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The Perils of Performance Measurement in the German Mutual-Fund Industry*

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Abstract

We document a curious feature of the German mutual fund industry. Unlike U.S. mutual funds, funds domiciled in Germany do not necessarily compute their net asset values (NAV) as of market close. Using a sample of German equity funds, we infer each fund's NAV closing time from the best-fit market model using both maximum likelihood and Bayesian estimation. The results of both approaches coincide perfectly and show that all but one of the funds domiciled in Germany report intraday NAVs. We show that using market returns computed at the end of the day instead of the best-fit time, usually leads to misleading inferences about mutual fund performance.

Keywords: CAPM regression, Dimson correction, mutual funds, net asset values, performance measurement.

JEL codes: G12, G24.

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1 Introduction

In this paper we uncover a curious anomaly in the German mutual fund industry. The vast majority of German equity mutual funds are domiciled either in Germany or in neighboring Luxembourg.[1] The two types of funds seem to have radically different investment styles as evidenced by the histograms of CAPM betas in Figures 1 and 2. (We describe the data and our computations leading to these figures in Section 2.2.) The Luxembourg-based funds (and one fund based in Great Britain) have a spread of CAPM betas, with a peak near one. The results are dramatically different for mutual funds domiciled in Germany, whose CAPM betas cluster around 0.5.

The result for German mutual funds domiciled in Luxembourg is unsurprising, simply because while some funds may provide diversification opportunities, it is difficult for most mutual funds to avoid holding a portfolio that approximates the entire market portfolio. The low market correlation of the German mutual funds domiciled in Germany is another matter. Taken at face value, this observation suggests that German mutual fund managers – but only those actually managing funds domiciled in Germany – have discovered a way to invest in the German stock market and the German stock market alone, to provide considerable diversification against broad market swings. What could explain such a dramatic difference? Regulatory differences? Some sort of systematic difference in cash policies? Differences in loading on a missing risk factor?

We provide circumstantial evidence that the explanation lies elsewhere, in a little-known aspect of the German mutual fund industry. Conversations with employees in the mutual fund industry have suggested to us that it is the custom in Germany to compute mutual fund NAVs in the middle of the day, rather than after market close as, for example, in the United States. When running the CAPM regression using daily returns, this custom leads to the returns on the fund from the middle of the day yesterday to the middle of the day today being compared to the returns of the market from the close of yesterday to the close of today. Since the correlation between market returns in the afternoon with returns in the morning is low, this time shift mechanically pushes the estimates of beta downward.

It is surprisingly difficult to determine the NAV computation time for a mutual fund. Fund prospectuses may report a deadline for when orders must be placed to be processed that day, but they do not report the time at which the NAV is computed, even though that determines the share price at which the investor is transacting. We contacted several mutual

[1]A mutual fund is domiciled in a country, if the fund's management company is registered as a legal entity in that country. Such a registration implies that the management company must manage the fund in compliance with the regulatory requirements in that country. These regulatory requirements vary across countries and thus may serve as an incentive or disincentive for a company to register in a particular country.

Figure 1: Histogram of estimated CAPM betas for funds with domicile in DE

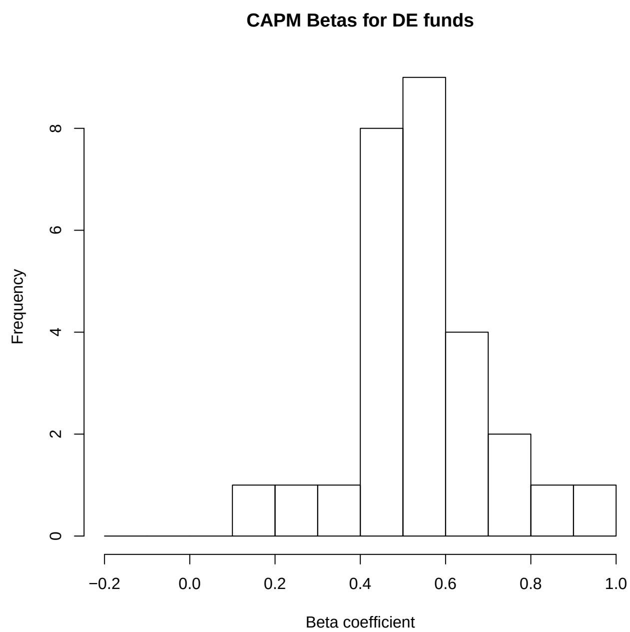
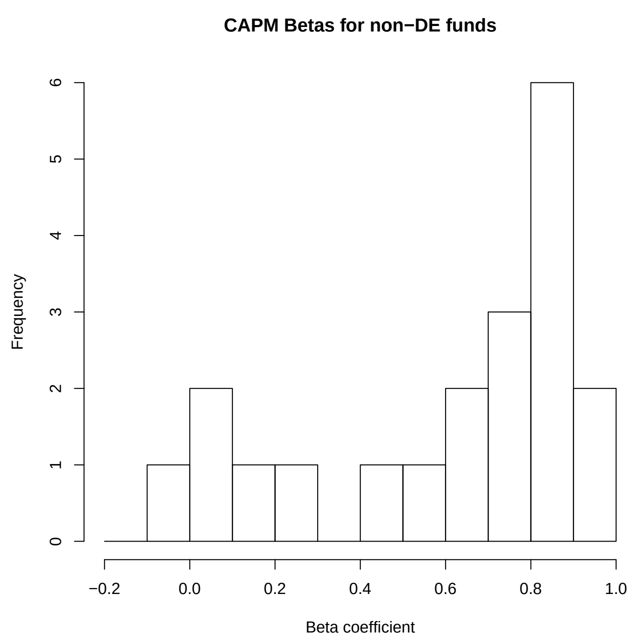


Figure 2: Histogram of estimated CAPM betas for funds with domicile in LU/GB



funds to elicit information on NAV computation times but were always only told order acceptance deadlines. Instead, we employ an indirect approach. Mutual funds generally provide a benchmark to use for comparison purposes. If a fund holds some fraction of the assets in the benchmark, then the fund's returns should match the return on the benchmark most closely at the time of NAV computation. We test this hypothesis using a sample of equity funds that use one of three indices in the DAX® index family[2] as a benchmark. We separate these funds into two groups, those registered in Germany and those registered outside Germany, notably Luxembourg and Great Britain. For all but one of the funds registered in Germany, the effect of early NAV computation time is readily apparent, that is, their returns are significantly more closely correlated with intraday benchmark returns than with end-of-day benchmark returns. On the contrary, the returns for most of the funds registered outside Germany are most closely correlated with benchmark returns calculated at closing time. (Curiously, several Luxembourg-based funds are most correlated with returns computed using the previous day. The simplest explanation is an off-by-one error in NAV dates in the database.)

We conduct our analysis using three different statistical approaches. First, we perform a multiple regression of each fund's returns against its benchmark returns at the previous-day close, at 1pm on the day of close, and at close and choose the beta coefficient with the largest t statistic as an indicator of the closing time. We then refine this intuitive yet ad-hoc procedure and turn to a more formal inference. For each fund, we regress its returns against its benchmark return at ten different times in the day. We then use maximum likelihood estimation and the likelihood ratio test to determine the most likely NAV closing time. Finally, as a robustness check we repeat this analysis using a Bayesian approach. The Bayesian estimates of the best fit closing time are identical to the maximum likelihood results for all funds in the sample.

Clearly, the results lead to the question why so many funds use intraday NAV reporting times. To answer this question, we briefly describe the regulatory environment both in the United States and in Germany. Neither the U.S. Investment Company Act of 1940 nor the German investment law provide mutual funds with specific rules for the timing of NAV computation times. But, while it has been a longstanding custom for mutual funds in the United States to compute their NAV as of 4pm, when the New York Stock Exchange closes (Zitzewitz, 2006), many funds registered in Germany appear to take advantage of this lack of a regulatory constraint. In fact, it appears as if the early editorial deadlines of leading news outlets leads mutual funds domiciled in Germany to report intraday NAVs.

[2] The stock indices in the DAX family are registered trademarks of Deutsche Börse AG, see Deutsche Börse (2013) for detailed information. In the remainder of the paper we omit the registered trademark symbol on all stock indices.

In the last part of the paper, we show that the reporting discrepancy is highly relevant for funds' performance measurement. We demonstrate that incorrectly using the benchmark closing returns leads to grossly misleading estimates for the funds' betas in the CAPM regression. In fact, we show that once we correct for the NAV reporting time, the aforementioned differences in the betas across the samples, see Figures 1 and 2, disappear. In addition, we examine how the Dimson correction (Dimson, 1979) can be employed to estimate the alphas and betas relying solely on end-of-day benchmark data. Finally, we extend the work on mutual fund timing ability by Busse (1999) and Bollen and Busse (2001) to German mutual funds. We show that any conclusions on mutual funds' timing abilities strongly depend on using the correct NAV reporting time.

The remainder of this paper is organized as follows. Section 2 describes our data set, reports CAPM betas computed at close, and presents initial NAV timing results. In Section 3 we identify each mutual fund's closing time by both maximum likelihood and Bayesian estimation. Section 4 takes a look at the regulatory environment for NAV reporting times. Section 5 compares the coefficient estimates between the CAPM regression at the best-fit time and at the closing time. In Section 6, we show that using the regressions at close instead of the regressions at the best-fit time usually leads to drastically different conclusions on the timing ability of a mutual fund manager. Section 7 concludes.

2 Data and Initial Results

In this section, we describe the data set and document the difference in CAPM betas computed at close between domiciles. We also provide initial evidence for the disparity in reporting times.

2.1 Data

We used Morningstar® (`www.morningstar.de`) to search for open-end mutual funds investing in German stocks, and compiled an initial list of 102 entries. We then obtained NAVs and dividend data for each fund from Datastream which we used to compute a return series for each fund. We dropped five funds for having less than six months of data. All remaining funds have at least six months of data, many of them for more than ten years.

Morningstar includes separate listings for each share class in a fund, so we used fund prospectuses to remove duplicates. (The correlation for returns between two share classes of the same fund generally exceeded 99%.) This left us with a sample of 69 funds. For all our tests of a mutual fund reported in this paper, we compare the fund to its self-reported benchmark. We restrict to funds that choose either DAX, HDAX, or CDAX as their benchmarks, which gives us a sample of 48 funds. Table 1 shows the number of funds by benchmark and country of domicile. Tables 14 and 15 in Appendix B provide the

Table 1: Overview of Funds and Benchmarks

	DAX	**HDAX**	**CDAX**	**Total**
DE	20	4	4	28
LU	11	7	1	19
GB	0	1	0	1
Total	31	12	5	48

Number of funds in sample by benchmark and country of domicile.
DE = Germany, LU = Luxembourg, GB = Great Britain.

names and the International Securities Identification Numbers (ISIN) of the final 48 funds. All funds in our final sample are registered in Germany, Luxembourg or Great Britain. (Eighteen of the twenty-one other funds from the initial list of 69 mutual funds are also registered in Germany or Luxembourg and have no benchmark or other benchmarks such as some MSCI index. The same is true for the remaining three funds who are registered in France, Denmark and Ireland, respectively.)

We obtained intraday data on German stock market indices for the period January 2, 2001 until December 31, 2010 (2533 trading days) from the Karlsruher Kapitalmarktdatenbank at the Karlsruhe Institute of Technology. Table 13 in Appendix B provides a brief description of these indices. The risk-free rate is derived from 1-month euro-dollar forwards using covered interest parity. The forward data is from Bloomberg. We performed all computations for the analysis in this paper in the software environment R.

2.2 CAPM Betas Computed At Close

In this paper we report results both from regressions based on market models using returns as well as standard CAPM regressions using excess returns. We denote returns by R_t, the risk-free rate by R_t^f, and excess returns by $R_t^e = R_t - R_t^f$.

The following table presents statistics for the coefficients of the CAPM regressions,

$$R^e_{F,t} = \alpha + \beta R^e_{M,t} + \varepsilon_t. \tag{1}$$

with excess fund and market returns, $R^e_{F,t}$ and $R^e_{M,t}$, respectively, computed at close. For each fund, we use the fund's benchmark as the market. (The results are similar for regressions against the DAX excess returns instead of the benchmark excess returns.) Table 2 presents a summary of the results which are depicted graphically in Figures 1 and 2 in the introduction. We observe a clear split between German-domiciled and non-German-

Table 2: CAPM coefficients computed at Close

	α				β				
	+		−		≤ 0.4	(0.4,0.6]	(0.6,0.8]	(0.8,1]	> 1
DE	2	(0)	26	(8)	3	17	6	2	0
non-DE	7	(1)	13	(2)	5	2	5	8	0

Counts of α and β coefficients. The count of α coefficients are by sign. (The quantities in parentheses are the number significant at the 5% level.) The count of β coefficients are grouped by value.

domiciled funds. Of the 28 funds domiciled in Germany, 20 have a CAPM beta below 0.6 and 8 have a CAPM beta above 0.6. Of the 20 funds domiciled outside of Germany, 7 have a CAPM beta below 0.6 and 13 have a CAPM beta above 0.6.

