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Abstract

Persistence of stock returns is an extensively studied and discussed theme in the analysis of financial markets. Antipersistence is usually attributed to volatilities. However, not only volatilities but also stock returns can exhibit antipersistence. Antipersistent noise has a somewhat rougher appearance than Gaussian noise. Heuristically spoken, price movements are more likely followed by movements in the opposite direction than in the same direction. The pertaining integrated process exhibits a smaller range – prices seem to stay in the vicinity of the initial value. We apply a widely used test based upon the modified R/S-Method by Lo [1991] to daily returns of 21 German stocks from 1960 to 2008. Combining this test with the concept of moving windows by Carbone et al. [2004], we are able to determine periods of antipersistence for some of the series under examination. Our results suggest that antipersistence can be found for stocks and periods where extraordinary corporate actions such as mergers & acquisitions or financial distress are present. These effects should be properly accounted for when choosing and designing models for inference.

JEL-Codes: C22, C52, G32, G34

Key words: Antipersistence, Capital and Ownership Structure, Efficient Market Hypothesis, Long Memory, Mergers and Acquisitions, Stock Returns

1 Introduction

Analysis of return series of financial assets with respect to long memory properties are mostly focused on persistence, see e.g. Lo [1991]; Lux [1996]; Assaf [2008]; Kunze and Strohe [2010]. However, antipersistence has been found in some cases, see Muckley [2004].

Antipersistence is studied in many different fields of research such as quantum physics, see e.g. Relaño *et al.* [2006] or environmental studies, see e.g. Tarafdar and Harper [2008] or Koutsoyiannis [2010]. It is closely related to chaotic behavior of a system which may be traffic flow considered by Krbalek *et al.* [2001] or nonlinear dynamic toy models by Sozanski and Zebrowski [2005].

Usually, the assertion that a time series has long memory is meant for the whole series. However, considerable changes of the long memory parameter over time have been found in empirical studies for example by Brooks [1995] and recently Hassler and Nautz [2008], albeit for some fractions of the series only. Carbone *et al.* [2004], Cajueiro and Tabak [2004], and Silva *et al.* [2007] have applied rolling analysis techniques to financial time series. For the notion of rolling analysis see e.g. Zivot and Wang [2006]. The concept of changing Hurst exponent can also be found in the analysis of heartbeat dynamics, see e.g. Martinis *et al.* [2004].

At the very end of their publication Willinger *et al.* [1999] point out that due to the very delicate nature of tests for long memory and the interplay of several effects tests may be eventually biased. Therefore "deeper understanding of the nature of the micro/macro-economic market forces that determine the price movements" is required.

In this paper we apply rolling analysis of antipersistence to 21 time series that have at least once belonged to the German DAX and cover a time span of about 48 years. First, we count all periods for which a test for antipersistence rejects the null hypothesis (no antipersistence) at the 5%-level. Second, we relate the periods of antipersistence to possible economic explanations pertaining to the capital structure of the respective company.

The rest of the paper ist organized as follows. In the next two sections models for antipersistent time series and tests are considered. The fourth section contains the empirical findings and in the fifth section we draw conclusions.

2 Antipersistence

In order to discuss some aspects of antipersistence a simple discrete fractionally integrated process is introduced. It was first introduced by Granger and Joyeux [1980] and Hosking [1981].

Definition 1 (fractionally differenced white noise) *Let ε_t be a process with $E(\varepsilon_t) = 0$, $E(\varepsilon_t^2) = \sigma^2$ and $E(\varepsilon_t \varepsilon_{t'}) = 0$ for $t \neq t'$ then the process X_t, defined by*

