
| Median       | 1.06**                   | 2.65**              | 2.08*        | −0.89**          | −1.93**                  | −0.22                | −0.20        |                  |
| N            | 25                       | 12                  | 13           | 4                | 25                       | 13                  | 12           | 3                |
| **Total**    |                          |                     |              |                  |                          |                     |              |                  |
| Mean         | 0.82***                  | 1.09***             | 0.52         | −0.98***         | −1.15***                 | −0.79**              | 0.69         |                  |
| Median       | 0.50***                  | 0.53***             | 0.33         | −0.73***         | −0.77***                 | −0.56***             | 0.17         |                  |
| 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
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 every 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
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 Promotions | Demotions | Long–short | Mean 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     | 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.

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Appendix

See Tables 8, 9, 10, 11, 12, and 13.
| 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. | DE000KSA0888       | Correctly predicted |
| 2015-09-03        | DAX   | DT-ANNINGTON IMM.SE | DE000A1M711        | Correctly predicted |
| 2015-09-03        | DAX   | LAXXESS AG | DE0005470405       | Correctly predicted |
| 2013-03-04        | DAX   | PROSIEBENSAT.1 NA O.N. | DE000PSM7770       | Wrongly predicted |
| 2013-03-04        | DAX   | LAXXESS AG | DE0005470405       | Wrongly predicted |
| 2012-09-05        | DAX   | CONTINENTAL AG O.N. | DE0005439004       | Correctly predicted |
| 2012-09-05        | DAX   | LAXXESS 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. | DE0006020005       | Not predicted        |
| 2019-03-05        | MDAX  | KNORR-BREMSE AG INH O.N. | DE000KBX1006      | Correctly predicted |
| 2019-03-05        | MDAX  | DIALOG SEMICOND. LS,-10 | GB00B5922006    | Correctly predicted |
| 2019-03-05        | MDAX  | GRENKE AG NA O.N. | DE000A161N30       | Wrongly predicted   |
| 2019-03-05        | MDAX  | SALZGITTER AG O.N. | DE0006020005       | 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 | DE000A0L2D2U1     | 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 | DE000A12D680       | Correctly predicted |
| 2018-06-05        | MDAX  | ALSTRIA OFFICE REIT AG | DE000A0L2D2U1      | 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  | STEINHOF INT.HLDG.EO,-50 | NL0011175019      | 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  | RHEN-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. | DE000A0ACAYB2      | Correctly predicted |
| 2016-03-03        | MDAX  | ALSTRIA OFFICE REIT AG | DE000A0L2D2U1      | Correctly predicted |
| 2016-03-03        | MDAX  | STEINHOF INT.HLDG.EO,-50 | NL0011175019      | 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 | DE000KCT01000      | 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.
Forecasting index changes in the German DAX family

### 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.PFANDBRIEFK AG | DE0008019001           | Not predicted           |
| 2015-09-03        | MDAX  | GERRY WEBER INTERNAT.O.N. | DE0003034101 | 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      | DE000KX88881           | Not predicted           |
| 2014-09-03        | MDAX  | RATIONAL AG        | DE0007010803           | Not predicted           |
| 2014-09-03        | MDAX  | SGL CARBON SE O.N. | DE0007235301           | Not predicted           |
| 2013-09-04        | MDAX  | EVONIK INDUSTRIES AG | DE000EVNIK013     | 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. | DE0005194602 | 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 | DE000A088488 | Correctly predicted     |
| 2013-03-06        | MDAX  | NORMA GROUP AG NA O.N. | DE000N1HBBV3    | 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 | DE000A0IFSM05 | Correctly predicted     |
| 2011-09-05        | MDAX  | DEMAG CRANES AG    | DE000DCAG010           | Correctly predicted     |
| 2011-09-05        | MDAX  | IVG IMMOBILIEN AG O.N. | DE0006250701 | Not predicted           |
| 2011-09-05        | MDAX  | GAGFAH S.A. NOM. EO 1.25 | LU0269583422 | Wrongly predicted      |
| 2010-09-03        | MDAX  | A.SPRINGER AG VNA   | DE0005510357           | Correctly predicted     |
| 2010-09-03        | MDAX  | BAUER AG           | DE0005168108           | Correctly predicted     |
| 2010-06-04        | MDAX  | BRENTTAG 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        | SDA   | AMADEUS FIRE AG    | DE0005093108           | Correctly predicted     |
| 2019-03-05        | SDA   | ADVA AG OPT.NETW.O.N. | DE0005103006 | Correctly predicted     |
| 2019-03-05        | SDA   | VARTA AG O.N.      | DE000A0TG355           | Correctly predicted     |
| 2019-03-05        | SDA   | BAYWA AG NA.       | DE0005194005           | Not predicted           |
| 2019-03-05        | SDA   | MEDIGENE AG NA O.N. | DE000A1X3W00           | Correctly predicted     |
| 2019-03-05        | SDA   | TELE COLUMBUS AG   | DE000TCAJ72            | Correctly predicted     |
| 2019-03-05        | SDA   | GILDEMEISTER AG O.N. | DE000F878033   | Correctly predicted     |
| 2019-03-05        | SDA   | 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.
| 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.  | DE000ADNAY5     | 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  | AROUND TOWN EO-.01       | LU1673108939    | Not predicted       |
| 2017-09-05        | SDAX  | DELIVERY HERO AG NA O.N. | DE000A2E4K43    | Not predicted       |
| 2017-09-05        | SDAX  | AROUND TOWN 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 PROP.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  | HORN BACH 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            | DE000A12DMS0    | Not predicted       |
| 2015-12-03        | SDAX  | SCHAFFLER 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                   | DE000A1BVP9     | 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   |
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.