If the mutual funds do report at midday, we show that the beta estimates will be biased for purely mechanical reasons. Imagine a fund that perfectly replicates the stock market, and therefore under the CAPM has a beta of exactly 1. Now imagine that the fund calculates its daily NAVs using the previous close or at 1pm. What does this do to the CAPM results? We can replicate these two imaginary scenarios by using lagged excess returns of the market benchmark itself as a kind of fund. For this purpose, we regress the benchmark excess returns at the previous day's close, $R^e_{M,t-1}$, against the benchmark's excess returns at close, $R^e_{M,t}$, so

$$R^e_{M,t-1} = \alpha + \beta R^e_{M,t} + \varepsilon_t.$$

Similarly, we regress the excess returns computed at 1pm, $R^e_{M(1pm),t}$, against the returns at close,

$$R^e_{M(1pm),t} = \alpha + \beta R^e_{M,t} + \varepsilon_t.$$

Table 3 shows the results from these CAPM regressions.[3] As we may expect, the coefficient estimates for beta are small for the regression of the previous day's close against the close. The beta estimates for the 1pm returns against close are less than 0.8 for all three indices. So, there is an apparent mechanical effect when we regress a benchmark's 1pm excess returns against its excess returns at close. We observe that the estimated coefficients are quite similar to the betas for the German-domiciled funds. This may suggest that the pattern of CAPM betas for mutual funds domiciled in Germany is due to early reporting.

[3]For all significance tests conducted in this paper, we computed the t statistics using White standard errors.

Table 3: CAPM regression of "wrong time" benchmarks

	DAX		**HDAX**		**CDAX**	
	α	β	α	β	α	β
Prev	-0.001	-0.034	-0.001	0.143	-0.001	-0.018
	(-3.192)	(-1.182)	(-4.300)	(3.470)	(-3.321)	(-0.600)
1pm	-0.000	0.558	-0.000	0.780	-0.000	0.588
	(-1.568)	(18.201)	(-1.957)	(30.364)	(-1.600)	(20.892)

The effect of regressing each benchmark against a lagged benchmark. (Numbers in parentheses are t ratios.) Prev = previous close.

Clearly, so far the evidence for this early reporting time hypothesis is highly circumstantial at best. We now provide more substantial evidence for this hypothesis.

2.3 NAV Reporting Times: Initial Results

To obtain information about the funds' NAV computation times, we tried checking fund prospectuses, but we were unable to find explicit statements about when NAVs are computed. We then contacted several funds directly, but received no information on NAV computation times. Funds only reported the daily order deadline to us. Similarly, some fund prospectuses (e.g., those of DWS Investments or Allianz Global Investors) explicitly mention an order acceptance deadline in the middle of the day but even these do not mention specific NAV computation times. Since the actual time of NAV computation does typically not appear to be publicly available, we employ an indirect approach to detect funds' NAV computation times. Assuming a fund invests a good fraction of its assets in stocks from its benchmark index, the fund's returns should be (more or less) closely correlated to the return on the benchmark. Moreover, this correlation should be most pronounced at the daily NAV computation time. Put differently, if a fund in fact computes its NAV in the middle of the day then the fund's returns should match the returns on the benchmark in the middle of the day better than returns computed at the end of the day. To examine this conjecture, we turn to statistical inference to assemble evidence of intraday NAV reporting times.[4]

One simple check is to regress each fund's returns on the return series of its benchmark at a few different times. For this purpose we compute the returns of a fund's benchmark

[4]Our analysis in this paper rests on the assumption that each fund has been computing its NAV on each day at the same time and that it did not change this time for the entire period for which we have data on the fund. If this assumption is violated, then the times reported in this paper represent only a roughly average reporting time.

at two different points in time: at 1pm and at closing time. (Returns are always computed relative to the same time on the previous day. For example, the 1pm return today would be the return between 1pm yesterday and 1pm today.) We then regress a fund's returns, $R_{F,t}$, against three different market benchmark returns, namely the lagged (previous-day) returns, $R_{M,t-1}$, the (lagged day-of) 1pm returns, $R_{M(1pm),t}$, and the returns at closing time, $R_{M,t}$, that is, we estimate the coefficients in the model[5]

$$R_{F,t} = \alpha + \beta_1 R_{M,t-1} + \beta_2 R_{M(1pm),t} + \beta_3 R_{M,t} + \varepsilon_t. \quad (2)$$

For a fund reporting at close, the opening and midday returns should not provide much additional information about the fund's returns, so we would expect the coefficient estimate for β_3 to be highly significant while the coefficient estimates for β_1 and β_2 should be less significant or even insignificant. On the contrary, if the coefficient estimate for β_2 is highly significant but the estimates for β_1 and β_3 are not, then such a result provides evidence that the fund reports early. Note that this first test is deliberately crude and will in all likelihood understate the true extent of intraday NAV calculations. The returns of a fund reporting at 10:00am will likely correlate more closely with the lagged returns from the previous close (the Xetra trading at the Frankfurt stock exchange begins at 9:00am) than with the 1pm returns; similarly, returns of a fund computing the NAV at 4pm will likely correlate most closely with the closing time returns (the Xetra trading at the Frankfurt stock exchange stops at 5:30pm).

In a sample of many funds, one would expect some of the coefficients to be significant solely because of estimation errors, so we apply the Bonferroni correction (see, for example, Rice, 2007) to the p-value for each coefficient. The Bonferroni correction is a conservative adjustment that, if anything, will understate the number of nonzero coefficients. Table 4 reports the results of the Bonferroni test.

Over 70% of the funds have significant midday coefficients (at the $\alpha = 0.1\%$ level), which is more than the number that have significant coefficients for the close. There is also a clear split between funds domiciled in Germany versus elsewhere, with over 96% (27 out of 28 funds) having significant midday coefficients, while only 28.6% (8 out of 28) have significant end-of-day coefficients. For funds domiciled outside of Germany, this pattern is reversed, with only 35% (7 out of 20) with midday significance versus 65% (13 out of 20) at closing.

The disparity is even more dramatic if we consider *which* benchmark returns have the

[5]Since mutual fund managers use market indices as benchmarks, we deliberately use a market model for our analysis and regress fund returns on benchmark returns. As a robustness check, we repeated all described regressions using excess returns and obtained qualitatively identical results.

Table 4: Bonferroni test ($\alpha = 0.001$) of coefficients in the multiple regression (2)

	Prev	**1pm**	**Close**	**No. of Funds**
All	21	34	21	48
DE	13	27	8	28
LU/GB	8	7	13	20

Number of significant coefficients after Bonferroni correction.
Prev = previous day closing time, Close = today's closing time.
DE = Germany, LU = Luxembourg, GB = Great Britain.

Table 5: Coefficient with largest t statistic in the multiple regression (2)

	Prev	**1pm**	**Close**
All	8	28	12
DE	3	25	0
LU/GB	5	3	12

Number of funds whose largest t statistic occurs at specified time.
prev = previous day closing time, close = today's closing time.
DE = Germany, LU = Luxembourg, GB = Great Britain.

biggest t statistic, see Table 5. For funds headquartered in Germany, almost all of them have the largest t statistic on the midday returns of their benchmark. For funds outside of Germany, the majority has the largest t statistic at the end of day.

Since the funds involved all trade in the same market, and all use benchmarks from the DAX index family, it's hard to imagine a passive stock market effect that would show up so strongly in the German-domiciled funds, but not in the funds domiciled abroad. This suggests that funds located in Germany do indeed usually compute their NAVs in the middle of the day, while those elsewhere wait until the end of the day. Using the largest t statistic is an intuitive yet ad-hoc procedure to derive this conclusion, so now we turn to more formal inference.

3 Best Fit Identification of Closing Times

We continue to choose as our measure of fit how well a market model

$$R_{F,t} = \alpha + \beta R_{M(h),t} + \varepsilon_t \tag{3}$$

explains fund returns. As before $R_{F,t}$ denotes daily fund returns. Now $R_{M(h),t}$ denotes a daily market benchmark return computed at time h (on day t). For $R_{M(h),t}$, we consider daily returns computed on the hour, every hour, using intraday data, that is, at 10am, 11am, ..., 5pm. In addition, we consider benchmark returns at the previous day's closing time (which we report as market opening returns at 9am in the figures below) and at the day-of closing time 5:30pm. So, in total, we consider benchmark returns at ten different times in a day. For each fund, we use the returns on its stated benchmark, either the DAX or HDAX or CDAX index.

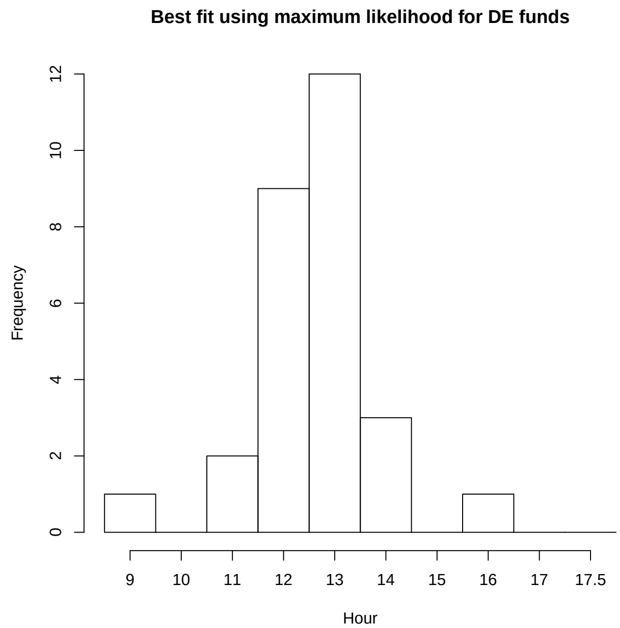
We use two different statistical methods to determine which hour gives the best fit. For the first method, we pick the best fit by using maximum likelihood. In our particular application, this approach is equivalent to picking the hour that gives the highest R^2. The maximum likelihood method has the advantage that we can use the likelihood ratio test to determine statistically if one fit is significantly better than another. As a robustness check, we repeat the analysis using a Bayesian method. We assume as a prior that every hour is equally likely, and use the data to compute a posterior distribution over the possible choices. The mean of this posterior gives us an estimate of the best fit, while the standard deviation gives us an estimate of the precision of the fit.

3.1 Maximum Likelihood

For each fund, we regress its returns against its own specified benchmark returns. As our ten candidates for the benchmark returns, we use, as previously mentioned, the returns at the previous close (reported as 9am), the returns computed on the hour each hour, and at the current (day-of) close at 5:30pm. We use maximum likelihood to pick the best match. Appendix C.1 provides a brief review of the maximum likelihood methodology. Tables 16 and 17 report the best match for all 48 funds in our sample. In addition, these tables report the R^2 statistics at close and at the best fit for all funds.

Figures 3 and 4 show the results for funds domiciled inside and outside of Germany. We observe a clear divergence: the first group is concentrated around the middle, while the second group is heavily weighted towards the close. Figure 3 shows that maximum likelihood never chooses 10am, 3pm, 5pm, or 5:30pm (closing time) as NAV computation time for funds domiciled in Germany. For 27 of the 28 funds in Germany maximum likelihood chooses an intraday time. This result corresponds exactly to the simple initial test results reported in Table 5 in the previous section. The three funds with maximum likelihoods at 9am or 11am had their highest t ratio in the initial test for the benchmark returns at the previous close, while the 25 funds with maximum likelihoods for returns calculated after 11am had their highest t ratio in the initial test for the midday (1pm) returns. Figure 4

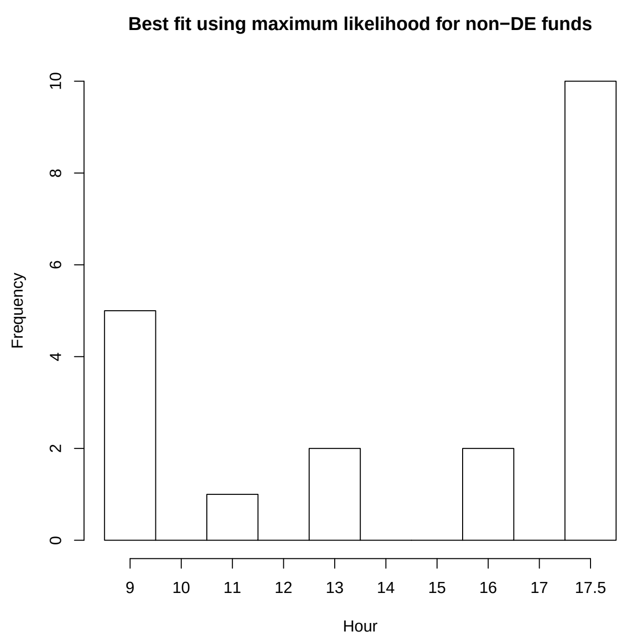
Figure 3: Estimated closing times of mutual funds with domicile DE



Number of funds with maximum likelihood at specified time.

(9 = 9am, ..., 16 = 4pm)

Figure 4: Estimated closing times of mutual funds with domicile LU/GB



Number of funds with maximum likelihood at specified time.

(9 = 9am, ..., 16 = 4pm, 17.5 = 5:30pm)

shows that only five of 20 funds domiciled outside of Germany report intraday returns. Five funds report previous closing returns. Half of the funds report at current closing time. Again the results coincide with those from the crude approach reported in Table 5. We can use the likelihood ratio test to check to see if the difference in likelihood between the maximum and the close is statistically significant; for all 32 funds with intraday computation times, 27 of the 28 funds domiciled in Germany and 5 of the 20 funds domiciled in Great Britain and Luxembourg, the difference is – even after the Bonferroni correction – statistically significant at the 0.1% level. Needless to say, for the 32 funds with intraday computation times, using the benchmark returns at the (approximated) NAV closing times instead of their end-of-day returns has also a dramatic impact on the R^2 values of the CAPM regression, see the last two columns in Tables 16 and 17.

