The current issue and full text archive of this journal is available on Emerald Insight at:
www.emeraldinsight.com/0307-4358.htm

Determinants of tracking error in German ETFs – the role of market liquidity

Friedrich Osterhoff and Christoph Kaserer
Department of Financial Management and Capital Markets, Technische Universität München, Munich, Germany

Received 13 April 2015
Revised 22 July 2015
6 September 2015
Accepted 17 September 2015

Abstract

Purpose – The purpose of this paper is to contribute to a better understanding of the impact of market liquidity on the daily tracking error of exchange-traded funds (ETFs). It puts a special focus on the liquidity cost of individual underlying stocks as well as the process of creation/redemption of ETF shares as key determinants of tracking ability.

Design/methodology/approach – The study is based on daily observations of fund data for eight fully replicating German equity ETFs for July 2001-October 2013. A regression model with fund fixed effects is chosen to determine the effect of liquidity cost, creation/redemption and other control variables on daily tracking error. Data were compiled from issuer websites and Datastream. Proprietary XETRA Liquidity Measure, which was used as proxy for liquidity cost was supplied by Deutsche Börse.

Findings – The study finds daily tracking error to significantly depend on the liquidity of underlying stocks. This finding emerges even though the ETFs in this study predominantly use in-kind creation/redemption. Even after controlling for creation/redemption, the liquidity impact remains basically unchanged. One reason might be imperfect replication of index weights: Either the in-kind-basket delivered in the course of creation/redemption does not perfectly match the benchmark-weights or the internal rebalancing of weights causes liquidity cost.

Originality/value – To the best of the authors' knowledge, this is the first paper that uses a specific liquidity measure for each single stock underlying an ETF. The findings extend the literature by corroborating the view that liquidity of individual stocks in the underlying portfolio has an impact on tracking error.

Keywords Financial markets, Fund management, Investment funds, Assets management

Paper type Research paper

1. Introduction

Over the past few years, exchange-traded funds (ETFs) have experienced a remarkable development from being a mere niche product to becoming "one of the most successful innovations in the history of investment" (Charupat and Miu, 2013, p. 427). As a result, they have drawn considerable attention from both researchers and investors. For any ETF trying to replicate the performance and risk of an underlying benchmark a decisive if not defining quality is its ability to track its corresponding benchmark as closely as possible. Although a growing body of literature has confirmed the significant impact of an ever-increasing number of factors on ETF tracking ability, research on some potential key determinants still appears to be in its inception, especially for ETFs in developed markets outside the USA, such as that of Germany.

JEL Classification — G12, G14, G15, G23

The authors would like to thank Deutsche Börse AG for providing access to the XETRA Liquidity Measure (XLM) for the major German stock indices.

Managerial Finance
Vol. 42 No. 5, 2016
pp. 417-437

0307-4358
DOI 10.1108/MF-04-2015-0105

Our intention in this paper is to shed new light on the relationship between stock market liquidity and the performance of the ETF industry. More specifically, we will investigate the extent to which stock market liquidity affects ETFs' tracking error. It should be noted that so far, this relationship has been more or less ignored in the literature. In fact, pertinent studies identify three factors which significantly drive an ETF's tracking error, as follows: the total expense ratio (e.g. Elton *et al.*, 2002; Agapova, 2011; Blitz *et al.*, 2012); changes in index composition and the index replication strategy (e.g. Frino *et al.*, 2004; Gastineau 2002; Aber *et al.*, 2009); and dividend payments (e.g. Frino *et al.*, 2004; Elton *et al.*, 2002; Blitz and Huij, 2012).

The impact of stock market liquidity has mostly been ignored based on the presumption that the creation/redemption of ETF shares is usually performed in-kind through authorised participants (APs), and that this should shelter the ETF from any market frictions like transaction costs. A very few studies acknowledge that market liquidity might nevertheless be an issue. However, these papers predominantly rely on ETF bid-ask spreads to capture market liquidity (cf. Milonas and Rompotis, 2006; Delcoure and Zhong, 2007; Shin and Soydemir, 2010); this proxy is somewhat flawed given that it measures liquidity merely at the aggregate fund level and that it does not take market depth into account (cf. Hendershott and Riordan, 2013; Krogmann, 2011).

In this study, we aim to contribute to a better understanding of the impact of market liquidity on the performance of the ETF industry, or more specifically, on the tracking error of ETFs. To the best of our knowledge, this is the first paper which uses a specific liquidity measure for each single stock underlying an ETF. This measure is Deutsche Börse's volume-weighted spread XETRA Liquidity Measure (XLM). It measures the order-size-dependent liquidity costs of a round trip for individual stocks, taking the entire depth of the limit order book into account (cf. Stange and Kaserer, 2011; Rösch and Kaserer, 2013). Applying XLM should allow for a more elaborate view of the liquidity costs of individual stocks in the underlying portfolio of an ETF and its effects on tracking error.

Our findings extend the literature by corroborating the view that the liquidity of individual stocks in the underlying portfolio of an ETF has a considerable impact on its tracking error. This finding emerges even though the ETFs under investigation in this paper predominantly use in-kind redemption or creation of shares through APs. In fact, even after controlling for creation/redemption, the liquidity effect remains basically unchanged. Therefore, the relationship between market liquidity and ETF tracking ability seems to be rather intriguing. We suggest some explanations in this paper, although we are not able to isolate any specific channel due to data limitations. Moreover, we are also able to show that besides the liquidity cost of stocks and the process of creation and redemption of ETF shares, portfolio adjustments, management fees, dividend yield, cash distributions to ETF investors and cash holdings also have a significant and sometimes substantial effect on an ETF's tracking ability. Finally, by using an orthogonalisation technique, we show that the effects of total expense ratio, basket liquidity and distributions on tracking error are highly non-linear.

The remainder of this paper is structured as follows: in Section 2, we give a brief overview of the relevant literature with a focus on the current state of research on potential determinants of tracking error. Section 3 comprises the empirical part of the study. Here, we describe the data and methodology (3.1) and subsequently present (3.2) and critically discuss (3.3) our findings. Finally, Section 4 provides concluding remarks, especially with regard to potential future fields of research.

2. Literature review

Tracking error can be broadly defined as the deviation of an ETF's price or net asset value (NAV) return from its corresponding benchmark index return. Price deviations from the ETF NAV in the form of premiums or discounts are quite common, yet given the arbitrage opportunities of daily creation and redemption of ETF shares, they can be expected to remain within rather tight bounds. In contrast, tracking error – that is, NAV return deviating from the return of the corresponding underlying index – can accumulate over time and hence significantly affect the long-term performance of ETFs (Charupat and Miu, 2013).

2.1 Determinants of tracking error in ETFs

The literature describes a wide array of factors which have a measurable effect on the tracking ability of ETFs. Due to the number of factors, the following section aims to provide some structure by clustering the relevant identified determinants along broader categories. However, given the interconnectivity between some of these parameters, it is sometimes difficult to draw definitive lines.

One widely recognised factor affecting tracking error is management fees: all other things being equal, the higher the expense ratio of a fund, the more an ETF can be expected to underperform its underlying index and hence, the larger the tracking error should be (Charupat and Miu, 2013). This view is supported by the vast majority of research: Elton *et al.* (2002), Lin and Chou (2006), Rompotis (2006, 2011), Agapova (2011), Elia (2012), Meinhardt *et al.* (2012) and Blitz *et al.* (2012), among others, show that an ETF's expense ratio is key to explaining its tracking error. In contrast to this majority, Rompotis (2012) cannot verify the relationship between expense ratio and tracking error to be statistically significant for his sample of German ETFs. Moreover, while Chu (2011) finds the magnitude of tracking error for ETFs listed on the Hong Kong Stock Exchange to be positively related to the expense ratio of a fund (and negatively related to fund size), he observes a negative relationship between expense ratio and tracking error in a later study of 21 ETFs traded in Hong Kong between 2009 and 2011 (Chu, 2013). He explains this rather unintuitive outcome by noting that his analysis does not differentiate between fully replicating ETFs and synthetic ETFs, and hence it does not account for the potential impact of replication strategy on tracking ability via expenses and transaction cost. Although this might be the reason for variation in absolute magnitude in tracking error, however, it does not sufficiently explain the negativity of the relation.