$$(1-B)^d X_t = \varepsilon_t. \tag{1}$$

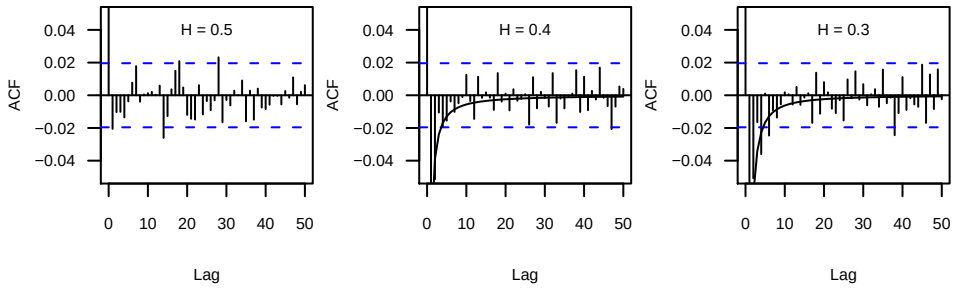

Figure 1: Autocorrelation function for simulated time series of length 10.000 points. Gaussian Series ($d = 0$), moderately antipersistent fractional Gaussian series ($d = -0.1$) and intermediately antipersistent fractional Gaussian series ($d = -0.2$). Solid lines: theoretical ACF.

with d non-integer is called fractionally differenced white noise.

The integration parameter d is related to Hurst coefficient H by

$$H = d + \frac{1}{2} \tag{2}$$

see e.g. Geweke and Porter-Hudak [1983]. A parameter $d = 0$ corresponds to Hurst parameter $H = 1/2$ which denotes Gaussian noise if the marginal distribution is normal. The process is invertible for $d > -\frac{1}{2}$. For $d < \frac{1}{2}$ it is weakly stationary. The fractional difference can be expressed as[1]

$$(1-B)^d = \sum_{k=0}^{\infty} \frac{\Gamma(d+1)}{\Gamma(k+1)\Gamma(d-k+1)} (-1)^k B^k \tag{3}$$

for any $d > -1$. The autocorrelation function of X_t is

$$\rho(k) = \frac{\Gamma(k+d)\Gamma(1-d)}{\Gamma(k-d+1)\Gamma(d)}. \tag{4}$$

For $d < 0$, the autocorrelation is negative at all lags, see Figure 1. This gives rise for the term antipersistence. As opposed to the case $d > 0$ the autocorrelations are summable. Therefore, estimation of parameters and prediction are not as complicated as for persistent processes, see e.g. Beran [1994]. However, autocorrelations still decay more slowly than for short range autocorrelated time series. Lo [1991] therefore calls antipersistent and persistent series long memory processes. Baillie [1996] calls antipersistent series intermediate memory processes, since on one hand autocorrelations are larger than for short range autocorrelated processes but on the other hand autocorrelations are summable.

Antipersistent processes are no semi-martingales. This aspect calls for new methods of derivative pricing, see e.g. Shiryaev [1999]; Cheridito [2003]; Bender *et al.* [2007].

[1] $\Gamma(x) = \int_0^\infty t^{x-1} e^{-t} dt$ denotes the Gamma-function.

3 Tests

For the present study we use Lo's extension of Hurst's rescaled range method, see Hurst [1951]; Lo [1991]. Consider a discrete stationary time series $\{x_i,\ i \in [1,2\ldots,N]\}$ with partial sums

$$X_{t,k} = \sum_{i=t}^{t+k} x_i. \tag{5}$$

The argument t marks the starting point, $t+k$ the end point of the summation. The modified statistics, also known as Lo's statistics is given by

$$Q_q(t,k) = R/S_q = \frac{R(t,k)}{\sigma_q(t,k)}. \tag{6}$$

The numerator in equation (6) is the range which is defined as

$$R(t,k) = \max_{0\le i\le k}\left[X_{t,i} - \frac{i}{k}X_{t,k}\right] - \min_{0\le i\le k}\left[X_{t,i} - \frac{i}{k}X_{t,k}\right] \tag{7}$$