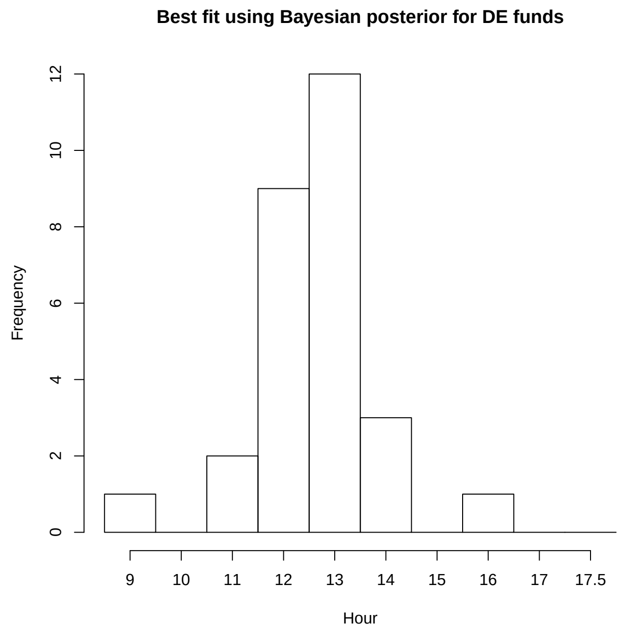
3.2 Bayesian Estimation

As an alternative to maximum likelihood estimation, we consider Bayesian estimation. Appendix C.2 provides a brief review of the applied methodology. Tables 16 and 17 report the posterior mean and the posterior standard deviation for all 48 funds in our sample. The numbers show that the Bayesian approach delivers very clear-cut results for the NAV computation times. Most of the standard deviations for the time estimates are tiny; for 43 out of the 48 funds the standard deviation is smaller than $5 \cdot 10^{-7}$. The largest standard deviation is smaller than 0.1. These results suggest that these time estimates are fairly exact. We summarize the Bayesian results on the estimated closing times in Figures 5 and 6. It becomes readily apparent that the Bayesian estimates and maximum likelihood estimates tell exactly the same story.

The statistical analysis in this section convincingly demonstrates that 27 out of the 28 funds in our sample domiciled in Germany use early closing times as compared with only 5 out of 20 funds domiciled in Luxembourg and Great Britain. While striking, the documented reporting discrepancy does not lead to any obvious arbitrage opportunity. In both Luxembourg and Germany, investor orders are always carried out at an NAV determined *after* the investor's order, so orders are not carried out at stale prices, see Qian (2011). Investing in a German-based mutual fund is similar to placing a market order that executes in the middle of the day rather than at close.

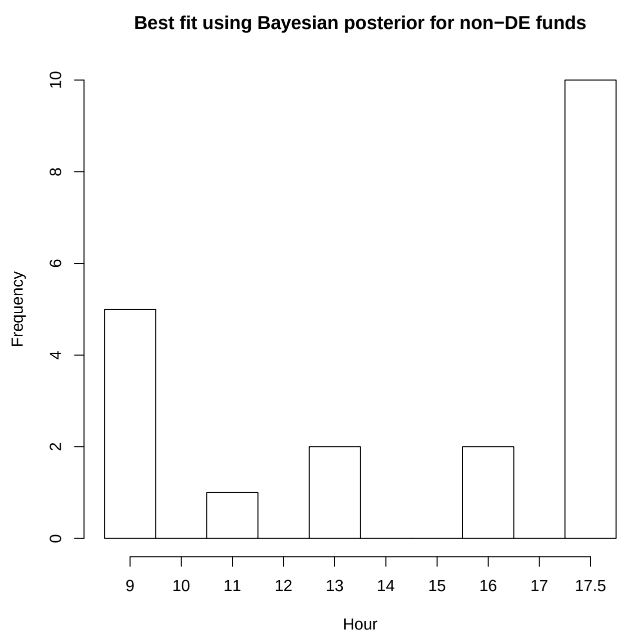
Naturally, now two questions arise. First, why do so many funds use intraday NAV computation times? Secondly, is this finding relevant in any way? In the remainder of this paper, we answer these two questions. First, Section 4 describes the NAV reporting regulation in Germany that leads to the intraday reporting times. Secondly, we demonstrate in Section 5 that incorrectly using the benchmark closing returns leads to grossly misleading

Figure 5: Histogram of estimated closing times of mutual funds with domicile DE



Number of funds with Bayesian posterior mean at specified time.
(9 = 9am, ..., 16 = 4pm)

Figure 6: Histogram of estimated closing times of mutual funds with domicile LU/GB



Number of funds with Bayesian posterior mean at specified time.
(9 = 9am, ..., 17.5 = 5:30pm)

estimates for the funds' betas in the CAPM regression. In Section 6, we also show that any conclusions on mutual funds' timing abilities strongly depend on using the correct NAV reporting time.

4 Institutional Environment

We briefly describe the regulatory environments for NAV reporting in the United States and in Germany. We provide an explanation for the results on early closing times documented in this paper by depicting the customary process how mutual funds domiciled in Germany publish their net asset values.

The U.S. Investment Company Act of 1940 provides little guidance on the timing of NAV calculations. The most precise statements are in Rule 22c-1 (see Appendix A) of the Securities and Exchange Commission Rules and Regulations "Part 270 – Rules and Regulations, Investment Company Act of 1940" but also these statements do not suggest a specific NAV computation time. Nevertheless it has been a longstanding custom for mutual funds in the United States to compute their NAV as of 4pm, when the New York Stock Exchange closes (Zitzewitz, 2006).[6] For Germany, section 36 of the German investment law (see Appendix A) provides directions for the calculation of the net asset value as well as the publication of the issue and redemption prices of mutual funds. Similar to U.S. law, the German law does not mention a specific NAV computation time. Unlike mutual funds in the United States, however, many funds registered in Germany appear to take advantage of this lack of a regulatory constraint.

Section 36(6) of the German investment law requires mutual funds to report their NAVs (to be more precise, their issue and redemption prices) in widely distributed business and daily newspapers as well as relevant electronic media outlets. The vast majority of mutual funds does not communicate directly with the news media but relies on intermediaries. The market leader in the publication of daily mutual fund information in Germany for both private and institutional investors is the company vwd (Vereinigte Wirtschaftsdienste AG). Most of the large mutual fund companies managing funds registered in Germany are clients of vwd (vwd, 2011). These funds report an NAV as well as an accompanying date to vwd which in turn reports them to the country's most important newspapers as well as some TV stations and online media outlets. vwd has a daily submission deadline of 2:30pm, that is, it expects a client mutual fund to report its NAV three hours before the closing of the Frankfurt Stock Exchange at 5:30pm. (vwd itself faces different editorial deadlines at

[6]A similar tradition exists in Switzerland. The leading Swiss stock exchange, the Six Swiss Exchange, and the Swiss Funds Association (2001) explicitly suggest to evaluate mutual fund assets on the basis of daily closing prices and to publish the resulting NAVs in daily newspapers two days later.

its numerous media partners, including some as early as 4pm.) New NAVs arrive at vwd throughout the day. Some funds report NAVs as early as 10am (with the accompanying date usually being the previous day). Many mutual funds report their NAVs in the early afternoon. If a fund fails to report a new NAV and vwd must meet an editorial deadline at a newspaper then it reports the most recent value and date.

The publishing deadlines make it obviously impossible for German mutual funds to ensure a publication of end-of-day NAVs in the following day's newspapers. These deadlines and the lack of regulatory constraints (on the specific NAV calculation time) leave them with two alternatives. Either, similar to funds registered in Switzerland, they publish the end-of-day NAV only on the second day after its calculation, or they compute the NAV in the middle of the day to meet the tight deadlines for publication on the immediately following day. The chosen alternative and the actual time of NAV computation does typically not appear to be publicly available. Mutual fund prospectuses usually do not provide an NAV computation time. Some fund prospectuses (e.g., those of DWS Investments or Allianz Global Investors) explicitly mention an order acceptance deadline in the middle of the day but even these do not mention specific NAV computation times.

The time constraints set by vwd and the historical importance of publishing NAVs in newspapers may well explain our results on early closing times. But, of course, the question arises whether the publication in newspapers remains relevant in the modern day and age of round-the-clock online news. Perhaps, regulators in Germany should contemplate a move to the Swiss reporting system: compute the NAV in the morning based on prices at the previous day's market close; report the NAV online in the late morning and report it to vwd; publish the NAV in newspapers on the next day.

5 Correct Betas

We first report results from the CAPM regressions using the best fit closing times of the individual funds. Next we show how the Dimson correction, see Dimson (1979), can be employed to estimate alphas and betas without intraday benchmark data.

5.1 Betas at Best Fit

We run the CAPM regressions using the best fit closing times. So, instead of running the CAPM regression against market close, see Equation (1), we now estimate the model

$$R^e_{F,t} = \alpha + \beta R^e_{M(b_F),t} + \varepsilon_t, \tag{4}$$

where $R^e_{M(b_F),t}$ denotes the market excess return computed at the best-fit time of the fund F. Table 6 is the analogue to Table 2 in Section 2.2. Complete results for all 32 funds using an early closing time are reported in Table 18. The German-domiciled funds' betas are now primarily clustered around 1. Interestingly, the four Luxembourg funds that are identified as reporting a day early are also shifted.

Table 6: CAPM coefficients computed at Best Fit

	α				β				
	$+$		$-$		≤ 0.4	(0.4,0.6]	(0.6,0.8]	(0.8,1]	> 1
DE	3	(0)	25	(5)	0	1	6	19	2
non-DE	7	(1)	13	(0)	1	1	5	12	1

Counts of α and β coefficients. The count of α coefficients are by sign. (The quantities in parentheses are the number of α coefficients significant at the 5% level.) The count of β coefficients are grouped by value.

The results in Table 6 draw a completely different picture than Table 2 which reports CAPM coefficients computed at close. Table 2 shows that only 8 of the 28 mutual funds domiciled in Germany have a beta coefficient computed at close exceeding 0.6. On the contrary, Table 6 reports that computed at best fit times all but one of the 28 mutual funds domiciled in Germany have a CAPM beta exceeding 0.6. In fact, the distributions of the funds' betas for groups of funds appear quite similar now. A close look at the detailed results in Table 18 reveals that for all 27 funds domiciled in Germany and all 5 funds domiciled in Luxembourg and Great Britain that use early closing times, the CAPM regression at close produces beta estimates that are smaller than those in the CAPM regression at best fit.

5.2 Dimson Correction

Dimson (1979) introduced a correction for regressions involving returns on assets that do not trade as frequently as the market. Not all assets are traded daily, so regressing returns on assets traded at different times can bias the coefficient estimates in the regression. Dimson provides a theoretical analysis that this bias can be corrected if the right-hand side of the regression contains sufficient leads and lags so that the possible timing of the left-had side return variable is covered by the leads and lags. We face a similar situation here, where the left-hand side return can occur at any point between the previous day and the current day, so in principle the NAV computation problem can be resolved similarly.

The idea behind the correction applies straightforwardly to the reporting-time question. Let $R^e_{F,i}$, $i = 1, 2, 3, 4$, be the fund excess returns from the previous morning, afternoon, and current morning and afternoon, respectively. Let $R^e_{M,i}$ be the same for the market and assume that $Cov(R^e_{M,i}, R^e_{M,j}) = 0$ for $i \neq j$. If the fund returns satisfy the CAPM, so $\alpha = 0$, then for each i,

$$R^e_{F,i,t} = \beta R^e_{M,i,t} + \varepsilon_{i,t}.$$

Let σ_1^2 be the morning and σ_2^2 be the afternoon market variance. If the firm reports at midday, then the excess returns for the fund are $R^e_{F,2} + R^e_{F,3}$. Let β_1 be the beta from the CAPM regression when using the current day's market returns. If returns computed at different times are uncorrelated, then β_1 satisfies

$$\beta_1 = \frac{Cov(R^e_{F,2} + R^e_{F,3}, R^e_{M,3} + R^e_{M,4})}{Var(R^e_{M,3} + R^e_{M,4})} = \beta \frac{\sigma_1^2}{\sigma_1^2 + \sigma_2^2}.$$

If we perform the same regression using the previous day's market, then the CAPM beta (call it β_2) satisfies

$$\beta_2 = \frac{Cov(R^e_{F,2} + R^e_{F,3}, R^e_{M,1} + R^e_{M,2})}{Var(R^e_{M,1} + R^e_{M,2})} = \beta \frac{\sigma_2^2}{\sigma_1^2 + \sigma_2^2}.$$

Both give you estimates of β that are biased, but if you add them together, the biases exactly compensate to give you β. This observation suggests a simple procedure to correct for the misaligned reporting times: perform a joint regression of fund excess returns on both the current and previous day's excess returns to estimate β_1 and β_2, so

$$R^e_{F,2,t} + R^e_{F,3,t} = \alpha + \beta_1 \left(R^e_{M,3,t} + R^e_{M,4,t}\right) + \beta_2 \left(R^e_{M,1,t} + R^e_{M,2,t}\right) + \varepsilon_t,$$

and then use $\beta_1 + \beta_2$ as the estimate of the CAPM beta.