Frino *et al.* (2004) use monthly data for the years 1994-1999 and show that tracking error in index mutual funds for the S&P 500 is significantly related to index revisions, share issuances, spin-offs, share repurchases, index replication strategy and fund size. Gastineau (2002) finds for equity index funds tracking the Russell 2000 and S&P 500 indices that changes in index composition (and to a lesser extent corporate actions) have a significant effect on tracking error due to the transaction cost involved in the necessary rebalancing of the underlying portfolio. He also argues that better timing of changes in portfolio composition because of index adjustments can lead to improved returns for the investor and even outperformance of the benchmark. Yet, he acknowledges that fund managers might be constrained in their ability to deviate from precise index replication. The conjecture that tracking error magnitude is affected by inflexible replication strategies due to fund-managers' reluctance to alter their portfolio composition before the official date of index adjustment, for example, has also been posited by Blume and Edelen (2003) for index mutual funds and by

Gastineau (2004) and Aber *et al.* (2009) for ETFs in a study of four iShares ETFs tracking broad US equity indices. In terms of share issuance in ETFs, Gallagher and Segara (2006), claim that at least in the case of creation/redemption in-kind – that is, delivery of the underlying basket in exchange for ETF shares – ETFs do not have to bear any liquidity cost and hence should not be affected in terms of tracking ability. Gastineau (2004) further points to the fact that ETF providers tend to charge a fee to the AP for the creation or redemption of shares, which should cover any other transaction cost.

Frino and Gallagher (2001) identify dividend payments as another factor with a significant impact on tracking error in passive funds. This is also verified by Frino *et al.* (2004) for their sample of index funds tracking the S&P 500. For the US-traded SPDR-ETF tracking the S&P 500, Elton *et al.* (2002) show that the main cause of tracking error besides total expense ratio is forfeited return due to delayed reinvestment of cash dividends. Chu (2013) also finds that dividend yield has a positive impact on tracking error and claims that delays in receiving dividends and costs incurred in reinvestment erode ETFs' ability to replicate index performance. For their sample of European ETFs, Blitz *et al.* (2012) find the explanatory power of dividend withholding taxes for fund underperformance with respect to its benchmark to be at least on par with fund expenses[1]. Applying these findings, Blitz and Huij (2012) show that emerging market equity ETFs' expected returns are equal to their respective gross benchmark index returns minus expense ratio and dividend taxes. Lin and Chou (2006) identify three factors which determine tracking error in Taiwan's first ETF, as follows: first, cash dividends, whose impact becomes particularly obvious during peak dividend pay-out-season; second, management expenses – indeed, these represent the main factor causing the gap between two different tracking error series; and third, stock replacement operations due to, for example, index adjustments in the underlying benchmark.

With regard to the effect of market liquidity on tracking error, previous research commonly focuses on widely accepted proxies such as trading volume and bid-ask spread[2]. Kundisch and Klein (2009) observe the daily returns and tracking ability of several DAX certificates and one DAX ETF for the period 2001-2006 and show that the trading volume of the respective ETF is negatively correlated with its tracking error; this means that on average, tracking error tends to decrease with increasing trading volume. In contrast, Chu (2013) identifies trading volume, dividend yield and market risk to be positively related to tracking error magnitude for his sample of Hong-Kong-traded ETFs. The outcome that trading volume positively affects tracking error may be unintuitive, yet Rompotis (2006) also presents results for his international sample of iShares which suggest a significant positive relationship between trading volume and tracking error, although this is very small in absolute terms. Closely linked with ETF trading volume is its bid-ask spread. The findings of several studies suggest a positive effect of spreads on tracking error. For instance, Milonas and Rompotis (2006), Delcoure and Zhong (2007) and to a lesser extent, Shin and Soydemir (2010) all verify that a fund's tracking error is positively affected by the bid-ask spread. Rompotis (2012) and Meinhardt *et al.* (2012) come to similar conclusions for the German ETF market. While Kostovetsky (2003) sees market liquidity in terms of bid-ask spread as one of the main determinants of tracking error in common index mutual funds, he rejects liquidity cost as a source of tracking error in ETFs based on the assumption that in-kind creation/redemption of ETF shares through APs should shield the fund from any cost.

2.2 *The current state of research and potential research gaps*

Although several studies have suggested that there is indeed variation in ETFs' tracking ability across different markets, research on developed markets outside the USA is still rather scarce. Given the size of Germany's ETF market – with a trading volume of approximately 114 billion Euros in 2013, it is the fifth largest and one of the most developed marketplaces in the world (Deutsche Bank Research, 2014) – further research on its microstructure could indeed prove valuable.

While an ever-growing body of literature confirms a significant impact of market liquidity on funds' tracking ability, the effect is usually addressed with proxies such as bid-ask spread or trading volume and normally on the aggregate ETF level[3]. By these means, however, it is impossible to either fully grasp all dimensions of liquidity, encompassing market breadth, market depth, immediacy of execution and market resiliency (cf. Krogmann, 2011) or comprehend the liquidity effect of individual underlying stocks' ETF portfolio.

Our research intends to contribute to existing literature in two ways: first, we extend the empirical evidence on market liquidity as a determinant of ETFs' tracking ability by capturing the liquidity impact of underlying stock in our analysis. We do so by using Deutsche Börse's unique volume-weighted XLM. Here, price impact information is used as a measure of the cost of immediate demand for liquidity by investors placing an order (cf. Krogmann, 2011). XLM measures the order-size-dependent liquidity costs of a round trip, whilst taking the entire depth of the limit order book into account, and condenses all daily market impact information for each individual stock into a single figure. Second, we examine the impact of creation and redemption of shares on an ETF's tracking ability. Gallagher and Segara (2006) and Gastineau (2004) both present arguments against this mechanism being a potential source of daily tracking error. However, to our knowledge, their claim has not yet been empirically tested.

3. Empirical part

The aim of this section is to describe our research design and subsequently report and critically discuss the results. Our study focuses on XETRA-traded funds which track equity indices in the DAX index universe, comprising Germany's large-cap index DAX, mid-cap index MDAX, small-cap index SDAX and technology index TecDAX, as well as related sub-indices and strategy indices based on the constituents of one of the other named indices.

The overall design of our study is geared towards answering two research questions, as follows:

RQ1. Does the liquidity cost of individual underlying securities have an impact on an ETF's tracking ability?

RQ2. Are there additional significant effects from cash holdings, accrued dividends, cash distribution to ETF investors, the process of daily share creation and redemption or portfolio adjustments on ETF tracking error – either independently or in interaction with liquidity cost?

3.1 *Data and methodology*

3.1.1 Data. Except for annual expense ratios, all data are collected on a daily basis for the time period of 1 July 2003-31 October 2013. Since the XLM is only calculated for stocks within the universe of the DAX index family, our sample is constrained to ETFs replicating one of these indices. In the given period, a total of 22 XETRA-listed ETFs tracked relevant indices. In order to calculate a daily weighted market liquidity proxy for each ETF portfolio, we have to match daily fund holdings with the respective daily XLM data on round-trip liquidity cost for individual securities. For this reason, we are constrained to physically replicating funds in our sample. Overall, ten ETFs on XETRA fulfil this requirement, two of which have to be taken out of the sample due to insufficient data availability. Thus, the final sample consists of eight ETFs which track a total of seven different indices within the DAX universe. As of April 2014, the eight funds in the sample covered roughly 23 per cent of total ETF trading volume (approximately 40 per cent, including over-the-counter trading) on Deutsche Börse's XETRA trading platform, with the latter covering 70 per cent of trading volume in DAX index universe ETFs[4].