The term $\frac{1}{k}X_{t,k}$ is the empirical mean of the partial series $\{x_i,\ i\in[t,\ldots,t+k]\}$. The difference $X_{t,i} - \frac{i}{k}X_{t,k}$ is the deviation of the partial sum from the trend with index $i \le k$. For $i = k$ the difference vanishes. Therefore the first term (maximum) is non-negative and the second term (minimum) is non-positive. It follows that, that $R(t,k)$ is non-negative. The denominator in equation (6) is a heteroscedasticity and autocovariance consistent (HAC) estimator of the variance of the time series given by

$$\begin{aligned}
\sigma_q^2(t,k) &= \frac{1}{k}\sum_{j=t}^{t+k}\left(x_j - \frac{1}{k}X_{j,k}\right)^2 \\
&+ \frac{2}{k}\sum_{j=1}^{q}\omega_j(q)\left\{\sum_{i=j+t}^{t+k}\left(x_i - \frac{1}{k}X_{i,k}\right)\left(x_{i-j} - \frac{1}{k}X_{i-j,k}\right)\right\} \\
&\omega_j(q) \equiv 1 - \frac{j}{q+1} \qquad q < n.
\end{aligned} \tag{8}$$

The choice $\omega_j(q)$ follows Newey and West [1987]. Different choices and a more general formulation of the summation weights can be found in Andrews [1991].

The probability distribution of $Q(t,k)$ under the null hypothesis 'Gaussian noise' was found by Kennedy [1976] and Siddiqui [1976] based on work by Feller [1951]. With the notation $F_Q(x) = P(Q < x)$ it reads

$$F_Q(x) = 1 + 2\sum_{k=1}^{\infty}(1 - 4k^2x^2)\exp\left(-2\,(kx)^2\right), \tag{9}$$

The first two moments of the distribution are $\mu = \sqrt{\pi/2}$ und $\sigma = \sqrt{\pi^2/6 - \pi/2}$. The null hypothesis should be rejected at the respective confidence level if the

Table 1: Quantiles of the distribution of $Q(t,k)$ under H_0, (Gaussian noise) ($H = 0.5$, 10000 simulations)

No.	H	Length	0.005	0.025	0.050	0.950	0.975	0.995
1	0.50	250	0.6699	0.7516	0.8003	1.6712	1.7931	2.0143
2	0.50	1000	0.6897	0.7797	0.8276	1.7037	1.8130	2.0758
3	0.50	10000	0.6985	0.7973	0.8483	1.7364	1.8591	2.1002
4	0.50	∞	0.7212	0.8094	0.8613	1.7473	1.8624	2.0977

absolute value of $Q(t,k)$ is larger (smaller) than the appropriate quantile. Quantiles are given in Table 1.

Short range autocorrelations can bias results of tests for persistence and antipersistence, see Lo [1991], Davidson and Sibbertsen [2009], and Kunze [2009]. In order to take short memory effects into account, the modified Lo statistic with lag 5 days is used and presented.

4 Empirical Results

We have investigated 21 time series of the German stock market who at least once belonged to the DAX (Deutscher Aktien-Index). Mostly, the time series start on January 5th 1960 and end on January 31st 2008. They have been transformed into daily percentage total return time series and are provided by the Karlsruher Kapitalmarktdatenbank[2] (KKMDB).

Throughout the study a time series is called antipersistent if the test statistics, equation (6), is smaller than the 5% quantile of the Feller distribution, equation (9), i.e.

$$Q_q(t,k) = R/S_q < 0.8613. \tag{10}$$

Antipersistence is measured for time windows of length fixed at $k = 1000$, 2000, and 4000 data points, corresponding to 4, 8, and 16 years. The pertaining value of the statistics is then attached to the last day in the time series. These windows are moved across the time series thus generating an analogue to a moving average or moving volatility. If not stated otherwise a lag of $q = 5$ (five days) is chosen.