We check to see how the Dimson correction works when applied to regressing the 1pm benchmark returns on the closing benchmark returns. This regression applies to a fund that matches the market perfectly, but reports its daily NAVs at 1pm. In this case, the theoretical argument indicates that the Dimson correction should produce $\beta = 1$. Table 7 reports the results for the three benchmarks DAX, HDAX, and CDAX. The Dimson correction appears to successfully correct for the bias, but it actually produces an overestimate of β of 4 to 8%. Nevertheless these estimates are a considerable improvement over the uncorrected estimates, which are more than 40% below 1 for the DAX and CDAX and more than 20% below 1 for the HDAX, see Table 3.

When we apply the Dimson correction to the actual funds, we see the same phenomenon. Table 18 reports the CAPM coefficients at best fit, at close, and the Dimson correction for the 27 funds domiciled in Germany and the 5 funds domiciled in Luxembourg and Great

Table 7: Dimson Correction Applied to Benchmarks

	DAX	HDAX	CDAX
α	0.00	0.00	0.00
	(0.43)	(0.53)	(0.47)
β	1.07	1.04	1.08
	(28.49)	(31.62)	(31.11)

The α and β coefficients for the Dimson correction to benchmarks at 1pm. (Numbers in parentheses are t ratios.)

Britain that use early closing times. For all but one fund the Dimson correction overstates the estimate for the beta coefficient at best fit. Notwithstanding this overestimation, for the vast majority of funds with an early closing time the Dimson correction produces estimates for the beta coefficient that are closer to the best fit estimate than the estimate derived from a regression at close.

Table 8 provides a summary of the results for all 48 funds in our sample including those that report at the end of day. The summary results clearly document the frequent

Table 8: CAPM coefficients computed with Dimson correction

	α				β				
	+		−		≤ 0.4	(0.4,0.6]	(0.6,0.8]	(0.8,1]	> 1
DE	21	(0)	7	(1)	0	1	0	8	19
non-DE	10	(1)	10	(0)	0	1	1	13	5

Counts of α and β coefficients. The count of α coefficients are by sign. (The quantities in parentheses are the number of α coefficients significant at the 5% level.) The count of β coefficients are grouped by value.

overestimation of the beta coefficients. Also, it is apparent that the Dimson correction is often much closer to the CAPM coefficients at best fit than the coefficients at close.

In sum, for all of the 32 funds using early closing times, using a regression against the closing returns leads to smaller estimates for the beta coefficient than the estimated beta from the best fit regression. While the Dimson correction systematically overestimates the best fit beta coefficient, it appears to deliver better results than the regression against closing returns.

In the next and final step of our analysis, we show that for all 32 funds using early closing times, using the best-fit NAV reporting times is also important for deriving correct conclusions on fund managers' market timing abilities.

6 Timing Measurement

Two classic papers, Busse (1999) and Bollen and Busse (2001), use daily returns to test mutual fund timing ability and use the Dimson correction. The German mutual fund setting provides a natural environment to examine both the impact of NAV reporting times on the conclusions of these papers, and the ability of the Dimson correction to correct for using wrong times.

Busse (1999) assesses the ability of mutual fund managers to time market volatility; a risk-averse manager will reduce his or her market exposure in response to an increase of market volatility. Let σ_t be the conditional volatility at time t, and $\bar{\sigma}$ the time-series average. If the manager has the ability to predict volatility, then the returns should be sensitive to the difference, $\sigma_t - \bar{\sigma}$. Busse (1999) tests this hypothesis by using the following specification,

$$R^e_{F,t} = \alpha + \beta R^e_{M,t} + \gamma(\sigma_t - \bar{\sigma}) R^e_{M,t} + \varepsilon_t.$$

Volatility is modeled using the EGARCH(1,1) model of Nelson (1991).

Bollen and Busse (2001) considers two specifications using daily returns to measure the ability of mutual fund managers to time the market level. The first specification, originally due to Treynor and Mazuy (1966), introduces a quadratic term for the market excess returns,

$$R^e_{F,t} = \alpha + \beta R^e_{M,t} + \gamma \left(R^e_{M,t}\right)^2 + \varepsilon_t.$$

A manager who can time the market will have a time-varying beta; when the market is moving up, beta will increase, and when the market is moving down, the beta will decrease. This effect can be captured by a beta of the form $\beta + \gamma R^e_{M,t}$, which the above specification reflects. Bollen and Busse (2001) also considers a different specification, originally due to Henriksson and Merton (1981) and Henriksson (1984). We define a second variable, $R^e_{*,t} = \max\left\{0, R^e_{M,t}\right\}$, which is zero when $R^e_{M,t}$ is negative, and $R^e_{M,t}$ itself when it is positive. Then this specification is as follows,

$$R^e_{F,t} = \alpha + \beta R^e_{M,t} + \gamma R^e_{*,t} + \varepsilon_t.$$

A mutual fund manager who can time the market increases his or her market exposure when the market moves up, so a manager with market timing ability has a positive γ.

We first use a panel regression to compare German and non-German domiciled funds, using closing price data. We compare the basic CAPM regression with the three timing specifications. The difference between the German-domiciled and non-German-domiciled funds is captured by interaction terms with an indicator variable for Germany. Table 9

Table 9: Timing Results for DE versus non-DE funds at Close

	CAPM	**TM**	**HM**	**Vol**
α	-0.000	-0.000	-0.001	-0.003
	(-4.268)	(-0.225)	(-7.525)	(-5.074)
β	0.658	0.659	0.608	0.657
	(51.040)	(51.940)	(38.593)	(50.889)
γ		-1.088	0.111	0.010
		(-2.998)	(4.561)	(4.901)
DE	-0.000	-0.000	0.001	-0.001
	(-2.090)	(-2.402)	(5.038)	(-1.599)
$DE * \beta$	-0.134	-0.134	-0.056	-0.134
	(-9.388)	(-9.492)	(-3.016)	(-9.388)
$DE * \gamma$		0.333	-0.170	0.004
		(0.813)	(-5.783)	(1.419)

The α, β, and γ coefficients for panel regression tests of timing ability. DE is an indicator variable that is 1 for German-domiciled funds, and 0 otherwise. (Numbers in parentheses are t ratios.)
TM = Treynor-Mazuy, HM = Henriksson-Merton, Vol = EGARCH(1,1) volatility.

reports the results. Several apparent findings stand out. In all four specifications, there is a statistically significant difference in the beta coefficients between the German-domiciled and non-German-domiciled funds. In the timing tests, we see statistically significant timing for all three specifications. The Treynor-Mazuy and Henriksson-Merton tests point to different conclusions. Treynor-Mazuy finds that non-German-domiciled funds are negatively timing while German-domiciled funds are less so, while Henriksson-Merton points to the opposite conclusion (the Treynor-Mazuy interaction term is not statistically significant). The volatility timing specification finds that while non-German-domiciled funds positively volatility time, that German-domiciled funds do so slightly more strongly.

Table 10 repeats the analysis using the best fit data. Most of the interesting findings go away. The difference between the beta coefficients disappears. Also, most of the significant timing results and timing differences disappear. The one exception is the volatility timing, which while still significant, drops 60% in magnitude.

The difference is to be expected for purely mechanical reasons. Table 11 shows the results from regressing the 1pm benchmark on the end of day benchmark, augmented with each timing variable. These regressions apply to a fund that matches the market perfectly, but reports its daily NAVs at 1pm. Such a fund has no timing ability, so its true β is 1 and its true γ is 0. The results are somewhat sensitive to the benchmark, but several of the γ estimates are significantly different from zero. With the exception of the Treynor-Mazuy specification for the DAX index, the early computation time has the effect of pushing

Table 10: Timing Results for DE versus non-DE funds at Best Fit

	CAPM	**TM**	**HM**	**Vol**
α	-0.000	-0.000	-0.000	-0.001
	(-2.153)	(-2.750)	(-0.409)	(-2.169)
β	0.865	0.870	0.870	0.864
	(70.049)	(77.812)	(37.171)	(69.774)
γ		0.921	-0.012	0.004
		(1.618)	(-0.324)	(2.094)
DE	-0.000	0.000	-0.000	0.000
	(-0.585)	(0.880)	(-0.349)	(0.390)
$DE * \beta$	-0.009	-0.013	-0.012	-0.009
	(-0.661)	(-1.060)	(-0.464)	(-0.640)
$DE * \gamma$		-0.812	0.007	-0.001
		(-1.317)	(0.157)	(-0.542)

The α, β, and γ coefficients for panel regression tests of timing ability. DE is an indicator variable that is 1 for German-domiciled funds, and 0 otherwise. (Numbers in parentheses are t ratios.)
TM = Treynor-Mazuy, HM = Henriksson-Merton, Vol = EGARCH(1,1) volatility.

estimates of γ down for both Treynor-Mazuy and Henriksson-Merton, and up for volatility timing.

We consider the impact of performance analysis on individual funds. We consider the 32 mutual funds that our tests indicate use intraday closing times. Table 19 shows results for the Treynor-Mazuy specification using the best fit, the close, and the Dimson correction. Then Table 20 shows the corresponding results for the Henriksson-Merton specification. Next, Table 21 shows the corresponding results for EGARCH(1,1) volatility specification. And finally we summarize all results in Table 12.

For each specification, the first line in Table 12 displays the number of γ coefficients that are positive or negative, and the second line displays the number that are statistically significant at the 5% level. The effect of the early reporting time are in line with the mechanical results from the previous table – the closing time regression produces lower γ estimates for the two level-timing measures than the best-fit regression. For example, Treynor-Mazuy measures 5 funds with significant positive timing ability when evaluated at the best-fit time, but none when evaluated at close. Henriksson-Merton identifies no funds with timing ability when evaluated at the best-fit time, but 7 funds with significantly negative timing ability at close. Likewise, the volatility timing results, which the mechanical evidence suggests will be overstated in the positive direction, find 13 funds with positive volatility timing when evaluated at close, and none in the middle of the day. In all three cases, the discrepancies match our predictions based on the hypothesis of early NAV

Table 11: Timing Regressions of the 1pm Benchmarks against the end-of-day Benchmarks

	DAX			HDAX			CDAX		
	α	β	γ	α	β	γ	α	β	γ
TM	-0.001	0.558	0.214	-0.000	0.754	-1.802	-0.000	0.589	-0.203
	(-1.505)	(18.368)	(0.205)	(-0.559)	(30.721)	(-3.337)	(-1.262)	(20.898)	(-0.207)
HM	-0.000	0.586	-0.058	0.000	0.854	-0.192	0.000	0.628	-0.084
	(-0.241)	(11.832)	(-0.633)	(1.788)	(22.460)	(-2.957)	(0.070)	(13.970)	(-0.996)
Vol	-0.000	0.557	0.014	-0.000	0.779	0.005	-0.000	0.587	0.012
	(-1.571)	(18.046)	(1.628)	(-1.966)	(30.159)	(2.077)	(-1.606)	(20.704)	(1.903)

The α, β, and γ coefficients for tests of the timing ability applied to the three benchmarks. (Numbers in parentheses are t ratios.)
TM = Treynor-Mazuy, HM = Henriksson-Merton, Vol = EGARCH(1,1) volatility.

Table 12: Signs of the γ Coefficients in the Three Timing Specifications

	Best		Close		Dimson	
	+	−	+	−	+	−
TM	20	12	10	22	23	9
	(5)	(1)	(0)	(0)	(8)	(1)
HM	17	15	5	27	14	18
	(0)	(0)	(0)	(7)	(4)	(0)
Vol	29	3	32	0	8	24
	(0)	(0)	(13)	(0)	(0)	(0)

Count of γ coefficients are by sign. (The quantities in parentheses are the number of γ coefficients significant at the 5% level.)
TM = Treynor-Mazuy, HM = Henriksson-Merton, Vol = EGARCH(1,1) volatility.

computation and the results for the three benchmarks.

In sum, we observe that using the closing time regressions leads to drastically different results for the timing ability of mutual funds than using the best-fit regressions. Unfortunately, the Dimson correction does not do a good job correcting for the time gap in the regressions at close; in particular for the EGARCH(1,1) volatility specification the results are far off. For a correct assessment of a fund manager's timing ability the use of correct closing times appears to be very important.

7 Conclusion

In this paper we have documented a curious feature of the mutual fund industry in Germany. Mutual funds must compute the value of their holdings, the net asset value (NAV), once a day. In many countries with well-developed mutual fund industries, such as, for example, the United States and Switzerland, the customary NAV computation time is the closing time of the country's stock market. In stark contrast, funds registered in Germany do not have a customary NAV computation time. Instead, each fund chooses its own time, often in the middle of the day. For the majority of German mutual funds, the actual NAV computation time does not seem to be publicly available, so we have used an indirect approach to show the widespread phenomenon of intraday NAV computation. Mutual funds generally provide a benchmark to use for comparison purposes. If a fund holds some fraction of the assets in the benchmark, then the fund's returns should match the return on the benchmark computed in the middle of the day better than returns computed at the end of the day. We have tested this hypothesis using a sample of equity funds that use one of three indices in the DAX index family as a benchmark. We have separated these funds into two groups, those registered in Germany and those registered outside Germany, notably Luxembourg and Great Britain. For all but one of the funds domiciled in Germany, the effect of early NAV computation time is readily apparent. On the contrary, for most of the funds registered outside Germany the effect is not present. So, these funds appear to compute their NAVs at closing time.