In terms of use of income, ETFs can either be reinvesting or distributing. That is, fund management has to decide upon inception whether to accumulate or distribute the cash dividends which the fund receives from its equity investments. Accordingly, its tracking ability is measured against a performance or price-index, respectively. An overview of the eight funds, their International Securities Identification Number, their use of income and their respective benchmark is given in Table I. Here, accumulating performance or total return indices are marked with TR, and distributing price indices are marked with PR.

Daily data on prices, returns and dividends for all relevant benchmark indices and their respective underlying stocks have been compiled from Thomson Reuters' Datastream. Daily ETF fund data, particularly portfolio holdings (including cash and derivatives), NAV, assets under management, total shares outstanding, shares created or redeemed, cash distributions to investors and total expense ratio were obtained manually from the websites of the respective ETF providers. Where missing, information on historical expense ratios is supplemented by Morningstar data.

Deutsche Börse AG has kindly provided daily XLM data for all securities in the DAX index universe. The XLM is a volume-weighted spread which is automatically calculated by the XETRA trading system for each individual security from the visible and invisible parts of the limit order book, including so-called "iceberg orders".

Fund name	ISIN	Benchmark	Use of income
Deka DAX® UCITS ETF	DE000ETFL011	DAX® (TR) EUR	Reinvesting
Deka DAX® (ausschüttend) UCITS ETF	DE000ETFL060	DAX® (PR) EUR	Distributing
Deka DAX® ex Financials 30 UCITS ETF	DE000ETFL433	DAX® ex Financials 30 (PR)	Distributing
Deka DAXplus® Maximum Dividend UCITS ETF	DE000ETFL235	DAXplus® Maximum Dividend (PR) EUR	Distributing
iShares DAX® UCITS ETF (DE)	DE0005933931	DAX® (TR) EUR	Reinvesting
iShares DivDAX® UCITS ETF (DE)	DE0002635273	DivDAX® (PR) EUR	Distributing
iShares MDAX® UCITS ETF (DE)	DE0005933923	MDAX® (TR) EUR	Reinvesting
iShares TecDAX® UCITS ETF (DE)	DE0005933972	TecDAX® (TR) EUR	Reinvesting

Note: This table reports the full name (as given in the official prospectus), ISIN, respective benchmark index (TR for total return and PR for price return index) and use of income for each of the eight physically replicating ETFs in the DAX index universe which represent the individual panels in regressions (4)-(6)

Table I.
Overview of ETFs in observed sample

Daily values of the XLM for each stock are calculated by XETRA as the equal-weighted average of all available minute-by-minute volume-weighted spread data points for several hypothetical standardised trading volumes (e.g. 10,000, 25,000, 50,000 and 100,000 Euros), thereby providing the relative liquidity cost of a round trip for the respective trading volumes[5].

Daily observations are only taken into account if all necessary information is available. Trading days with ETFs holding any assets other than equity or cash – derivatives such as certificates or options, for instance – are also taken out of the sample.

3.1.2 Methodology. In a first step, we calculate daily returns for all eight ETFs and their respective benchmark indices. Analogous to the majority of literature, we use the NAV return for the examination of an ETF's tracking error to its benchmark. One reason is that given a high-frequency trading environment and differences in exchange closing times for ETF and index trading, it is almost impossible to perfectly match daily ETF closing prices with the corresponding index prices. Another more important reason for using NAV returns is that contrary to quoted price returns, they are not biased by premiums or discounts which have not been arbitraged away. Using price instead of NAV returns would bear the risk of wrongfully attributing differences between the ETF return and benchmark return to tracking ability which are actually caused by non-arbitraged NAV-price deviations. The daily NAV return of ETF i and the return of its corresponding benchmark index are expressed by formulae (1) and (2), respectively:

$$NR_{it} = \frac{NAV_{it} - NAV_{it-1}}{NAV_{it-1}} \tag{1}$$

$$IR_{it} = \frac{Index_{it} - Index_{it-1}}{Index_{it-1}} \tag{2}$$

There are actually numerous ways to define and calculate tracking error. Most studies refer to the methods brought forward by Roll (1992) and Pope and Yadav (1994). The latter authors further argue that high-frequency data bear the risk of overestimating tracking error. This is why most studies base their analyses on weekly or monthly data. However, Meinhardt *et al.* (2012) show in their analysis of the German ETF market that the risk of overestimation of tracking error is just as high in lower-frequency data. We intend to shed light on the short-term effects of market liquidity on tracking error, and hence, as in Meinhardt *et al.* (2012) and Qadan and Yagil's (2012) work, our research design is based on an estimator that reflects daily tracking ability. Due to their overall structure, including the ability to create and redeem shares throughout the trading day, ETFs are increasingly used for short-term investments and hedging strategies. In light of their potential use as short-term investment vehicles, we deem it relevant to scrutinise and better understand the effect of inter-day changes in basket liquidity on daily tracking ability. With this focus, we have to deviate from previous studies' research design, where tracking error is mostly calculated as the standard deviation of differences between benchmark and NAV over a period of time. For the calculation of daily standard deviations, intra-day matching of the benchmark index and NAV returns would be required. Yet, given that the intra-day NAVs which are being reported by are merely indicative figures (iNAV), this procedure would be unreliable. We therefore resort to an alternative method used and corroborated by Milonas and Rompotis (2006), Shin and Soydemir (2010) and Chu (2011, 2013), among others, where we calculate daily tracking error for ETF i at day t as the absolute daily deviation of i's NAV return from its corresponding benchmark index' return:

$$TE_{it} = |NR_{it} - IR_{it}| \tag{3}$$

In this section, we perform a panel regression, with fund fixed effects to control for ETF-inherent characteristics. The model with the proposed factors to explain tracking error *TE* can be expressed as follows:

$$TE_{it} = (\alpha + v_i) + \beta_1 \cdot TER_{it} + \beta_2 \cdot XLM_{it} + \beta_3 \cdot RelCash_{it} + \beta_4 \cdot DivYield_{it} + \beta_5 \cdot DISTR_{it} + \beta_6 \cdot RelNetCR_{it} + \beta_7 \cdot PortAdj_{it} + \varepsilon_{it} \tag{4}$$

where v_i is the fixed effect of individual ETF i and *TER* the annual total expense ratio that is charged by the issuer of ETF i on day t. As corroborated by most of the literature, this is one of the key determinants of fund-tracking ability, and in line with previous studies, we expect *TER* to be positively related to tracking error.

XLM is a weighted average of the daily XETRA Liquidity Measure figures of all securities held in ETF i's portfolio at day t. Hence, it serves as a proxy for the average liquidity of ETF i's underlying securities. Illiquid securities are expected to have higher round-trip cost (expressed as per cent of trading volume), which should consequently drive up the overall portfolio cost. This, in turn, should have a positive impact on an ETF's daily tracking error.

A fund's daily cash holdings relative to its total assets under management are controlled for by *RelCash*. This factor should also be positively related to tracking error, for a fund's cash holdings cannot track the underlying benchmark and should hence contribute to deviations from benchmark return. Thus, tracking error should be higher in funds which have relatively higher cash holdings. The reasons for holding cash at all can be manifold: For example, the fund (or the APs) can face difficulties obtaining/selling the underlying securities in the aftermath of an index revision. Another reason can be that cash inflows from dividends cannot be paid out until a certain date. Dividends on securities held in the portfolio, calculated as yield to current NAV, are also separately accounted for in the model by *DivYield*. Again, the relation between this factor and tracking error should be positive, since dividends represent forfeited portfolio returns unless they are immediately reinvested. While *DivYield* accounts for cash inflows from underlying assets to the fund, we control for distribution of cash from the ETF to its shareholders by $DISTR_{it}$, which is calculated as the sum distributed to each ETF share on day t relative to the NAV of ETF i at t. By transferring cash to investors, a distributing ETF should be able to come closer to its price-index benchmark. Hence, we expect the tracking error to be negatively affected by cash distribution.