In Figure 2 the number of antipersistent periods for windows of 4, 8, and 16 years are graphically presented for each of the titles included in the study. Neglecting the strong correlations between overlapping windows an error of the first kind is expected for 5% of the periods of one series under study. Most of the time series consist of about 12.000 return values. Consequently, if more than 550, 500, or 400 periods of a series are considered antipersistent by the test in the 4-, 8-, and 18-year window respectively, there is strong indication for antipersistence.

[2]Homepage: http://fmi.fbv.uni-karlsruhe.de

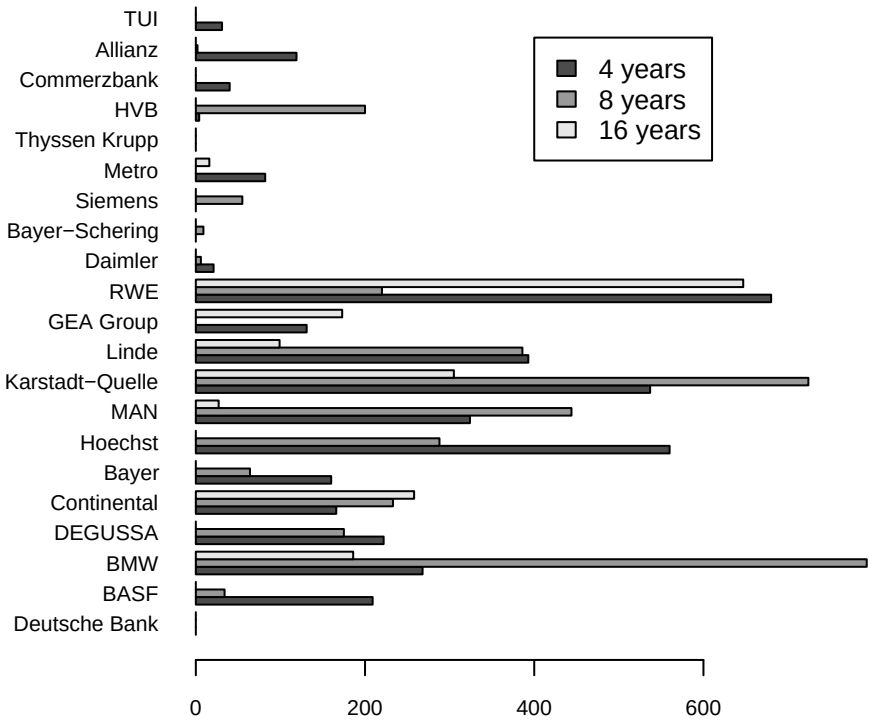

Figure 2: Number of antipersistent periods for windows of size 4, 8, and 16 years.

First, note that titles in the financial industry sector show very few periods of antipersistence, especially Deutsche Bank, which has no single period of antipersistence. On the other hand four titles show more than the required number of periods of antipersistence. These companies are

- BMW (www.bmw.com)
- Hoechst (www.hoechst.com – www.sanofi-aventis.de)
- Karstadt-Quelle (www.karstadt.com)
- RWE (www.rwe.com).

In the following, these four companies will be analysed in some detail. Information regarding history, ownership, mergers, etc. cited here is provided on the respective web pages given above, www.wikipedia.de, or the web page http://www.wer-zu-wem.de.