Furthermore we have shown that using market returns computed at the end of the day instead of at a mutual fund's NAV computation time will typically lead to completely misleading inferences about the fund's performance. While this result suggests the apparently grim conclusion that mutual fund performance must be done using intraday market data, we have also shown that the technique of Dimson (1979), originally proposed to handle econometric issues with nonsynchronous trading, also corrects for most of the biases caused by the timing of the NAV computation. The Dimson fix requires only end-of-day data, so it is readily applied in any mutual fund research that uses return data.

Finally, we have extended the classical work by Busse (1999) and Bollen and Busse (2001) on the timing abilities of mutual fund managers to the funds in our sample with intraday NAV computation times. We have shown that any conclusions on a fund's timing ability depend strongly on using the correct NAV reporting time. Again using market returns computed at close may result in wrong conclusions. Unfortunately, the Dimson correction does not provide good indications on fund managers' abilities (or the lack thereof) to time the market in the absence of intraday market returns.

Appendix

A Regulation of NAV Calculations

For completeness we provide excerpts from U.S. and German investment regulations on the calculation of NAVs.

The U.S. Investment Company Act of 1940 (Sections 22 and 23) provides little guidance on the timing of NAV calculations. The most precise statements are in Rule 22c-1 of the Securities and Exchange Commission Rules and Regulations "Part 270 – Rules and Regulations, Investment Company Act of 1940". Specifically, Rule 22c-1(2)(b)(1) states concerning the frequency and timing of NAV calculations:

The current net asset value of any such security shall be computed no less frequently than once daily, Monday through Friday, at the specific time or times during the day that the board of directors of the investment company sets, in accordance with paragraph (e) of this section except on:

(i) Days on which changes in the value of the investment company's portfolio securities will not materially affect the current net asset value of the investment company's redeemable securities;

(ii) Days during which no security is tendered for redemption and no order to purchase or sell such security is received by the investment company; or

(iii) Customary national business holidays described or listed in the prospectus and local and regional business holidays listed in the prospectus;

Section 36 of the German investment law provides directions for the calculation of the net asset value as well as the publication of the bid and ask prices of mutual funds. Here we state Sections 36(1) and 36(6) which are the only sections explicitly referring to frequency and timing of NAV calculations.

§ 36 InvG Ermittlung des Anteilwertes, Veröffentlichung des Ausgabe- und Rücknahmepreises

(1) Der Wert des Anteils ergibt sich aus der Teilung des Wertes des Sondervermögens durch die Zahl der in den Verkehr gelangten Anteile. Der Wert eines Sondervermögens ist auf Grund der jeweiligen Kurswerte der zu ihm gehörenden Vermögensgegenstände abzüglich der aufgenommenen Kredite und sonstigen Verbindlichkeiten von der Depotbank unter Mitwirkung der Kapitalanlagegesellschaft oder von der Kapitalanlagegesellschaft selbst börsentäglich zu ermitteln. An

gesetzlichen Feiertagen im Geltungsbereich dieses Gesetzes, die Börsentage sind, sowie am 24. und 31. Dezember jedes Jahres können die Kapitalanlagegesellschaft und die Depotbank von einer Ermittlung des Wertes absehen. Im Falle schwebender Verpflichtungsgeschäfte ist anstelle des von der Kapitalanlagegesellschaft zu liefernden Vermögensgegenstandes die von ihr zu fordernde Gegenleistung unmittelbar nach Abschluss des Geschäfts zu berücksichtigen. Für die Rückerstattungsansprüche aus Wertpapierdarlehen ist der jeweilige Kurswert der als Darlehen übertragenen Wertpapiere maßgebend.

(6) Gibt die Kapitalanlagegesellschaft oder die Depotbank den Ausgabepreis bekannt, so ist sie verpflichtet, auch den Rücknahmepreis bekannt zu geben; wird der Rücknahmepreis bekannt gegeben, so ist auch der Ausgabepreis bekannt zu geben. Ausgabe- und Rücknahmepreis sind bei jeder Ausgabe oder Rücknahme von Anteilen, mindestens jedoch zweimal im Monat, in einer hinreichend verbreiteten Wirtschafts- oder Tageszeitung oder in den in den Verkaufsprospekten bezeichneten elektronischen Informationsmedien zu veröffentlichen.

B Stock Indices and Mutual Funds

Table 13 briefly describes the stock indices that we used for our analysis in this paper. For

Table 13: Definition of Stock Indices

DAX	The DAX comprises the 30 largest and most actively traded companies listed at the Frankfurt Stock Exchange.
TecDAX	The TecDAX tracks the 30 largest and most liquid issues from the various technology sectors beneath the DAX.
MDAX	The MDAX comprises 50 mid-cap issues from traditional sectors which, in terms of size and turnover, rank below the DAX.
SDAX	The SDAX comprises the next 50 issues from the traditional sectors that are ranked below the MDAX.
HDAX	The HDAX comprises the 30 DAX issues, the 50 MDAX issues, and the 30 TecDAX issues.
CDAX	The CDAX tracks all German shares admitted to the Prime Standard and General Standard segments.

Source: Guide to the Equity Indices of Deutsche Börse (Deutsche Börse, 2013).

details on these indices such as index design, calculation intervals, etc. see the "Guide to the Equity Indices of Deutsche Börse" (Deutsche Börse, 2013).

Tables 14 and 15 provide a list of the 48 mutual funds in our study.

C Methodology

We briefly review the methodology (using generic notation) that we applied for our analysis in Sections 3.1 and 3.2. For more details on maximum likelihood estimation see Rice (2007) and for Bayesian estimation see Judge et al. (1985).

C.1 Maximum Likelihood Estimation

We regress each fund on its benchmark at different times during the day, and use maximum likelihood to pick the best match. Let $y \in \mathbb{R}^n$ be the vector of returns for a single fund, where n denotes the number of observations. We consider a set of k possible benchmark returns, indexed by $i = 1, 2, \ldots, k$. Let X_i be the $n \times 2$ matrix of right-hand side variables. In our particular application, the second column of X_i is just the lagged benchmark and the first column a vector of ones to capture the constant term. (Of course, we could include additional control variables.) For a fixed i, we fit the standard linear model

$$y = X_i \beta_i + \varepsilon_i,$$

with $\beta_i \in \mathbb{R}^2$ and $\varepsilon_i \in \mathbb{R}^n$. Then we choose the index i that gives the best fit according to maximum likelihood estimation. We assume that ε is normally distributed, with mean zero, and unknown variance σ_i^2. The log-likelihood is

$$\ln L(i, \beta_i, \sigma_i^2 | y) = -\frac{n}{2} \ln(2\pi) - \frac{n}{2} \ln(\sigma_i^2) - \frac{1}{2\sigma_i^2} (y - X_i\beta_i)'(y - X_i\beta_i).$$

We maximize the log-likelihood in two stages. First, for given i, we find the maximizing value for the other two parameters. Then we simply compare the resulting k likelihoods to find the maximizing value for i.

For a fixed i, the likelihood is maximized by

$$\hat{\beta}_i = (X_i'X_i)^{-1} X_i' y \tag{5}$$

$$\hat{\sigma}_i^2 = \frac{e_i' e_i}{n} \tag{6}$$

where $e_i = y - X_i \hat{\beta}_i$ denotes the vector of residuals from the i-th regression. (Recall that the maximum likelihood estimators of β are identical to the OLS estimators.) Plugging the estimates into the log-likelihood function, we obtain

$$\begin{aligned} \ln L(i, \hat{\beta}_i, \hat{\sigma}_i^2 | y) &= -\frac{n}{2}\ln(2\pi) - \frac{n}{2}\ln\left(\frac{e_i'e_i}{n}\right) - \frac{1}{2\frac{e_i'e_i}{n}}e_i'e_i \\ &= \frac{n}{2}\left(-\ln(2\pi) + \ln(n) - 1\right) - \frac{n}{2}\ln(e_i'e_i). \end{aligned}$$

Choosing the maximizing value $i^\star$ for i is equivalent to choosing the benchmark with the smallest residual variance, or equivalently, the highest R^2.

One advantage of the explicit formula for the likelihood is that we can use a likelihood ratio test to compare the efficacy of different models. In particular, we compare the maximum likelihood at the closing time $i = k$, $L(k, \hat{\beta}_k, \hat{\sigma}_k^2|y)$ to the corresponding value for $i^\star$, $L(i^\star, \hat{\beta}_{i^\star}, \hat{\sigma}_{i^\star}^2|y)$. The smaller the likelihood ratio

$$\Lambda = \frac{L(k, \hat{\beta}_k, \hat{\sigma}_k^2|y)}{L(i^\star, \hat{\beta}_{i^\star}, \hat{\sigma}_{i^\star}^2|y)},$$

the larger is the test statistic

$$\chi^2 = -2\ln\Lambda = -2\left(\ln L(k, \hat{\beta}_k, \hat{\sigma}_k^2|y) - \ln L(i^\star, \hat{\beta}_{i^\star}, \hat{\sigma}_{i^\star}^2|y)\right).$$

In our application, the test statistic has (approximately) a chi-squared distribution with 1 degree of freedom. The right tail of the distribution above the value of χ^2 yields a p-value for the hypothesis test with the null hypothesis $H_0 : i = k$ (reporting at closing time). In our tests we employ a level of significance of $\alpha = 0.001$ corresponding to a critical value of 10.828.

C.2 Bayesian Estimation

We briefly review the methodology applied in Section 3.2 (using the same assumptions and generic notation as above). The (conditional) likelihood function for a given benchmark (time) i with data X_i and the parameters $\beta \in \mathbb{R}^2$ and $\sigma^2 > 0$ of a bivariate normal distribution is

$$L(\beta, \sigma | i, y) = \frac{1}{(2\pi\sigma^2)^{-n/2}} \exp\left(-\frac{1}{2\sigma^2}(y - X_i\beta)'(y - X_i\beta)\right).$$

We assume that the k different possible times for the benchmark are equally likely, that is, the prior probability distribution for the benchmark times is the discrete uniform distribution,

$$p(i) = \frac{1}{k} \quad \forall i = 1, 2, \ldots, k.$$

For β and σ, we use the standard diffuse improper prior, so

$$p(\beta, \sigma^2) \propto \frac{1}{\sigma^2}.$$

The resulting posterior distribution of β conditional on σ^2 is the bivariate normal distribution, $N\left(\hat{\beta}_i, (X_i'X_i)^{-1}\sigma^2\right)$ where $\hat{\beta}_i$ is the OLS estimate given in (5) and $(X_i'X_i)^{-1}\sigma^2$ is the estimator's covariance matrix. The posterior distribution of σ^2 is the inverted chi-squared distribution with $n-2$ degrees of freedom, $\mathrm{Inv}-\chi^2\,(n-2, s_i^2)$, where $s_i^2 = \frac{e_i'e_i}{n-2}$ with $e_i = y - X_i\hat{\beta}_i$ is the OLS estimate for σ^2. The joint posterior distribution for given i is then

$$\begin{aligned} p(\beta, \sigma^2|i, y) &= p(\beta|\sigma^2, i, y)\; p(\sigma^2|i, y) \\ &\propto \frac{(X_i'X_i)^{1/2}}{\sigma} \exp\left(-\frac{1}{2}(\beta - \hat{\beta}_i)'\frac{X_i'X_i}{\sigma^2}(\beta - \hat{\beta}_i)\right) \\ &\quad \times \left(\sigma^2\right)^{-(\frac{n-2}{2}+1)} \exp\left(-\frac{e_i'e_i}{2\sigma^2}\right) \\ &\propto \sigma^{-(n+1)} \exp\left(-\frac{1}{2\sigma^2}\left[e_i'e_i + (\beta - \hat{\beta}_i)'X_i'X_i(\beta - \hat{\beta}_i)\right]\right) \end{aligned}$$

If we compute the mean time with respect to the posterior, this gives an estimate of the NAV computation time,

$$\sum_i \int_0^\infty \int_\beta ip(i, \beta, \sigma) d\beta d\sigma^2.$$

We can simplify this problem considerably by integrating out β and γ. Up to a constant factor,

$$\int p(i, \beta, \sigma) d\beta \sim \sigma^{K-T} |X'X|^{-1/2} \exp -\frac{T\hat{\sigma}_i^2}{2\sigma^2},$$

where K is the number of regressors, and

$$\int_0^\infty \sigma^{-T} |X'X|^{-1/2} \exp -\frac{T\hat{\sigma}_i^2}{2\sigma^2} d\sigma^2 \sim |X'X|^{-1/2} \hat{\sigma}_i^{(K-T)/2}.$$

We can also employ techniques from "Bayesian model comparison" as an alternative approach in Bayesian statistics to predict NAV computation times. Alternative "models" in our application are the different benchmark times $i = 1, 2, \ldots, k$. Bayes' rule yields

$$p(i|y) \propto p(y|i)p(i)$$

where

$$p(y|i) = \int_0^\infty \int_{-\infty}^\infty p(\beta, \sigma^2|i, y) d\beta d\sigma^2.$$

Note that $p(y|i)$ is in fact the denominator in the joint posterior distribution of β and σ^2. The posterior odds ratio in favor of benchmark time i_1 against benchmark time i_2 is then the ratio

$$\frac{p(i_1|y)}{p(i_2|y)} = \frac{\int_0^\infty \int_{-\infty}^\infty p(\beta, \sigma^2|i_1, y) d\beta d\sigma^2}{\int_0^\infty \int_{-\infty}^\infty p(\beta, \sigma^2|i_2, y) d\beta d\sigma^2}$$

since the two benchmarks have identical prior probabilities. The term on the right-hand side is also called the "Bayes factor".