One of the most important mechanisms of an ETF is the opportunity to create and redeem shares throughout the trading day. With *RelNetCR*, a fund's daily net creation/redemption of shares is expressed as absolute relative change in current assets under management. It is calculated as the net change in shares outstanding on day t, multiplied with the closing NAV (i.e. the net transaction volume caused by the creations/redemptions on the trading day) and then divided by current assets under management. Although the creation/redemption of shares is usually performed in-kind through APs, hence shielding the ETF and its assets from the largest part of transaction cost, we still expect *RelNetCR* to have a measurable positive effect on tracking error, due to imperfect index replication in the in-kind-basket delivered by or to the AP and possible delays in the settlement of the in-kind transaction. We also address the impact of market transactions beyond the dimension of creation and redemption in our model by controlling for changes in the composition of the constituents in the underlying basket through the dummy variable *PortAdj*. Given that this kind of adjustment results in transaction costs, we expect tracking error to be higher on these days.

Daily tracking error is also regressed on each independent variable individually to control for multicollinearity and to better determine explanatory power of individual factors. In model (5), we include squared terms of the key independent variables to identify potential non-linearity of relations between tracking error and independent variables. The model can be expressed as follows:

$$\begin{aligned} TE_{it} = {} & (\alpha+v_i)+\beta_1\cdot TER_{it}+\beta_2\cdot TER_{it}^2+\beta_3\cdot XLM_{it}+\beta_4\cdot XLM_{it}^2+\beta_5\cdot RelCash_{it} \\ & +\beta_6\cdot RelCash_{it}^2+\beta_7\cdot DivYield_{it}+\beta_8\cdot DivYield_{it}^2+\beta_9\cdot DISTR_{it} \\ & +\beta_{10}\cdot DISTR_{it}^2+\beta_{11}\cdot RelNetCR_{it}+\beta_{12}\cdot RelNetCR_{it}^2+\beta_{13}\cdot PortAdj_{it}+\varepsilon_{it} \end{aligned} \tag{5}$$

As suggested in the previous paragraphs, we also posit that the liquidity costs of underlying securities should have a further, indirect effect on other independent variables. The reason for this is that any market transaction, whether caused by a reinvestment of cash, a creation/redemption of shares or a portfolio adjustment, should bear transaction costs. With increasing liquidity costs of underlying assets, the reinvestment of cash, portfolio adjustment or creation/redemption of shares should become more expensive for the respective ETF. $XLM \times RelCash$ controls for the relationship between relative cash holdings of a fund and the liquidity cost of its underlying basket. With the interaction term of *RelNetCR* and *liquidity* $(XLM \times RelNetCR)$, we can test whether it is really the AP who bears all liquidity cost, and $XLM \times PortAdj$ measures the interaction between liquidity and market transactions which have been initiated by management, for example due to index adjustments. Model (5) can hence be augmented by additional terms to account for the interaction between *XLM* and relative cash holdings, portfolio adjustments and the daily net creation/redemption of shares, respectively:

$$\begin{aligned} TE_{it} = {} & (\alpha+v_i)+\beta_1\cdot TER_{it}+\beta_2\cdot TER_{it}^2+\beta_3\cdot XLM_{it}+\beta_4\cdot XLM_{it}^2+\beta_5\cdot RelCash_{it} \\ & +\beta_6\cdot RelCash_{it}^2+\beta_7\cdot DivYield_{it}+\beta_8\cdot DivYield_{it}^2+\beta_9\cdot DISTR_{it}+\beta_{10}\cdot DISTR_{it}^2 \\ & +\beta_{11}\cdot RelNetCR_{it}+\beta_{12}\cdot RelNetCR_{it}^2+\beta_{13}\cdot PortAdj_{it} \\ & +\beta_{14}\cdot(XLM_{it}\times RelCash_{it})+\beta_{15}\cdot(XLM_{it}\times RelNetCR_{it}) \\ & +\beta_{16}\cdot(XLM_{it}\times PortAdj_{it})+\varepsilon_{it} \end{aligned} \tag{6}$$

We are testing for heteroscedasticity, time-series autocorrelation and cross-sectional dependence between panels in our sample; we obtain clearly positive results for all tests. In order to ensure valid statistical inference of all our models, we therefore apply robust standard errors. Driscoll and Kraay (1998) provide a computational method which generates standard errors which are heteroscedasticity and autocorrelation consistent, as well as consistent for cross-sectional dependence (as cited in Hoechle, 2007). Furthermore, given the large number of second-order terms and interaction terms in regressions (5) and (6), we have to account for potential multicollinearity and the resulting inflation of standard errors. We do so by centring all independent variables and by means of polynomial orthogonalisation. The latter approach creates a set of squared variables, from which all effects of their respective lower-order terms are removed[6]. That is, the squared terms only represent the purely non-linear effects of the independent variables.

3.2 Empirical results

We present our empirical findings in three steps. First, we report the descriptive statistics for the tested variables. Subsequently, we test the previously described variables individually and as part of basic models (4) and (5). Finally, in a third step, we test the full model (6) including interaction terms for the full period.

3.2.1 Descriptive statistics. The descriptive statistics for the sample ETFs' daily tracking error over time are reported in Table II. For all years, tracking error exhibits a left-tailed skew and substantial leptocurtosis, implying fatter tails than observed in normal distributions. Our sample confirms the general view that on average, ETFs tend to underperform their paper-based benchmark indices: For 10,483 of the total 14,077 observations, the ETFs could not beat their respective benchmarks, underperforming by a daily average of 0.05 per cent. On 3,594 observation days, approximately a quarter of our sample, the ETFs performed equal to or better than their respective benchmarks with an average daily outperformance of 0.15 per cent.

Table II.
Descriptive statistics for daily tracking error per sample year (in per cent)

Year	No. of ETFs	No. of obs.	Mean	Median	SD	Min.	Max.	Skew.	Kurtosis	Raw mean
2003	3	384	0.6035***	0.4229	0.5708	0.0010	3.2906	1.87	7.58	−0.0054
2004	3	768	0.4344***	0.3113	0.3996	0.0023	2.5390	1.62	6.10	−0.0069
2005	4	964	0.2648***	0.2005	0.2688	0.0001	2.4237	1.68	8.35	−0.0018
2006	4	1,020	0.0101***	0.0014	0.0952	0.0000	2.8268	26.00	756.01	−0.0015
2007	4	1,008	0.0100***	0.0014	0.1003	0.0000	2.8482	23.71	645.14	−0.0017
2008	6	1,350	0.0111***	0.0013	0.1319	0.0000	4.5518	30.77	1,044.41	−0.0012
2009	7	1,705	0.0360***	0.0016	0.3101	0.0000	9.1722	20.85	526.66	−0.0046
2010	7	1,785	0.0214***	0.0014	0.1756	0.0000	5.0715	21.22	534.10	−0.0018
2011	7	1,785	0.0238***	0.0016	0.1821	0.0000	4.8078	18.58	418.71	−0.0013
2012	7	1,757	0.0269***	0.0015	0.2282	0.0000	7.1482	23.05	639.37	−0.0022
2013	8	1,551	0.0261***	0.0015	0.1917	0.0000	5.3592	19.59	477.74	−0.0017
Total	8	14,077	0.0771***	0.0019	0.2746	0.0000	9.1722	10.08	192.76	−0.0024

Notes: This table contains descriptive statistics for daily tracking error in per cent over time for the full ETF sample. It reports the mean, median, standard deviation, minimum, maximum, skewness, and kurtosis for the daily tracking error per sample year. Furthermore, it reports the number of observations and ETFs in the sample that are active in the respective year. In the last column, the raw mean daily tracking error is presented (Raw mean). Tracking error is calculated according to formula (3) as the absolute difference between daily NAV and the index return for each ETF in the sample. Raw tracking error is calculated as the difference between the daily NAV and index return for each ETF in the sample, accounting for negativity and positivity of deviations. Years 2003 and 2013 are not complete. The statistical significance of the result is different from zero based on a two-tailed test at the ***1 per cent confidence level

Table III provides some further descriptive statistics on the key variables for the eight observed ETFs. For the period from July 2003 to October 2013, daily tracking error in the observed sample was roughly 0.08 per cent per day. Relative cash positions (*RelCash*) average approximately 0.39 per cent of total AuM per day, with comparably high standard deviation, suggesting considerable variation in daily cash holdings over time and across funds. The ETF with the highest cash-to-assets ratio in our sample holds an average of 2.06 per cent of its total assets in cash, while the ETF with the lowest ratio exhibits an average cash holding of merely 0.01 per cent relative to AuM. Relative net creation/redemption averages 1.63 per cent of AuM per day for the full sample, meaning that on average, fund holdings fluctuate by that net figure per trading day due to newly created or redeemed fund shares. Similar to daily cash holdings, *RelNetCR* is subject to considerable variation over time and across funds, with a maximum daily average net creation/redemption relative to AuM of 4.66 per cent and a minimum average of merely 0.12 per cent of AuM.