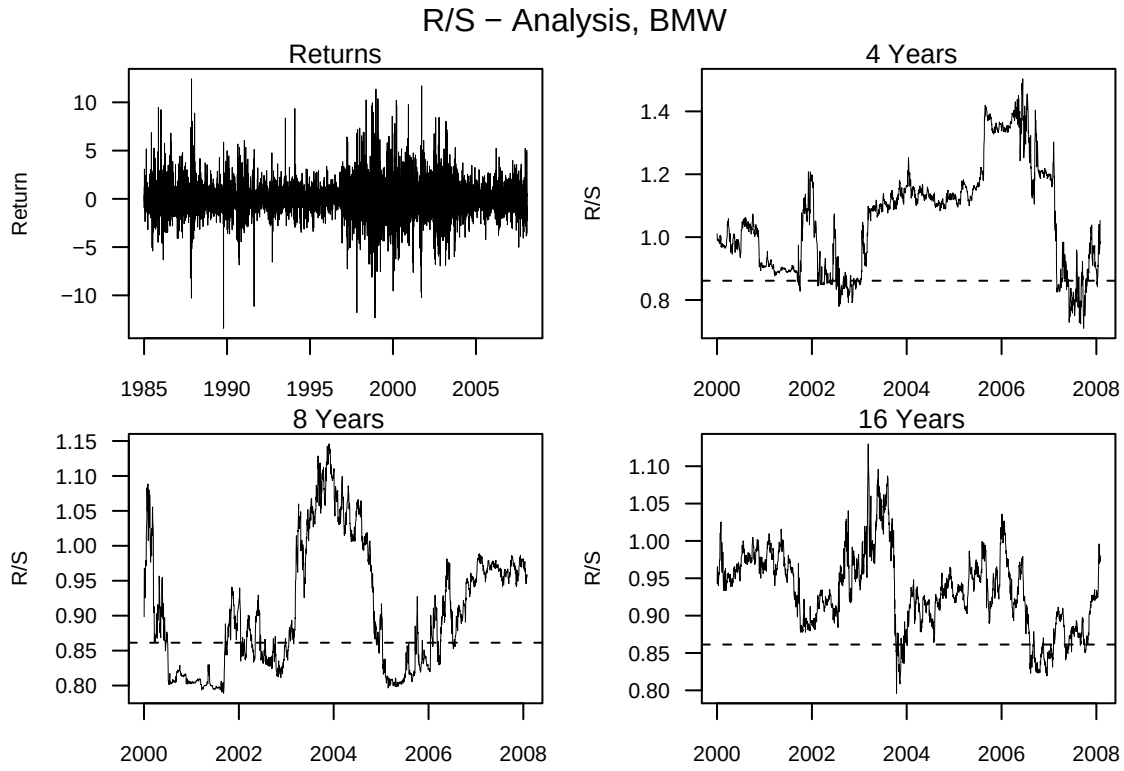

Figure 3: R/S-Analysis of BMW. Lo's estimator with Lag 5 days. Top left: Total Returns. Top right: Four year window. Bottom left: Eight year window. Bottom right: Sixteen year window. Below the dashed line the null hypothesis must be rejected at the 5% level. Time-scale of returns starts 15 years before R/S-statistics.

BMW BMW, founded in 1916, is owned at about 47 % by families Quandt and Klatten (2008). The remaining portion is free float. From 1994 to 2000 the company owned the Rover Group. During the period of this ownership BMW suffered severe losses putting the whole company at risk. In Figure 3 time resolved results of the test for antipersistence are given. Several four year periods ending in the years 2002 and 2008 are antipersistent. In the case of eight year windows, several periods ending between 2000 and 2006 are antipersistent. These findings suggest that there is a link between the period of financial distress and the antipersistent behavior of the stock returns the more so as almost half of the company are owned by a very small number of decision takers.

Hoechst Hoechst AG, founded in 1863, was one of the three largest German companies in the chemical and pharmaceutical sector. Starting with the production of dyes, acids and pharmaceuticals the number of products sold in the 1990s amounted to about 25.000. Deficiencies in profitability brought about danger of