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Table 14: List of mutual funds with domicile in DE

ISIN	Name
DE0008471608	ALTE LEIPZIGER TST.INV. GESELL.FONDS A
DE0008471368	AXA INV.MGRS.DTL.
DE0008484650	BADEN WUERTT.KPL.AKN. STRATEGIE DTL.
DE0009766865	BADEN WUERTT.KPL.FVB DT. AKTFD.
DE0008471038	COMINVEST ASTMGMT. PUBLIKFD.ADIG ADIFONDS
DE0008471012	COMINVEST ASTMGMT. PUBLIKFD.ADIG FONDAK
DE0008480732	DEKA FRANKFURTER SPARINVEST
DE0009771964	DEKA LBBW TOP SELECTION
DE0008474503	DEKAFONDS
DE0008471434	DIT ALLIANZ AKTIEN DEUTSCHLAND
DE0008475005	DIT CONCENTRA
DE0008475013	DIT THESAURUS
DE0009769869	DWS INVESTMENT AKN. STRATEGIE DTL.
DE0008490962	DWS INVESTMENT DTL.
DE0008474008	DWS INVESTMENT INVESTA
DE0008476565	DWS SELECT INVEST
DE0008478058	FRANKFURT TRUST INV.FT FRANKFURT EFFEKTEN FONDS
DE0008489808	INTERNATIONALE KPL.HSBC TRUS CAPITAL
DE0009754119	MEAG MUNICH ERGO KPL. PROINVEST
DE0005321038	MONEGA KPL.GERMANY
DE000A0RL2F6	PIONEER INVESTMENTS KPL. GERMAN EQUITY H DA
DE0009752303	PIONEER INVESTMENTS TOP GERMANY
DE0008473471	SEB INVEST AKTIENFONDS
DE0008488206	UBS BRINSON INVESTMENT D AKN.FDS SPECIAL I DTL.
DE000A0Q2HY7	UNION INV.PRIVATFONDS GMBH UNIDEUTSCHLAND I
DE0008491002	UNION INV.PRIVATFONDS UNIFONDS
DE0009763201	VERITAS SG INV.TST.VERI VALEUR FONDS
DE0009765446	WARBURG INVEST KPL. DAXTREND FONDS

List of 28 mutual funds with domicile in Germany in alphabetical order.

Table 15: List of mutual funds with domicile in LU/GB

ISIN	Name
LU0325630407	BNP PARI.ASTMGMT. GERMAN EQ.L CAP.
LU0391761227	COMINVEST ASTMGMT.FONDAK WAIT OR GO P
LU0228581061	DB PLATINUM CROCI R2C
LU0062624902	DEKALUX DEUTSCHLAND TF
LU0074279729	DT.POSTBANK ASTMGMT.DYM. DAX R T
LU0028514155	EUPAR.MLT.INV.FD.GERMANY INDEX A LOAD
LU0390221256	EUROPEAN FD.ADM.EFA MAINFIRST GERMANY FD.A
LU0048580004	FIDELITY FUNDS GERM.FD.A GLOBAL CERT.
LU0346986788	GENERALI FD.MAN.SA INVS. GERMAN EQUITIES B CAP.
LU0346987596	GENERALI INV.SICAV GRM. EQUITIES DX
LU0121803570	HORNBLOWER FUND.MAX VAL. B
LU0117905850	JPMF.ASTMGMT.EU.GERMANY EQ.JF A
LU0111753843	JPMF.GERMAN OPPS.A ER.
LU0048167570	JULIUS BAER LX.MST.GRM. VALUE STOCK FD.A
LU0390221926	MAIN FIRST GERMANY C2
LU0046920988	MM WARBURG LUX-LINEA
LU0325629656	PARVEST FUNDS GERMAN EQ. CLASSIC CAP EUR
LU0228581574	POSTBANK MIX PARAPLUFOND DB PLAT.CROCI GERMANY 1C
LU0074349449	SANTANDER DEUTSCHE AKN.B
GB0008192063	BARING GERMAN GROWTH AC. EUR

List of 20 mutual funds with domicile in Luxembourg or Great Britain in alphabetical order.

Table 16: Maximum likelihood and Bayesian fits of mutual funds with domicile DE

	Maximum Likelihood	**Posterior Mean**	**Posterior Std. Dev.**	R^2 **Close**	R^2 **Best**
DE0008471608	12.0	12.000000	0.000000	0.223	0.873
DE0008471368	13.0	13.000000	0.000000	0.300	0.432
DE0008484650	13.0	13.000000	0.000000	0.318	0.814
DE0009766865	13.0	13.000000	0.000000	0.310	0.774
DE0008471038	13.0	13.000000	0.000000	0.270	0.897
DE0008471012	13.0	13.000000	0.000000	0.258	0.815
DE0008480732	11.0	11.000000	0.000000	0.199	0.876
DE0009771964	13.0	12.890502	0.097509	0.309	0.470
DE0008474503	11.0	11.000000	0.000000	0.199	0.869
DE0008471434	12.0	12.000000	0.000000	0.259	0.878
DE0008475005	12.0	12.000000	0.000000	0.256	0.895
DE0008475013	13.0	13.014546	0.014335	0.289	0.412
DE0009769869	14.0	14.000000	0.000000	0.377	0.548
DE0008490962	12.0	12.000000	0.000000	0.277	0.834
DE0008474008	12.0	12.000000	0.000000	0.243	0.818
DE0008476565	12.0	12.000000	0.000000	0.231	0.764
DE0008478058	12.0	12.000000	0.000000	0.271	0.899
DE0008489808	13.0	13.000000	0.000000	0.305	0.884
DE0009754119	12.0	12.000000	0.000000	0.077	0.543
DE0005321038	12.0	12.000000	0.000000	0.260	0.940
DE000A0RL2F6	13.0	12.999986	0.000034	0.242	0.632
DE0009752303	13.0	13.000000	0.000000	0.317	0.914
DE0008473471	9.0	9.000000	0.000000	0.120	0.355
DE0008488206	14.0	14.000000	0.000000	0.431	0.615
DE000A0Q2HY7	14.0	14.000000	0.000000	0.424	0.624
DE0008491002	16.0	16.000000	0.000000	0.428	0.608
DE0009763201	13.0	13.000000	0.000000	0.257	0.842
DE0009765446	13.0	13.000000	0.000000	0.082	0.457

Best fit closing times according to maximum likelihood estimation; posterior means and standard deviations from Bayesian estimation; R^2 statistics for the market model regression (3) at close and at the best fit time.

Table 17: Maximum likelihood and Bayesian fits of mutual funds with domicile LU/GB

	Maximum Likelihood	**Posterior Mean**	**Posterior Std. Dev.**	R^2 **Close**	R^2 **Best**
LU0325630407	17.5	17.500000	0.000000	0.843	0.843
LU0391761227	9.0	9.000000	0.000000	0.001	0.320
LU0228581061	17.5	17.500000	0.000000	0.758	0.758
LU0062624902	13.0	12.999266	0.000734	0.310	0.466
LU0074279729	11.0	11.000000	0.000000	0.173	0.935
LU0028514155	17.5	17.500000	0.000000	0.856	0.856
LU0390221256	17.5	17.500000	0.000000	0.523	0.523
LU0048580004	17.5	17.500000	0.000000	0.491	0.491
LU0346986788	9.0	9.000000	0.000000	0.000	0.947
LU0346987596	9.0	9.000000	0.000000	0.000	0.775
LU0121803570	9.0	9.000000	0.000000	0.023	0.443
LU0117905850	16.0	16.000000	0.000000	0.394	0.442
LU0111753843	16.0	16.000000	0.000000	0.373	0.428
LU0048167570	17.5	17.500000	0.000000	0.680	0.680
LU0390221926	17.5	17.500000	0.000000	0.516	0.516
LU0046920988	9.0	9.000000	0.000000	0.033	0.471
LU0325629656	17.5	17.500000	0.000000	0.935	0.935
LU0228581574	17.5	17.500000	0.000000	0.749	0.749
LU0074349449	17.5	17.500000	0.000000	0.595	0.595
GB0008192063	13.0	13.000014	0.000014	0.346	0.471

Best fit closing times according to maximum likelihood estimation; posterior means and standard deviations from Bayesian estimation; R^2 statistics for the market model regression (3) at close and at the best fit time.

Table 18: Comparison of CAPM coefficients

	Best		Close		Dimson	
	α	β	α	β	α	β
DE0008471608	-0.000	0.811	-0.001	0.427	-0.000	0.967
	(-2.760)	(50.526)	(-2.599)	(16.631)	(-0.588)	(33.588)
DE0008471368	-0.000	0.930	-0.000	0.786	0.000	1.043
	(-0.240)	(13.169)	(-0.811)	(12.500)	(0.222)	(20.412)
DE0008484650	-0.000	0.888	-0.000	0.570	0.000	1.048
	(-0.749)	(32.010)	(-1.592)	(18.726)	(0.285)	(26.812)
DE0009766865	-0.000	0.768	-0.001	0.500	-0.000	0.944
	(-2.356)	(36.937)	(-2.495)	(19.560)	(-0.725)	(29.918)
DE0008471038	-0.000	0.926	-0.001	0.523	-0.000	1.035
	(-2.255)	(42.225)	(-2.314)	(18.641)	(-0.493)	(30.657)
DE0008471012	-0.000	0.793	-0.000	0.460	0.000	0.919
	(-0.914)	(29.622)	(-1.848)	(17.629)	(0.041)	(27.462)
DE0008480732	-0.000	0.943	-0.001	0.459	0.000	1.051
	(-0.734)	(46.696)	(-1.889)	(15.299)	(0.215)	(29.292)
DE0009771964	0.000	1.057	-0.000	0.870	0.000	1.221
	(0.408)	(12.824)	(-0.369)	(12.015)	(0.972)	(19.995)
DE0008474503	-0.000	0.947	-0.001	0.463	0.000	1.064
	(-1.024)	(41.200)	(-2.004)	(15.077)	(0.082)	(29.020)
DE0008471434	-0.000	0.968	-0.000	0.547	0.000	1.090
	(-0.371)	(42.230)	(-1.588)	(17.332)	(0.377)	(28.720)
DE0008475005	-0.000	0.933	-0.001	0.520	0.000	1.052
	(-0.787)	(43.825)	(-1.780)	(17.571)	(0.191)	(29.524)
DE0008475013	-0.000	0.921	-0.000	0.783	0.000	1.006
	(-0.011)	(13.286)	(-0.550)	(12.708)	(0.314)	(19.523)
DE0009769869	0.000	1.073	0.000	0.905	0.000	1.224
	(1.274)	(12.999)	(0.329)	(13.013)	(1.710)	(22.378)
DE0008490962	-0.000	0.942	-0.000	0.566	0.000	1.110
	(-0.138)	(54.423)	(-1.409)	(20.280)	(0.783)	(32.627)
DE0008474008	-0.000	0.878	-0.001	0.498	0.000	1.051
	(-1.050)	(38.875)	(-1.860)	(17.751)	(0.214)	(31.154)
DE0008476565	-0.000	0.861	-0.000	0.492	0.000	1.035
	(-0.200)	(37.721)	(-1.412)	(17.554)	(0.630)	(29.268)
DE0008478058	-0.000	0.905	-0.001	0.518	0.000	1.015
	(-1.131)	(49.846)	(-1.847)	(18.287)	(0.025)	(30.047)
DE0008489808	-0.000	0.936	-0.000	0.565	0.000	1.062
	(-0.943)	(59.011)	(-1.737)	(19.229)	(0.188)	(29.483)
DE0009754119	-0.000	0.758	-0.001	0.299	0.000	1.064
	(-1.307)	(20.493)	(-2.386)	(7.965)	(0.027)	(33.373)
DE0005321038	-0.000	0.958	-0.000	0.526	0.000	1.060
	(-0.628)	(60.027)	(-1.555)	(17.063)	(0.253)	(29.358)
DE000A0RL2F6	0.001	0.949	0.001	0.547	0.001	0.939
	(1.028)	(21.178)	(0.939)	(8.771)	(0.782)	(8.819)
DE0009752303	-0.000	0.999	-0.000	0.605	0.000	1.123
	(-0.370)	(62.654)	(-1.607)	(20.909)	(0.475)	(30.456)
DE0008488206	-0.000	0.757	-0.000	0.642	-0.000	0.957
	(-1.177)	(24.759)	(-1.486)	(20.834)	(-0.046)	(24.806)
DE000A0Q2HY7	-0.000	0.759	-0.000	0.634	0.000	0.990
	(-1.339)	(31.950)	(-1.592)	(22.927)	(0.022)	(31.942)
DE0008491002	-0.000	0.816	-0.000	0.644	0.000	0.996
	(-0.816)	(35.466)	(-1.467)	(22.587)	(0.130)	(30.348)
DE0009763201	-0.000	0.875	-0.001	0.497	-0.000	1.015
	(-2.331)	(45.426)	(-2.441)	(18.546)	(-0.509)	(32.123)
DE0009765446	-0.001	0.412	-0.001	0.181	-0.001	0.573
	(-4.649)	(20.823)	(-4.839)	(9.999)	(-3.529)	(24.599)
LU0062624902	0.000	1.033	-0.000	0.855	0.000	1.169
	(0.286)	(13.572)	(-0.444)	(12.803)	(0.790)	(21.807)
LU0074279729	-0.000	0.954	-0.001	0.420	-0.000	1.012
	(-1.211)	(95.712)	(-2.102)	(13.489)	(-0.082)	(27.959)
LU0117905850	-0.000	0.856	-0.000	0.802	-0.000	0.919
	(-0.502)	(11.878)	(-0.734)	(12.499)	(-0.336)	(23.941)
LU0111753843	-0.000	0.901	-0.000	0.836	-0.000	0.973
	(-0.545)	(12.190)	(-0.843)	(12.739)	(-0.288)	(23.449)
GB0008192063	-0.000	0.954	-0.000	0.830	0.000	1.091
	(-0.090)	(13.387)	(-0.643)	(12.830)	(0.526)	(23.420)