Except for the effect of portfolio adjustments, our postulations for the relations between the tested independent variables and ETF tracking error are further supported by the pairwise correlations between the variables over the full period, reported in Table IV. Although statistically insignificant in one case, the correlations

Variable	Observations	Mean	SD	Min.	Max.
TE	14,077	0.0771	0.2746	0.0000	9.1722
TER	14,082	0.3351	0.1587	0.0500	0.5200
XLM	12,444	0.3015	0.3853	0.0508	4.2814
RelCash	14,082	0.3856	1.1143	−1.0015	10.0687
Div Yield	12,910	0.0134	0.0747	0.0000	1.7388
DISTR	14,082	0.0167	0.3248	0.0000	17.9461
RelNetCR	14,079	1.6325	26.6014	0.0000	1,566.3320

Note: This table reports the number of observations, mean, standard deviation, minimum and maximum observations for daily tracking error (*TE*), total annual expense ratio (*TER*), weighted underlying liquidity cost (*XLM*), cash holdings relative to total AuM (*RelCash*), dividend yield to NAV (*Div Yield*), distribution to ETF shareholders relative to NAV (*DISTR*) and net creation/redemption of ETF shares expressed as relative change in current total AuM (*RelNetCR*)

Table III. Descriptive statistics for the tested variables in the full ETF sample (in per cent)

	TE	TER	XLM	RelCash	DivYield	Distrib	RelNetCR	PortAdj
TE	1.0000							
TER	0.1254***	1.0000						
XLM	0.0056	0.6454***	1.0000					
RelCash	0.0467***	−0.1277***	−0.1037***	1.0000				
Div Yield	0.1552***	−0.0368***	−0.0347***	0.1090***	1.0000			
DISTR	−0.3707***	0.0054	0.0076	−0.0136	−0.0231***	1.0000		
RelNetCR	0.0356***	−0.0182**	−0.0183**	0.0416***	0.1989***	0.0013	1.0000	
PortAdj	−0.0146*	0.0216**	0.0286***	−0.0037	−0.0113	0.0045	−0.0014	1.0000

Notes: The matrix reports the pairwise correlations for daily tracking error (*TE*), total annual expense ratio (*TER*), weighted portfolio liquidity cost (*XLM*), cash holdings relative to total AuM (*RelCash*), dividend yield to NAV (*Div Yield*), distribution to ETF shareholders relative to NAV (*DISTR*), net creation/redemption of ETF shares expressed as relative change in current total AuM (*RelNetCR*) and portfolio adjustments (*PortAdj*). The statistical significance of the result is different from zero based on a two-tailed test at the *10, **5 and ***1 per cent confidence levels

Table IV. Matrix of pairwise correlations between tested variables still suggest a negative effect of DISTR and a positive effect of *TER*, *XLM*, *RelCash*, *DivYield* and *RelNetCR* on an ETF's tracking error.

3.2.2 Tracking error determinants. The outcomes for the basic panel regression models (4) and (5) are reported in Tables V and VI, respectively. Tracking error is first regressed on each of the independent variables separately before testing all factors together.

Overall, the two tables report highly significant coefficients for all tested variables. To be more specific, the outcome suggests that daily tracking error of ETFs in the DAX index universe is significantly affected by the liquidity cost of their respective underlying securities, their relative cash holdings, dividend yield, distribution of cash to investors, daily net creation and redemption of shares, as well as portfolio adjustments. The results for the tested factors clearly verify our posited hypotheses, except for that concerning the effect of portfolio adjustments. Significant results for *XLM*, in particular, confirm the postulated effect of liquidity cost of underlying securities on ETF tracking error.

The results for the squared variables reported in Table VI further suggest that the relations between tracking error on the one hand and total expense ratio, basket liquidity and distributions on the other are significantly non-linear in nature. Except for the total expense ratio, all significant non-linear relations exhibit a concave shape, implying a constantly declining slope in the magnitude of impact of these factors on ETFs' tracking ability. The respective maximum and minimum points of effect on tracking error for identified non-linear effects are reported in Table AI.

In regression (6), we control for potential interactions of liquidity cost with relative cash holdings, the daily creation/redemption process of ETF shares and portfolio adjustments (see Table VII). With regard to the key independent variables in the full sample, we obtain results that are similar to the ones observed in Tables V and VI. That is, all key variables have a statistically significant impact on tracking error, with *TER*, *XLM* and *DISTR* exhibiting non-linear relationships. Similar to the findings in the basic model (5), *DISTR* has the greatest single effect with a beta of approximately −0.12, followed by *TER*, *DivYield*, the *XLM* effect of underlying liquidity and *RelCash*[7]. Relative net creation/redemption of shares also has a significant, albeit rather small effect on *TE*. From the insignificance of $XLM \times RelNetCR$, we can further infer that the impact of the creation or redemption of ETF shares on daily tracking error is independent from liquidity cost involved in obtaining or selling the basket of underlying securities. The only significant interaction in our augmented model (6) is between liquidity cost and portfolio adjustments. This suggests that in addition to its direct effect on ETF tracking ability, the liquidity cost of underlying securities also has an indirect effect through its interaction with market transactions caused by changes in the composition of the ETF's portfolio constituents.

3.3 Discussion of findings

The finding of all tested key variables exhibiting significant effects on tracking error in ETFs corroborates most of our postulated hypotheses. The liquidity cost of underlying securities in particular has a measurable and positive effect on the tracking ability of ETFs. The findings further confirm our notion that cash holdings, dividend yield and daily creation/redemption of ETF shares have a significant and positive effect on tracking error. Cash distributions to ETF investors appear to substantially reduce return deviations from a price-index benchmark, as do portfolio adjustments, albeit to a much smaller degree.

Table V. Results for individual determinants of tracking error and regression (4)

Variable	Dependent variable TE							
TER	1.0546 (0.0002)***							1.0203 (0.0003)***
XLM		0.0821 (0.0159)**						0.0760 (0.0147)**
RelCash			0.0187 (0.0039)***					0.0157 (0.0089)***
DivYield				0.5310 (0.0000)***				0.4873 (0.0000)***
DISTR					−0.3127 (0.0411)**			−0.3584 (0.0311)**
RelNetCR						0.0004 (0.0098)***		0.0001 (0.0711)*
PortAdj							−0.0474 (0.0035)***	−0.0230 (0.0362)**
Constant	0.0771 (0.0000)***	0.0611 (0.0000)***	0.0771 (0.0000)***	0.0615 (0.0000)***	0.0771 (0.0000)***	0.0771 (0.0000)***	0.0775 (0.0000)***	0.0618 (0.0000)***
Observations	14,077	12,444	14,077	12,907	14,077	14,074	14,077	12,442
R^2 (adj.)	0.0480	0.0054	0.0042	0.0238	0.1396	0.0015	0.0002	0.2908
No. of ETFs	8	8	8	8	8	8	8	8
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Max. VIF	–	–	–	–	–	–	–	1.05