| Announcement date | Index | Stock | ISIN | Result          |
|-------------------|-------|-------|------|-----------------|
| 2015-09-03        | SDAX  | VILLEROY + BOCH AG VZ | DE0007657231 | Correctly predicted |
| 2015-06-03        | SDAX  | TELECOLUMBUS 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 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                                                             | DE000A2DM03           | 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.)                                             | AT0000AE9W5           | 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        | TECDA| SOLARWORLD AG O.N. | DE000A1YCM2     | Wrongly predicted       |
| 2014-03-05        | TECDA| ADVA AG OPT.NETW.O.N. | DE0005103006  | Correctly predicted    |
| 2013-09-04        | TECDA| NEMETSCHEK AG O.N.   | DE0006452907   | Not predicted          |
| 2013-09-04        | TECDA| COMPUGROUP HOL.AG O.N.  | DE0005437305  | Not predicted          |
| 2013-09-04        | TECDA| SUSS MICROTEC NA O.N.  | DE000A1K0235  | Not predicted          |
| 2013-09-04        | TECDA| EUROMICRON AG NA O.N. | DE000A1K0300  | Not predicted          |
| 2013-09-06        | TECDA| TELEFONICA DTLD HLDG AG  | DE000A1J5RX9  | Correctly predicted    |
| 2013-09-06        | TECDA| SOLARWORLD AG O.N. KONV. | DE000A1YCM2   | Not predicted          |
| 2013-06-06        | TECDA| XING AG               | DE000XNG8888   | Wrongly predicted      |
| 2012-09-05        | TECDA| LPKF LASER+ ELECTRON. | DE0005103000  | Correctly predicted    |
| 2012-09-05        | TECDA| BB BIOTECH NAM. SF 1  | CH0038399992  | Not predicted          |
| 2012-09-05        | TECDA| ARQUIES INDUSTRIES AG | DE0005156004  | Correctly predicted    |
| 2012-09-05        | TECDA| SINGULUS TECHNOL., EO 1 | DE000A1681X5  | Not predicted          |
| 2012-06-05        | TECDA| SARTORIUS AG O.N.     | DE0007165607   | Not predicted          |
| 2012-06-05        | TECDA| CANCOM IT SYSTEME AG   | DE0005419105   | Not predicted          |
| 2012-06-05        | TECDA| CENTROTHERM PHOTOVOLT. | DE000A0JMMN2  | Not predicted          |
| 2012-06-05        | TECDA| BB BIOTECH NAM. SF 1  | CH0038399992  | Not predicted          |
| 2012-03-05        | TECDA| EUROMICRON AG NA O.N. | DE000A1K0300  | Not predicted          |
| 2012-03-05        | TECDA| SARTORIUS AG VZO O.N. | DE0007165631   | Wrongly predicted      |
| 2012-03-05        | TECDA| Q-CELLS SE            | DE0005558662   | Correctly predicted    |
| 2011-09-05        | TECDA| XING AG               | DE000XNG8888   | Correctly predicted    |
| 2011-09-05        | TECDA| PSI AG F.PR.U.SYS. NA | DE000A0ZJH9   | Wrongly predicted      |
| 2011-09-05        | TECDA| PHOENIX SOLAR AG O.N. | DE000A0BUG93  | Correctly predicted    |
| 2011-09-05        | TECDA| ROTH + RAU O.N.       | DE000A0JCG51   | Correctly predicted    |
| 2011-03-03        | TECDA| SUSS MICROTEC NA O.N. | DE000A1K0235  | Not predicted          |
| 2011-03-03        | TECDA| ARQUIES INDUSTRIES AG | DE0005156004  | Not predicted          |
| 2011-03-03        | TECDA| SUSS MICROTEC O.N.    | DE0007226706   | Wrongly predicted      |
| 2011-03-03        | TECDA| CONERGY AG O.N. KONV. | DE000A1KRCCK4 | Correctly predicted    |
| 2011-03-03        | TECDA| MANZ AUTOMATION AG    | DE000A0JQSU3   | Not predicted          |
| 2011-03-03        | TECDA| CONERGY AG O.N.       | DE00051040025  | Wrongly predicted      |
| 2010-09-03        | TECDA| ADVA AG OPT.NETW.O.N. | DE0005103006  | Correctly predicted    |
| 2010-09-03        | TECDA| MEDITGENE 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.