Table 19: Comparison Treynor-Mazuy

	Best			Close			Dimson		
	α	β	γ	α	β	γ	α	β	γ
DE0008471608	-0.000	0.812	0.270	-0.000	0.429	-0.889	-0.000	0.967	-0.036
	(-2.272)	(53.497)	(0.472)	(-1.489)	(16.798)	(-1.100)	(-0.491)	(33.769)	(-0.061)
DE0008471368	-0.000	1.012	4.216	-0.000	0.822	2.516	-0.000	1.076	2.580
	(-1.622)	(26.308)	(2.043)	(-1.412)	(19.747)	(1.147)	(-0.902)	(23.628)	(4.548)
DE0008484650	0.000	0.886	-1.479	-0.000	0.572	-1.465	0.000	1.049	-0.093
	(1.093)	(34.848)	(-1.314)	(-0.110)	(19.499)	(-1.514)	(0.339)	(26.820)	(-0.109)
DE0009766865	-0.000	0.766	-1.147	-0.000	0.501	-1.132	-0.000	0.943	0.193
	(-0.060)	(40.113)	(-1.502)	(-1.072)	(19.878)	(-1.432)	(-0.875)	(30.422)	(0.276)
DE0008471038	-0.000	0.926	-0.167	-0.000	0.524	-0.606	-0.000	1.035	0.044
	(-0.810)	(42.691)	(-0.178)	(-1.637)	(18.612)	(-0.783)	(-0.534)	(30.514)	(0.078)
DE0008471012	0.000	0.792	-0.993	-0.000	0.462	-1.301	-0.000	0.918	0.280
	(0.591)	(30.903)	(-0.897)	(-0.377)	(17.982)	(-1.572)	(-0.293)	(27.872)	(0.396)
DE0008480732	-0.000	0.942	-0.215	-0.000	0.461	-1.391	0.000	1.051	0.074
	(-0.132)	(44.797)	(-0.262)	(-0.563)	(15.396)	(-1.612)	(0.120)	(29.216)	(0.110)
DE0009771964	-0.000	1.145	4.532	-0.000	0.903	2.312	-0.000	1.258	2.904
	(-1.079)	(22.239)	(1.727)	(-0.889)	(17.571)	(0.826)	(-0.202)	(22.861)	(3.239)
DE0008474503	-0.000	0.945	-0.323	-0.000	0.466	-1.760	-0.000	1.062	0.468
	(-0.166)	(38.438)	(-0.330)	(-0.364)	(15.375)	(-1.951)	(-0.441)	(29.207)	(0.701)
DE0008471434	-0.000	0.968	-0.059	-0.000	0.548	-0.910	0.000	1.090	0.050
	(-0.121)	(41.543)	(-0.063)	(-0.662)	(17.468)	(-0.886)	(0.306)	(28.632)	(0.074)
DE0008475005	-0.000	0.934	0.133	-0.000	0.521	-0.930	0.000	1.052	0.104
	(-0.563)	(42.816)	(0.148)	(-0.810)	(17.706)	(-1.029)	(0.066)	(29.548)	(0.167)
DE0008475013	-0.000	1.008	4.507	-0.000	0.822	2.750	-0.000	1.037	2.430
	(-1.616)	(27.944)	(2.509)	(-1.335)	(21.093)	(1.396)	(-0.728)	(22.677)	(4.411)
DE0009769869	-0.000	1.172	5.221	-0.000	0.955	3.484	0.000	1.262	2.946
	(-0.980)	(33.373)	(2.545)	(-0.890)	(24.325)	(1.628)	(0.401)	(26.204)	(3.509)
DE0008490962	-0.000	0.944	0.529	-0.000	0.566	-0.552	0.000	1.109	0.469
	(-0.981)	(58.052)	(0.977)	(-0.844)	(20.173)	(-0.583)	(0.273)	(33.037)	(0.626)
DE0008474008	-0.000	0.879	0.295	-0.000	0.500	-1.156	-0.000	1.050	0.363
	(-0.967)	(37.670)	(0.320)	(-0.685)	(17.959)	(-1.388)	(-0.209)	(31.633)	(0.518)
DE0008476565	-0.000	0.862	0.440	-0.000	0.494	-0.834	0.000	1.034	0.357
	(-0.700)	(37.577)	(0.538)	(-0.574)	(17.516)	(-0.991)	(0.190)	(30.001)	(0.439)
DE0008478058	-0.000	0.906	0.165	-0.000	0.519	-0.660	0.000	1.016	-0.338
	(-0.861)	(50.985)	(0.228)	(-1.074)	(18.299)	(-0.758)	(0.411)	(29.933)	(-0.545)
DE0008489808	0.000	0.935	-0.724	-0.000	0.566	-0.745	0.000	1.062	-0.182
	(0.580)	(63.285)	(-1.218)	(-0.890)	(19.137)	(-0.818)	(0.377)	(29.302)	(-0.263)
DE0009754119	-0.000	0.759	0.170	-0.000	0.300	-2.491	0.000	1.065	-0.607
	(-1.000)	(19.145)	(0.110)	(-0.468)	(8.679)	(-1.923)	(0.635)	(33.312)	(-0.751)
DE0005321038	-0.000	0.959	0.506	-0.000	0.526	-0.257	-0.000	1.059	0.288
	(-1.264)	(68.767)	(0.866)	(-1.167)	(17.066)	(-0.262)	(-0.079)	(29.271)	(0.468)
DE000A0RL2F6	0.001	0.938	-4.546	0.001	0.546	0.502	0.001	0.965	-6.237
	(1.764)	(20.870)	(-2.136)	(0.743)	(8.436)	(0.173)	(1.910)	(10.168)	(-2.483)
DE0009752303	-0.000	1.000	0.594	-0.000	0.605	-0.355	-0.000	1.122	0.775
	(-1.267)	(69.014)	(1.015)	(-1.170)	(20.932)	(-0.359)	(-0.318)	(31.261)	(0.968)
DE0008488206	-0.000	0.756	-0.397	-0.000	0.642	-0.135	-0.000	0.956	0.253
	(-0.407)	(23.999)	(-0.328)	(-1.001)	(21.165)	(-0.113)	(-0.294)	(25.329)	(0.251)
DE000A0Q2HY7	-0.000	0.761	0.561	-0.000	0.634	0.005	0.000	0.991	-0.271
	(-1.691)	(32.902)	(0.727)	(-1.483)	(22.955)	(0.006)	(0.384)	(31.924)	(-0.413)
DE0008491002	-0.000	0.816	-0.112	-0.000	0.644	-0.110	-0.000	0.995	0.359
	(-0.610)	(34.786)	(-0.139)	(-1.203)	(22.714)	(-0.121)	(-0.297)	(30.713)	(0.428)
DE0009763201	-0.000	0.875	0.188	-0.001	0.498	-0.288	-0.000	1.014	0.390
	(-1.613)	(46.420)	(0.248)	(-1.939)	(18.379)	(-0.353)	(-0.985)	(32.339)	(0.771)
DE0009765446	-0.001	0.412	0.058	-0.001	0.182	-0.749	-0.000	0.574	-0.241
	(-3.483)	(20.613)	(0.081)	(-3.596)	(10.279)	(-1.533)	(-2.914)	(24.890)	(-0.559)
LU0062624902	-0.000	1.122	4.623	-0.000	0.891	2.511	-0.000	1.205	2.794
	(-1.297)	(26.571)	(2.085)	(-1.073)	(19.900)	(1.050)	(-0.360)	(25.538)	(4.505)
LU0074279729	-0.000	0.953	-0.185	-0.000	0.420	-0.519	0.000	1.014	-0.842
	(-0.632)	(93.597)	(-0.760)	(-1.419)	(13.530)	(-0.499)	(0.860)	(28.013)	(-1.219)
LU0117905850	-0.001	0.921	3.815	-0.001	0.853	3.549	-0.000	0.935	1.249
	(-1.774)	(21.353)	(1.868)	(-1.879)	(22.289)	(1.817)	(-0.970)	(25.526)	(2.382)
LU0111753843	-0.000	0.962	3.569	-0.001	0.885	3.382	-0.000	0.989	1.276
	(-1.557)	(21.626)	(1.566)	(-1.763)	(22.255)	(1.582)	(-0.904)	(25.157)	(2.618)
GB0008192063	-0.000	1.039	4.399	-0.000	0.872	2.925	-0.000	1.120	2.252
	(-1.595)	(26.684)	(2.087)	(-1.416)	(19.141)	(1.279)	(-0.510)	(26.763)	(3.989)