Notes: This table reports the results for the fixed effects regression of tracking error (*TE*) on individual centred independent variables as well as on regression (4) in per cent. The tested independent variables are total annual expense ratio (*TER*), weighted portfolio liquidity cost (*XLM*), cash holdings relative to total AuM (*RelCash*), dividend yield to NAV (*DivYield*), distribution to ETF shareholders relative to NAV (*DISTR*), net creation/redemption of ETF shares expressed as relative change in current total AuM (*RelNetCR*) and portfolio adjustments (*PortAdj*). Respective *p*-values are reported in parentheses. Furthermore, the number of observations, adjusted R^2, the number of ETFs for the respective regression and the maximum variance inflation factor (VIF) are stated. Statistical significance of result being different from zero based on a two-tailed test at *10, **5 and ***1 per cent confidence levels

Table VI. Results for individual determinants of tracking error and regression (5)

Variable	Dependent variable TE							
TER	0.0594 (0.0000)***							0.0577 (0.0000)***
TER^2	0.0850 (0.0000)***							0.0859 (0.0000)***
XLM		0.0188 (0.0038)***						0.0178 (0.0032)***
XLM^2		−0.0225 (0.0024)***						−0.0207 (0.0020)***
RelCash			0.0177 (0.0039)***					0.0135 (0.0045)***
$RelCash^2$			−0.0076 (0.4157)					0.0028 (0.7366)
DivYield				0.0396 (0.0000)***				0.0372 (0.0000)***
$DivYield^2$				0.0032 (0.6583)				0.0021 (0.7289)
DISTR					−0.1016 (0.0062)***			−0.1165 (0.0039)***
$DISTR^2$					−0.0666 (0.0008)***			−0.0678 (0.0004)***
RelNetCR						0.0104 (0.0050)***		0.0042 (0.0252)**
$RelNetCR^2$						−0.0023 (0.3885)		0.0011 (0.4080)
PortAdj							−0.0474 (0.0035)***	−0.0195 (0.0393)**
Constant	0.0771 (0.0000)***	0.0611 (0.0000)***	0.0771 (0.0000)***	0.0615 (0.0000)***	0.0771 (0.0000)***	0.0771 (0.0000)***	0.0775 (0.0000)***	0.0584 (0.0000)***
Observations	14,077	12,444	14,077	12,907	14,077	14,074	14,077	12,442
R^2 (adj.)	0.1242	0.0122	0.0047	0.0239	0.1995	0.0015	0.0002	0.4716
No. of ETFs	8	8	8	8	8	8	8	8
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Max. VIF	1.00	1.00	1.00	1.00	1.00	1.00	–	1.08

Notes: This table reports the results for the fixed effects regression of tracking error (*TE*) on individual centred independent variables, including squared terms, as well as on regression (5) in per cent. The tested independent variables are total annual expense ratio (*TER*), weighted portfolio liquidity cost (*XLM*), cash holdings relative to total AuM (*RelCash*), dividend yield to NAV (*DivYield*), distribution to ETF shareholders relative to NAV (*DISTR*), net creation/redemption of ETF shares expressed as relative change in current total AuM (*RelNetCR*), and portfolio adjustments (*PortAdj*). Respective *p*-values are reported in parentheses. Furthermore, the number of observations, adjusted R^2, the number of ETFs for the respective regression, and the maximum variance inflation factor (VIF) are stated. Statistical significance of result being different from zero based on a two-tailed test at **5 and ***1 per cent confidence levels

Variables	Dependent variable TE for different samples Model (5) excl. interaction terms	Model (6) incl. interaction terms
TER	0.0577 (0.0000)***	0.0576 (0.0000)***
TER^2	0.0859 (0.0000)***	0.0859 (0.0000)***
XLM	0.0178 (0.0032)***	0.0179 (0.0034)***
XLM^2	−0.0207 (0.0020)***	−0.0208 (0.0019)***
RelCash	0.0135 (0.0045)***	0.0139 (0.0044)***
$RelCash^2$	0.0028 (0.7366)	0.0034 (0.6963)
DivYield	0.0372 (0.0000)***	0.0373 (0.0000)***
$DivYield^2$	0.0021 (0.7289)	0.0022 (0.7242)
DISTR	−0.1165 (0.0039)***	−0.1165 (0.0039)***
$DISTR^2$	−0.0678 (0.0004)***	−0.0678 (0.0004)***
RelNetCR	0.0042 (0.0252)**	0.0055 (0.0138)**
$RelNetCR^2$	0.0011 (0.4080)	0.0021 (0.1704)
PortAdj	−0.0195 (0.0393)**	−0.0179 (0.0410)**
XLM × *RelCash*		−0.0306 (0.3478)
XLM × *RelNetCR*		−0.0011 (0.1848)
XLM × *PortAdj*		−0.0851 (0.0190)**
Constant	0.0584 (0.0000)***	0.0585 (0.0000)***
Observations	12,442	12,442
R^2 (adj.)	0.4716	0.4718
No. of ETFs	8	8
Fixed effects	Yes	Yes
Max. VIF	1.08	1.88

Notes: This table reports the results for fixed effects regressions (5) and (6) of tracking error (*TE*) on centred independent variables in per cent, namely, total annual expense ratio (*TER*), weighted portfolio liquidity cost (*XLM*), cash holdings relative to total AuM (*RelCash*), dividend yield to NAV (*DivYield*), distribution to ETF shareholders relative to NAV (*DISTR*), net creation/redemption of ETF shares expressed as relative change in current total AuM (*RelNetCR*), portfolio adjustments (*PortAdj*) and the interaction terms of XLM with RelCash (*XLM* × *RelCash*), RelNetCR (*XLM* × *RelNetCR*) and portfolio adjustments (*XLM* × *PortAdj*). Respective *p*-values are reported in parentheses. Furthermore, the number of observations, adjusted R^2, the number of ETFs for the respective regression and the maximum variance inflation factor (VIF) are stated. The statistical significance of the results is different from zero based on a two-tailed test at the **5 and ***1 per cent confidence levels

Table VII. Determinants of tracking error in regressions (5) and (6)

The empirical evidence on the effects of liquidity of the underlying portfolio on ETF tracking error presented in this paper can be considered an extension of the works by Rompotis (2012) and Meinhardt *et al.* (2012), who confirm a positive impact for German ETFs. While these works address the relation between liquidity and tracking ability on an aggregate level of ETF liquidity, we take a more bottom-up approach by taking liquidity of individual stocks into consideration. Theoretically, the only time that the liquidity cost of underlying securities is bound to have an effect is at the occurrence of a market transaction. Then we should expect liquidity costs to play a role only in events triggering portfolio adjustments. Controlling for cash holdings, portfolio adjustments and creation/redemption separately, we still find *XLM* to have a strongly significant and independent effect on ETF tracking error. A possible explanation is that relatively small internally initiated market transactions that are not fully captured by the rather large-transaction-oriented factors *RelNetCR* or *PortAdj* cause liquidity-related transaction costs. These can occur, for instance through constant rebalancing by fund management in order to better match or optimise index weights over time. In these cases, XLM represents the liquidity cost borne by the ETF for its attempts to optimise the weights of the underlying portfolio.

This, in turn, suggests that although daily creation/redemption usually takes place as an in-kind transaction, ETFs are not fully protected from the effect of the liquidity cost of their underlying securities. Whilst the magnitude of the positive relation between liquidity cost and tracking error in absolute figures is indeed small, we still have to challenge Kostovetsky's (2003) claim that liquidity is not at all a determining factor of tracking error. To put the absolute magnitude of the figures into some perspective, it should be re-emphasised that this study addresses tracking error at the daily level.