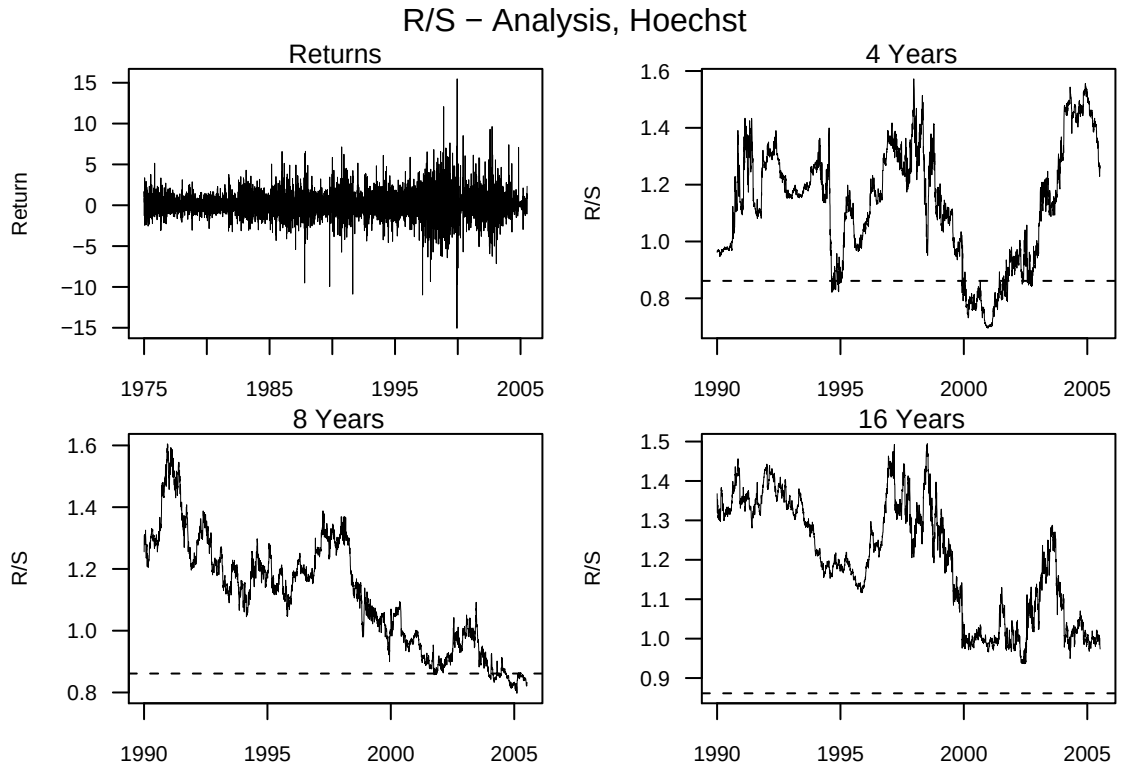

Figure 4: R/S-Analysis of Hoechst. Lo's estimator with Lag 5 days. Top left: Total Returns. Top right: Four year window. Bottom left: Eight year window. Bottom right: Sixteen year window. Below the dashed line the null hypothesis must be rejected at the 5% level. Time-scale of returns starts 15 years before R/S-statistics.

hostile takeover. In 1994 a major change in management style took place at Hoechst. At the same time, restructuring of the company and portfolio of assets (companies) as well as products and markets was started. Several mergers and acquisitions took place. On the other hand product lines and pertaining companies were sold. In the sequel Hoechst decided to focus on the life sciences (pharmaceuticals, agriculture) and looked for a suitable partner for a merger. In December 1998 the merger of Hoechst and Rhone-Poulenc to form the company Aventis which in turn merged in 2004 with Sanofi-Synthélabo to form Sanofi-Aventis. More details can be found e.g. in Seifert [2008]. Figure 4 shows the evolution of the stock-returns together with the modified R/S-statistics. It is clearly visible that most four year periods ending between 2000 and 2001 are antipersistent.