Table 20: Comparison Hendriksson-Merton

	Best			Close			Dimson		
	α	β	γ	α	β	γ	α	β	γ
DE0008471608	-0.000	0.811	-0.000	0.000	0.499	-0.150	0.000	0.981	-0.030
	(-1.144)	(25.176)	(-0.002)	(0.421)	(12.219)	(-2.004)	(0.189)	(26.400)	(-0.550)
DE0008471368	-0.001	0.865	0.182	-0.000	0.796	-0.024	-0.001	0.954	0.235
	(-1.035)	(6.869)	(0.996)	(-0.193)	(6.496)	(-0.138)	(-1.923)	(15.108)	(2.248)
DE0008484650	0.001	0.943	-0.117	0.000	0.647	-0.162	0.000	1.076	-0.058
	(1.207)	(41.553)	(-1.268)	(1.043)	(13.596)	(-1.824)	(1.027)	(20.636)	(-0.774)
DE0009766865	0.000	0.822	-0.116	0.000	0.565	-0.137	0.000	0.957	-0.026
	(0.948)	(35.690)	(-1.760)	(0.420)	(12.806)	(-1.856)	(0.012)	(23.774)	(-0.412)
DE0008471038	-0.000	0.937	-0.024	0.000	0.578	-0.116	0.000	1.047	-0.026
	(-0.294)	(22.734)	(-0.342)	(0.009)	(12.393)	(-1.451)	(0.106)	(22.754)	(-0.427)
DE0008471012	0.000	0.843	-0.106	0.000	0.539	-0.167	0.000	0.937	-0.038
	(1.135)	(20.470)	(-1.227)	(1.156)	(12.033)	(-2.214)	(0.650)	(21.530)	(-0.578)
DE0008480732	-0.000	0.950	-0.015	0.000	0.546	-0.182	0.000	1.073	-0.046
	(-0.011)	(28.256)	(-0.221)	(1.023)	(10.538)	(-2.150)	(0.889)	(21.693)	(-0.693)
DE0009771964	-0.001	0.992	0.182	0.000	0.889	-0.049	-0.001	1.130	0.240
	(-0.685)	(6.764)	(0.823)	(0.096)	(6.320)	(-0.242)	(-1.182)	(14.512)	(1.704)
DE0008474503	-0.000	0.954	-0.017	0.001	0.570	-0.223	0.000	1.064	0.000
	(-0.087)	(28.003)	(-0.218)	(1.404)	(10.914)	(-2.568)	(0.049)	(21.599)	(0.005)
DE0008471434	0.000	0.973	-0.011	0.000	0.615	-0.142	0.000	1.105	-0.032
	(0.041)	(24.545)	(-0.144)	(0.656)	(11.829)	(-1.530)	(0.744)	(21.468)	(-0.465)
DE0008475005	-0.000	0.929	0.009	0.000	0.588	-0.143	0.000	1.065	-0.026
	(-0.403)	(25.187)	(0.128)	(0.645)	(12.072)	(-1.669)	(0.557)	(22.750)	(-0.403)
DE0008475013	-0.001	0.840	0.227	-0.000	0.783	-0.002	-0.001	0.914	0.242
	(-1.229)	(6.915)	(1.291)	(-0.221)	(6.584)	(-0.011)	(-1.965)	(13.387)	(2.418)
DE0009769869	-0.001	0.985	0.242	-0.000	0.884	0.054	-0.000	1.134	0.236
	(-0.760)	(6.679)	(1.138)	(-0.159)	(6.643)	(0.286)	(-0.909)	(16.822)	(1.809)
DE0008490962	-0.000	0.921	0.045	0.000	0.624	-0.124	0.000	1.117	-0.016
	(-1.085)	(27.730)	(0.896)	(0.616)	(13.513)	(-1.511)	(0.758)	(24.172)	(-0.231)
DE0008474008	-0.000	0.859	0.042	0.000	0.573	-0.158	0.000	1.065	-0.029
	(-1.036)	(22.205)	(0.570)	(0.818)	(12.348)	(-1.972)	(0.596)	(23.754)	(-0.423)
DE0008476565	-0.000	0.848	0.027	0.000	0.566	-0.155	0.000	1.054	-0.040
	(-0.533)	(21.508)	(0.381)	(1.025)	(12.030)	(-1.909)	(0.960)	(23.428)	(-0.537)
DE0008478058	-0.000	0.904	0.002	0.000	0.574	-0.117	0.000	1.044	-0.061
	(-0.437)	(25.634)	(0.031)	(0.343)	(12.111)	(-1.421)	(1.053)	(23.241)	(-0.998)
DE0008489808	0.000	0.959	-0.049	0.000	0.626	-0.129	0.000	1.077	-0.032
	(0.647)	(52.192)	(-0.959)	(0.545)	(12.176)	(-1.508)	(0.652)	(21.844)	(-0.490)
DE0009754119	-0.000	0.769	-0.024	0.001	0.430	-0.279	0.000	1.080	-0.034
	(-0.295)	(14.375)	(-0.199)	(1.336)	(8.798)	(-2.511)	(0.556)	(26.067)	(-0.493)
DE0005321038	-0.000	0.944	0.030	0.000	0.574	-0.099	0.000	1.066	-0.013
	(-0.936)	(26.452)	(0.637)	(0.214)	(11.294)	(-1.095)	(0.376)	(21.388)	(-0.190)
DE000A0RL2F6	0.001	1.039	-0.190	0.001	0.530	0.032	0.002	1.107	-0.323
	(2.045)	(22.161)	(-1.861)	(0.530)	(4.031)	(0.174)	(2.272)	(9.472)	(-1.629)
DE0009752303	-0.000	0.980	0.041	0.000	0.649	-0.093	-0.000	1.113	0.022
	(-1.186)	(29.485)	(0.879)	(0.131)	(14.212)	(-1.084)	(-0.023)	(24.479)	(0.300)
DE0008488206	-0.000	0.774	-0.038	0.000	0.683	-0.085	-0.000	0.953	0.009
	(-0.055)	(17.397)	(-0.375)	(0.254)	(14.363)	(-0.893)	(-0.147)	(19.118)	(0.103)
DE000A0Q2HY7	-0.001	0.736	0.051	0.000	0.669	-0.073	0.000	0.995	-0.010
	(-1.458)	(16.881)	(0.709)	(0.058)	(15.086)	(-0.899)	(0.196)	(21.712)	(-0.148)
DE0008491002	-0.000	0.790	0.057	0.000	0.680	-0.076	-0.000	0.980	0.033
	(-1.361)	(23.842)	(0.794)	(0.168)	(15.416)	(-0.902)	(-0.428)	(21.143)	(0.420)
DE0009763201	-0.000	0.875	-0.001	-0.000	0.546	-0.103	-0.000	1.011	0.007
	(-0.933)	(21.751)	(-0.009)	(-0.216)	(11.658)	(-1.317)	(-0.513)	(24.772)	(0.133)
DE0009765446	-0.001	0.421	-0.018	-0.000	0.244	-0.133	-0.001	0.567	0.012
	(-1.984)	(13.125)	(-0.298)	(-0.700)	(8.755)	(-2.587)	(-2.745)	(20.174)	(0.280)
LU0062624902	-0.001	0.958	0.210	-0.000	0.867	-0.033	-0.001	1.073	0.253
	(-0.928)	(7.097)	(1.062)	(-0.007)	(6.685)	(-0.178)	(-1.587)	(15.882)	(2.228)
LU0074279729	0.000	0.966	-0.026	0.000	0.485	-0.137	0.000	1.052	-0.082
	(0.350)	(64.557)	(-0.902)	(0.299)	(9.908)	(-1.476)	(1.241)	(20.828)	(-1.207)
LU0117905850	-0.001	0.783	0.196	-0.001	0.755	0.121	-0.001	0.862	0.149
	(-1.183)	(5.941)	(1.057)	(-0.938)	(6.186)	(0.707)	(-1.994)	(18.053)	(2.190)
LU0111753843	-0.000	0.862	0.105	-0.000	0.813	0.060	-0.001	0.922	0.134
	(-0.686)	(6.201)	(0.537)	(-0.614)	(6.389)	(0.336)	(-1.693)	(16.745)	(1.743)
GB0008192063	-0.001	0.895	0.166	-0.000	0.824	0.015	-0.000	1.027	0.168
	(-0.883)	(6.967)	(0.895)	(-0.322)	(6.588)	(0.086)	(-1.219)	(17.357)	(1.633)

Table 21: Comparison EGARCH Volatility

	Best			Close			Dimson		
	α	β	γ	α	β	γ	α	β	γ
DE0008471608	-0.000	0.810	0.004	-0.001	0.426	0.017	-0.000	0.967	-0.001
	(-2.765)	(50.628)	(1.471)	(-2.607)	(16.482)	(2.381)	(-0.585)	(33.483)	(-0.180)
DE0008471368	-0.000	0.929	0.002	-0.000	0.785	0.007	0.000	1.043	0.001
	(-0.242)	(13.051)	(0.306)	(-0.814)	(12.472)	(0.975)	(0.220)	(20.359)	(0.090)
DE0008484650	-0.000	0.888	0.002	-0.000	0.569	0.014	0.000	1.049	-0.002
	(-0.751)	(31.908)	(0.910)	(-1.597)	(18.616)	(1.599)	(0.286)	(26.801)	(-0.372)
DE0009766865	-0.000	0.767	0.004	-0.001	0.498	0.014	-0.000	0.944	-0.001
	(-2.361)	(36.834)	(1.691)	(-2.503)	(19.469)	(1.998)	(-0.722)	(29.919)	(-0.213)
DE0008471038	-0.000	0.926	0.002	-0.001	0.521	0.015	-0.000	1.035	-0.002
	(-2.253)	(42.255)	(0.566)	(-2.317)	(18.466)	(1.681)	(-0.489)	(30.589)	(-0.239)
DE0008471012	-0.000	0.793	0.003	-0.000	0.458	0.015	0.000	0.919	-0.000
	(-0.916)	(29.591)	(0.903)	(-1.856)	(17.525)	(2.262)	(0.041)	(27.407)	(-0.011)
DE0008480732	-0.000	0.943	0.001	-0.001	0.458	0.017	0.000	1.051	-0.002
	(-0.735)	(46.726)	(0.539)	(-1.895)	(15.195)	(2.028)	(0.216)	(29.214)	(-0.304)
DE0009771964	0.000	1.057	-0.000	-0.000	0.869	0.006	0.000	1.221	-0.002
	(0.406)	(12.699)	(-0.040)	(-0.372)	(11.984)	(0.855)	(0.970)	(19.929)	(-0.243)
DE0008474503	-0.000	0.946	0.002	-0.001	0.462	0.018	0.000	1.064	-0.002
	(-1.026)	(41.180)	(0.758)	(-2.011)	(14.979)	(2.090)	(0.083)	(28.943)	(-0.251)
DE0008471434	-0.000	0.968	0.003	-0.000	0.545	0.016	0.000	1.090	-0.002
	(-0.373)	(42.217)	(0.728)	(-1.593)	(17.196)	(1.930)	(0.377)	(28.670)	(-0.260)
DE0008475005	-0.000	0.933	0.003	-0.001	0.518	0.017	0.000	1.053	-0.001
	(-0.790)	(43.803)	(1.013)	(-1.785)	(17.430)	(2.027)	(0.191)	(29.443)	(-0.129)
DE0008475013	-0.000	0.921	0.000	-0.000	0.782	0.005	0.000	1.006	-0.001
	(-0.012)	(13.168)	(0.057)	(-0.551)	(12.678)	(0.659)	(0.313)	(19.527)	(-0.085)
DE0009769869	0.000	1.073	-0.001	0.000	0.904	0.005	0.000	1.225	-0.003
	(1.269)	(12.868)	(-0.145)	(0.324)	(12.971)	(0.740)	(1.707)	(22.283)	(-0.424)
DE0008490962	-0.000	0.941	0.005	-0.000	0.563	0.016	0.000	1.110	0.000
	(-0.143)	(54.402)	(1.495)	(-1.420)	(20.083)	(2.474)	(0.780)	(32.555)	(0.076)
DE0008474008	-0.000	0.878	0.004	-0.001	0.496	0.017	0.000	1.051	-0.001
	(-1.052)	(38.900)	(1.062)	(-1.867)	(17.660)	(2.037)	(0.215)	(31.153)	(-0.180)
DE0008476565	-0.000	0.861	0.001	-0.000	0.491	0.013	0.000	1.036	-0.004
	(-0.201)	(37.683)	(0.224)	(-1.417)	(17.424)	(1.665)	(0.632)	(29.192)	(-0.698)
DE0008478058	-0.000	0.905	0.002	-0.001	0.516	0.015	0.000	1.015	-0.001
	(-1.132)	(49.901)	(0.701)	(-1.852)	(18.128)	(1.876)	(0.026)	(29.999)	(-0.185)
DE0008489808	-0.000	0.936	0.001	-0.000	0.564	0.014	0.000	1.062	-0.003
	(-0.944)	(58.866)	(0.567)	(-1.741)	(19.103)	(1.659)	(0.190)	(29.531)	(-0.434)
DE0009754119	-0.000	0.757	0.006	-0.001	0.295	0.019	0.000	1.065	-0.002
	(-1.310)	(20.422)	(1.771)	(-2.395)	(7.856)	(2.809)	(0.030)	(33.159)	(-0.388)
DE0005321038	-0.000	0.958	0.001	-0.001	0.525	0.015	0.000	1.061	-0.002
	(-0.612)	(60.294)	(0.308)	(-1.607)	(16.932)	(1.554)	(0.266)	(29.363)	(-0.300)
DE000A0RL2F6	-0.005	0.958	0.179	-0.013	0.574	0.473	-0.005	0.962	0.199
	(-1.098)	(19.255)	(1.113)	(-2.150)	(8.954)	(2.192)	(-0.951)	(8.509)	(1.025)
DE0009752303	-0.000	0.999	0.001	-0.000	0.603	0.012	0.000	1.124	-0.003
	(-0.371)	(62.832)	(0.424)	(-1.612)	(20.719)	(1.857)	(0.477)	(30.432)	(-0.465)
DE0008488206	-0.000	0.756	0.003	-0.000	0.641	0.010	-0.000	0.957	-0.002
	(-1.178)	(24.716)	(0.809)	(-1.489)	(20.719)	(1.215)	(-0.044)	(24.766)	(-0.257)
DE000A0Q2HY7	-0.000	0.759	0.003	-0.000	0.633	0.011	0.000	0.990	-0.001
	(-1.340)	(32.003)	(0.873)	(-1.595)	(22.797)	(1.227)	(0.024)	(32.013)	(-0.201)
DE0008491002	-0.000	0.816	0.002	-0.000	0.643	0.010	0.000	0.996	-0.003
	(-0.817)	(35.369)	(0.525)	(-1.470)	(22.448)	(1.125)	(0.131)	(30.340)	(-0.366)
DE0009763201	-0.000	0.874	0.006	-0.001	0.496	0.018	-0.000	1.015	0.000
	(-2.335)	(45.430)	(1.293)	(-2.447)	(18.403)	(2.134)	(-0.508)	(32.023)	(0.025)
DE0009765446	-0.001	0.412	0.006	-0.001	0.180	0.014	-0.001	0.573	0.001
	(-4.654)	(20.738)	(1.949)	(-4.845)	(9.876)	(2.605)	(-3.519)	(24.392)	(0.259)
LU0062624902	0.000	1.033	-0.001	-0.000	0.854	0.005	0.000	1.170	-0.002
	(0.285)	(13.441)	(-0.072)	(-0.446)	(12.769)	(0.736)	(0.788)	(21.743)	(-0.235)
LU0074279729	-0.000	0.954	0.002	-0.001	0.418	0.018	-0.000	1.012	-0.001
	(-1.210)	(95.229)	(0.588)	(-2.108)	(13.374)	(2.016)	(-0.082)	(27.916)	(-0.123)
LU0117905850	-0.000	0.855	0.004	-0.000	0.801	0.006	-0.000	0.918	0.003
	(-0.539)	(11.767)	(0.527)	(-0.777)	(12.476)	(0.868)	(-0.364)	(23.945)	(0.469)
LU0111753843	-0.000	0.901	0.001	-0.000	0.835	0.004	-0.000	0.972	0.001
	(-0.543)	(12.062)	(0.179)	(-0.843)	(12.706)	(0.645)	(-0.287)	(23.554)	(0.098)
GB0008192063	-0.000	0.952	0.005	-0.000	0.828	0.009	0.000	1.090	0.003
	(-0.098)	(13.273)	(0.786)	(-0.648)	(12.806)	(1.350)	(0.519)	(23.365)	(0.419)

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