For our set of German DAX ETFs we find cash flows into or out of the fund to have a substantial effect on tracking error. In terms of dividend yield, our results are in line with the findings of Elton *et al.* (2002) and Blitz *et al.* (2012), who show for the US and European markets, respectively, that the main cause of tracking error besides total expense ratio is forfeited return due to delayed reinvestment of cash dividends. Fund managers have been aware of this effect for quite some time and apply various strategies to reduce or at least control the effect, provided of course that such measures are possible given the regulatory constraints. The notion of forfeited returns on delayed investment especially holds true for distributing ETFs. Being unable to reinvest the proceeds from dividend payments, these ETFs have to rely on a few fixed distribution dates to reduce accumulated cash holdings. Again, fund management is usually aware of this source of tracking error and it might indeed be worthwhile to determine whether it is the optimal strategy to solely rely on a few distribution dates or whether there are still better ways to smooth the effects of idle cash on tracking error.

Frino and Gallagher (2002) use cash flows in their model to control for cost-inducing cash transactions of passive funds. However, to our knowledge, daily holdings of cash relative to total assets under management as potential explanatory variable of ETF tracking error have not been tested yet. This having been said, our analysis does indeed verify the positive and significant impact on tracking ability.

The process of creation and redemption of shares is fundamental to the entire concept of ETFs, as it ensures continuous arbitrage trading and hence NAVs which are very close to index prices. However, reviewing the available literature, creation/redemption does not seem to be a topic of focus for research on tracking error. Both Gallagher and Segara (2006) and Gastineau (2004) argue that ETFs should not be affected in their tracking ability by creation/redemption of shares due to the in-kind-delivery and fees charged to the AP. Still, our findings confirm a positive independent effect on tracking error. With the insignificance of the interaction term between *RelNetCR* and *XLM*, it becomes apparent that the process of creating and redeeming ETF shares has an effect on tracking ability beyond the dimension of liquidity cost of the underlying basket. Thus, while we can agree with Gallagher and Segara (2006) and Gastineau (2004) that the cost of creation/redemption is successfully transferred to the AP, we have to challenge their conclusion that this implies that creation/redemption has no impact on ETF tracking ability at all. One possible explanation for the effect has to do with the imperfect replication of index weights: since creation/redemption of shares takes place in pre-defined lot sizes, it is almost impossible for an AP to perfectly allocate the corresponding NAV value among the index constituents due to indivisibility of individual stock shares. That is, there will most probably be a remainder in cash or in stocks which does not perfectly match the actual index weights. As a result, the ETF will exhibit tracking error due to differences between the benchmark and the underlying basket. Yet this effect should be rather small for ETFs with large assets under management. Another explanation could be daily charging or attribution of fees from or to the fund: although they are effectively paid on a monthly or quarterly basis, fees to or from the fund (e.g. securities-lending fees or management fees) are commonly calculated and attributed to ETF NAV on a daily basis. A substantial change in AuM from one day to another due to creation/redemption, would also significantly affect the base for calculating such fees and hence daily attribution of fees to NAV.

With portfolio adjustments having a negative effect on an ETF's tracking error, we have to reject the hypothesis that they reduce tracking ability through transaction costs. Instead, we observe days on which ETFs change the composition of their underlying portfolio by swapping constituents (mostly due to officially announced index adjustments) to exhibit less pronounced tracking error even after controlling for the interaction with liquidity cost. This suggests that portfolio adjustments have an impact on tracking error beyond the dimension of liquidity-related transaction costs, allowing the portfolio to better track the benchmark index. Once more, we attribute this effect to the imperfect replication of index weights in the ETF portfolio: similar to cash distributions to investors, portfolio adjustment events seem to be a change to dispose of unwanted weight deviations which have accumulated over time.

Since the XLM is only available for constituents of the DAX index universe, our ETF sample is constrained to the German equity market. We still consider the sample to be representative for the German market for two reasons: first, with 23 per cent of the total ETF trading volume (approximately 40 per cent including OTC trading) as of April 2014, the sample funds represent a substantial part of overall ETF trading in Germany. Second, in terms of trading volume and market capitalisation, the replicated indices cover by far the largest part of the German equity market. Even for the identified funds, data availability is somewhat poor, with some funds exhibiting data gaps in their respective time series and some funds falling out of the sample altogether. However, the issue of data gaps is mainly driven by an individual fund, which exhibits a longer time period of missing data. Therefore, we believe that in the panel cross-section, the effect should be smoothed and should not substantially affect results.

We understand that the high number of squared terms and interaction terms in our models bears the risk of high multicollinearity. While acknowledging this risk, we still consider it essential to leave the variables in the model and to control for all these factors separately. We partly circumvent the problem by centring all independent variables and by orthogonalisation of all second-order terms. As a result, the measured maximum variance inflation factors do not exceed 1.88 for any of our models.

4. Conclusion

In this study, we have tried to identify the determining factors of daily tracking error in ETFs in the German DAX index universe. We particularly focused on the liquidity of individual underlying securities as a potential factor affecting ETF tracking ability.

As postulated, we found daily tracking error to be dependent on liquidity of stocks in the underlying portfolio, management fees, cash holdings, dividend yield, cash distributions from an ETF to its investors, portfolio adjustments and the process of creation/redemption of ETF shares. Liquidity affects tracking error both directly and in interaction with portfolio adjustments, implying that liquidity cost plays a significant role in various events which trigger a market transaction. Still, cash inflows and outflows in the form of dividends and distributions, respectively, appeared to be the factors with the most substantial effect on tracking error in our model.

Research on some of the tested variables seems to have just commenced. This is especially true for liquidity of individual underlying stocks or the process of creation/redemption of ETF shares. In particular, our findings on the latter clearly challenge the current notion of ETF tracking ability being immune against effects from creation/redemption due to in-kind transactions.

It was our aim to contribute to a broader discussion of potential tracking error determinants and to provide some new insights to their dependence on market conditions. Due to the lack of availability of XLM data, research beyond the DAX index universe seems to be unmanageable at this time. Yet, there are other liquidity proxies which are similar to Deutsche Börse's XLM, such as the cost of round-trip trade introduced by Irvine *et al.* (2000), which could help to further elaborate on true liquidity effects on ETF tracking error in other markets. Furthermore, since there is still no consensus in the literature on the impact of economic regimes on tracking error and its determinants, it might also prove valuable to apply our model to sample periods with more extreme return patterns, such as the global financial crisis.

Notes

1. As a consequence, Blitz *et al.* (2012) argue that with tracking error being inevitable, active fund managers should refrain from using a "paper" index as benchmark; rather, they should use a corresponding passive fund, which already incorporates these frictions, such as an ETF or mutual index fund. This view is supported by Kostovetsky (2003), who argues that tracking error itself is difficult to model, since there is no true benchmark for comparison. In his view, any performance comparison with paper indices is fallacious because it assumes efficient paper transactions at all times.
2. See Stoll (2003) for a detailed discussion of the bid-ask spread as indicator of the cost of trading and the illiquidity of a market.
3. See, for example, Delcoure and Zhong (2007), among others.
4. Data provided by Deutsche Börse AG. OTC trading volume based on all settled transactions conducted via Clearstream OTC Cascade Functionality.
5. Further theoretical background on XETRA Liquidity Measure is provided by Hachmeister (2007), Stange and Kaserer (2011), and Rösch and Kaserer (2013).
6. For further theoretical background on orthogonalisation, see Golub and Van Loan (1996).
7. Note that with the inclusion of interaction terms, the interpretation of all coefficients changes. In model (6), an independent variable (e.g. XLM) represents the unique effect under the assumption that all other variables that might be interacting with it (XLM) are equal to zero.

References

Aber, J.W., Li, D. and Can, L. (2009), "Price volatility and tracking ability of ETFs", *Journal of Asset Management*, Vol. 10 No. 4, pp. 210-221.

Agapova, A. (2011), "Conventional mutual index funds versus exchange-traded funds", *Journal of Financial Markets*, Vol. 14 No. 2, pp. 323-343.

Blitz, D. and Huij, J. (2012), "Evaluating the performance of global emerging markets equity exchange-traded funds", *Emerging Markets Review*, Vol. 13 No. 2, pp. 149-158.

Blitz, D., Huij, J. and Swinkels, L. (2012), "The performance of European index funds and exchange-traded funds", *European Financial Management*, Vol. 18 No. 4, pp. 649-662.