Karstadt Karstadt AG was founded in 1881. Until 1999 it grew and acquired competitors, such as Neckermann (1976/1977) or Hertie (1994). In 1999 Karstadt AG and Quelle Schickedanz AG & Co merged to form KarstadtQuelle AG. Since

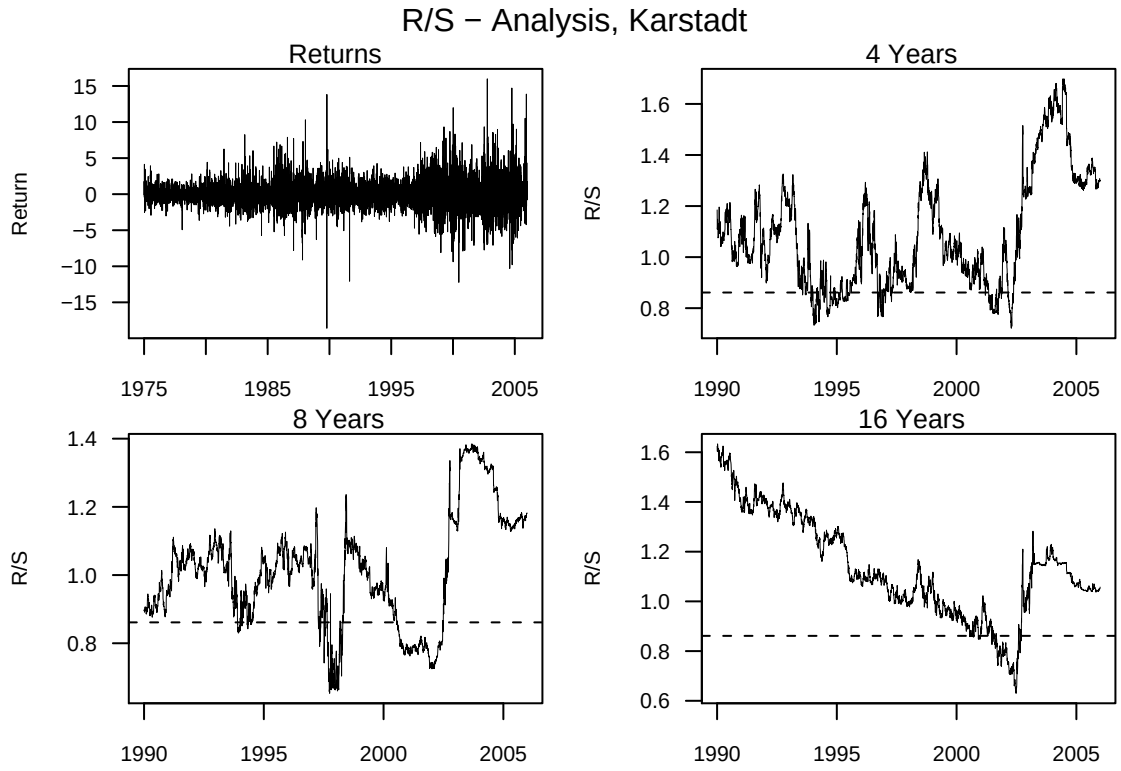

Figure 5: R/S-Analysis of Karstadt-Quelle. Lo's estimator with Lag 5 days. Top left: Total Returns. Top right: Four year window. Bottom left: Eight year window. Bottom right: Sixteen year window. Below the dashed line the null hypothesis must be rejected at the 5% level. Time-scale of returns starts 15 years before R/S-statistics.

then top management and ownership structure changed several times.

In Figure 5 the time resolved results of the test for antipersistence are given. Several four and eight year periods ending between 1994 and 2002 show an R/S–Value below the threshold for antipersistence (5% confidence). Abruptly, periods of all tested sizes ending after 2002 show Gaussian behavior. Remember, that expectation value of the R/S-statistics under the null hypothesis is $\sqrt{\pi/2} \approx 1.25$. A German documentary claims that in October 2002 owners and creditors agreed to sell large parts of the shares owned by Madeleine Schickedanz[3]. This information fits well with the empirical finding.