Blume, M.E. and Edelen, R.M. (2003), "S&P 500 indexers, delegation costs and liquidity mechanisms", Paper No. 04-03, The Wharton School, University of Pennsylvania, The Rodney L. White Center for Financial Research, Philadelphia, PA.

Charupat, N. and Miu, P. (2013), "Recent developments in exchange-traded fund literature – pricing efficiency, tracking ability, and effects on underlying securities", *Managerial Finance*, Vol. 39 No. 5, pp. 427-443.

Chu, P.K.-K. (2011), "Study on the tracking errors and their determinants: evidence from Hong Kong exchange traded funds", *Applied Financial Economics*, Vol. 21 No. 5, pp. 309-315.

Chu, P.K.-K. (2013), *Tracking Errors and Their Determinants: Evidence from Hong Kong Exchange Traded Funds*, University of Macau, Macau.

Delcoure, N. and Zhong, M. (2007), "On the premiums of iShares", *Journal of Empirical Finance*, Vol. 14 No. 2, pp. 168-195.

Deutsche Bank Research (2014), *ETF Annual Review and Outlook*, Deutsche Bank Securities Inc., London.

Driscoll, J. and Kraay, A.C. (1998), "Consistent covariance matrix estimation with spatially dependent data", *Review of Economics and Statistics*, Vol. 80 No. 4, pp. 549-560.

Elia, M. (2012), "Tracking error of traditional and synthetic European exchange-traded funds", working paper, University of Turin, Turin.

Elton, E.J., Gruber, M.J., Comer, G. and Li, K. (2002), "Spiders: where are the bugs?", *Journal of Business*, Vol. 75 No. 3, pp. 453-472.

Frino, A. and Gallagher, D.R. (2001), "Tracking S&P 500 index funds", *Journal of Portfolio Management*, Vol. 28 No. 1, pp. 44-55.

Frino, A. and Gallagher, D.R. (2002), "Is index performance achievable?: an analysis of Australian equity index funds", *Abacus*, Vol. 38 No. 2, pp. 200-214.

Frino, A., Gallagher, D.R., Neubert, A.S. and Oetomo, T.N. (2004), "Index design and implications for index tracking – evidence from S&P 500 index funds", *Journal of Portfolio Management*, Vol. 30 No. 2, pp. 89-95.

Gallagher, D.R. and Segara, R. (2006), "The performance and trading characteristics of exchange-traded funds", *Journal of Investment Strategy*, Vol. 1 No. 2, pp. 49-60.

Gastineau, G.L. (2002), "Equity index funds have lost their way – a solution to growing problems", *Journal of Portfolio Management*, Vol. 28 No. 2, pp. 55-64.

Gastineau, G.L. (2004), "The benchmark index ETF performance problem – a simple solution", *Journal of Portfolio Management*, Vol. 30 No. 2, pp. 96-103.

Golub, G.H. and Van Loan, C.F. (1996), *Matrix Computations*, 3rd ed., Johns Hopkins University Press, Baltimore, MD.

Hachmeister, A. (2007), *Informed Traders As Liquidity Providers: Evidence from the German Equity Markets*, Deutscher Universitäts-Verlag, Wiesbaden.

Hendershott, T. and Riordan, R. (2013), "Algorithmic trading and the market for liquidity", *Journal of Financial and Quantitative Analysis*, Vol. 48 No. 4, pp. 1001-1024.

Hoechle, D. (2007), "Robust standard errors for panel regressions with cross-sectional dependence", *The Stata Journal*, Vol. 7 No. 3, pp. 281-312.

Irvine, P.J., Benston, G.J. and Kandel, E. (2000), "Liquidity beyond the inside spread: measuring and using information in the limit order book", SSRN eLibrary.

Kostovetsky, L. (2003), "Index mutual funds and exchange-traded funds – a comparison of two methods of passive investment", *Journal of Portfolio Management*, Vol. 29 No. 4, pp. 80-92.

Krogmann, M. (2011), "Quantifying liquidity risk", in Kaur, P., Lubecka, K. and Hornbrook, A. (Eds), *Buy-Side Intelligence: The Euromoney Guide to Securities Trading*, Euromoney Trading Ltd., North Hill, pp. 37-41.

Kundisch, D. and Klein, C. (2009), "DerTracking Error von indexnachbildenden Instrumenten auf den DAX – eine empirische Analyse des ETFs DAX EX sowie zehn Indexzertifikaten", *Der Betrieb*, Vol. 62 No. 22, pp. 1141-1145.

Lin, A. and Chou, A. (2006), "The tracking error and premium/discount of Taiwan's first exchange traded fund", *Web Journal of Chinese Management Review*, Vol. 9 No. 3, pp. 1-20.

Meinhardt, C., Mueller, S. and Schoene, S. (2012), "Synthetic ETFs: will full replication survive?", SSRN working paper, Humboldt University, Berlin, available at: http://ssrn.com/abstract=2026409 http://dx.doi.org/10.2139/ssrn.2026409 (accessed 8 July 2013).

Milonas, N.T. and Rompotis, G.G. (2006), "Investigating European ETFs: the case of the Swiss exchange traded funds", working paper for Annual Conference of HFAA, University of Athens, Thessaloniki.

Pope, P.F. and Yadav, P.K. (1994), "Discovering errors in tracking error", *Journal of Portfolio Management*, Vol. 20 No. 2, pp. 27-32.

Qadan, M. and Yagil, J. (2012), "On the dynamics of tracking indices by exchange traded funds in the presence of high volatility", *Managerial Finance*, Vol. 38 No. 9, pp. 804-832.

Roll, R. (1992), "A mean/variance analysis of tracking error", *Journal of Portfolio Management*, Vol. 18 No. 4, pp. 15-24.

Rompotis, G.G. (2006), "Evaluating the performance and the trading characteristics of iShares", working paper, Department of Economics, University of Athens, Athens.

Rompotis, G.G. (2011), "Predictable patterns in ETFs' return and tracking error", *Studies in Economics and Finance*, Vol. 28 No. 1, pp. 14-35.

Rompotis, G.G. (2012), "The German exchange traded funds", *The IUP Journal of Applied Finance*, Vol. 18 No. 4, pp. 62-82.

Rösch, C. and Kaserer, C. (2013), "Market liquidity in the financial crisis: the role of liquidity commonality and flight-to-quality", *Journal of Banking and Finance*, Vol. 37 No. 7, pp. 2284-2302.

Shin, S. and Soydemir, G. (2010), "Exchange-traded funds, persistence in tracking errors and information dissemination", *Journal of Multinational Financial Management*, Vol. 20 No. 4, pp. 214-234.

Stange, S. and Kaserer, C. (2011), "The impact of liquidity risk: a fresh look", *International Review of Finance*, Vol. 11 No. 3, pp. 269-301.

Stoll, H.R. (2003), "Market microstructure", in Constantinides, G.M., Harris, M. and Stulz, R.M. (Eds), *Handbook of the Economics of Finance*, Vol. 1, Part A, Elsevier, Amsterdam, pp. 553-604.

Appendix

Table AI. Max. and min. Points of impact of independent variables for regression (5)

Variable	Max./min. point
TER (min.)	−0.3358
XLM (max.)	0.4301
DISTR (max.)	−0.8589

Notes: This table reports the maximum and minimum points of impact of the respective variables on tracking error. The variables with a significant non-linear relationship with tracking error are total annual expense ratio (*TER*), weighted portfolio liquidity cost (*XLM*) and distribution of cash to investors relative to NAV (*DISTR*)

About the authors

Friedrich Osterhoff is a Researcher and Doctoral Candidate at the Department of Financial Management and Capital Markets at the Technische Universität München, Munich, Germany. Friedrich Osterhoff is the corresponding author and can be contacted at: friedrich.osterhoff@tum.de

Christoph Kaserer is a Chair of Financial Management and Capital Markets and is Co-Director of the Center for Entrepreneurial and Financial Studies (CEFS) at the Technische Universität München, Munich, Germany.