RWE RWE was founded in 1898 to supply the city of Essen with electrical power. It was an essential part of the strategy of the company on one hand to

[3]Rückschau: KARSTADT – Der große Schlussverkauf (WDR) – Wie das Warenhaus in die Pleite geriet - Ein Film von Ingolf Gritschneder und Georg Wellmann

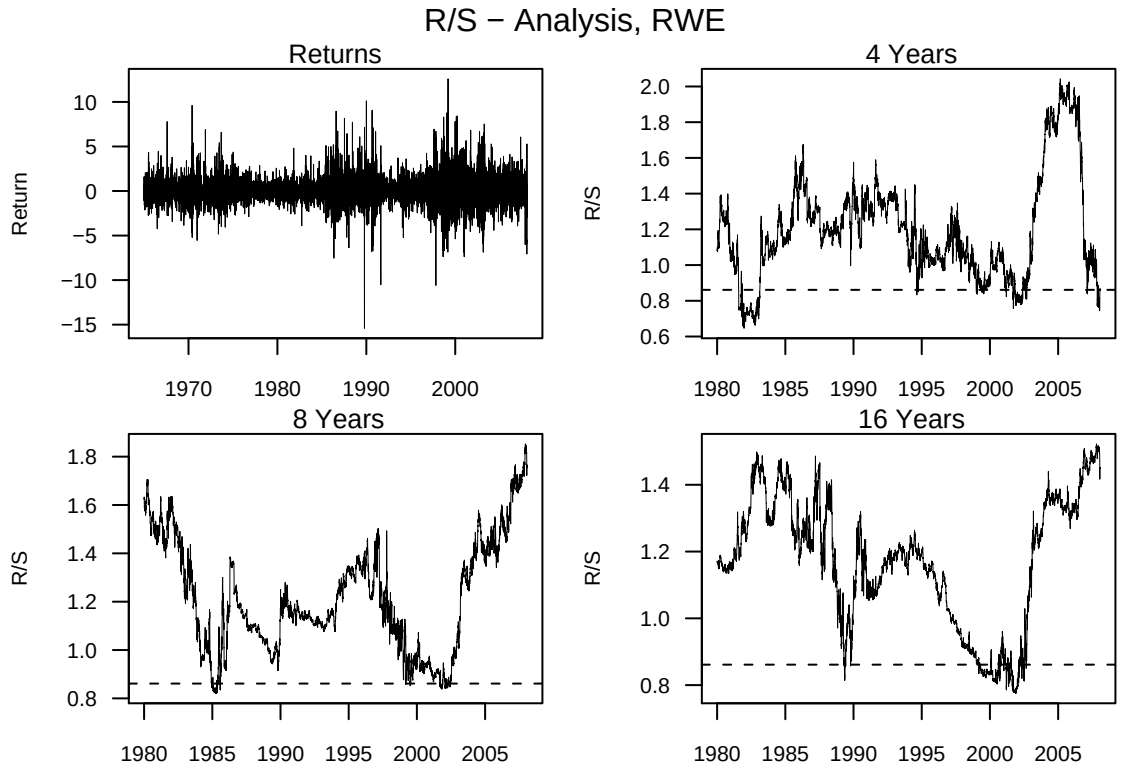

Figure 6: R/S-Analysis of RWE. Lo's estimator with Lag 5 days. Top left: Total Returns. Top right: Four year window. Bottom left: Eight year window. Bottom right: Sixteen year window. Below the dashed line the null hypothesis must be rejected at the 5% level. Time-scale of returns starts 15 years before R/S-statistics.

grow its own demand by the acquisition of small railway and tramway companies. On the other hand the company held a well-adjusted balance between private and public owners. Until 1998 public owners were granted voting rights in such a way that they always had the majority. Some sources attribute weak development of the share price to the political influence, see e.g. Flauger [2005]; Schraven [2008]. Public ownership had its maximum at about 37 %, in July 2005 it amounted to 31%, in July 2007 to 26 % and December 2009 to 16 % of total number of shares. This development brought about two aspects. Firstly, in the course of time decisions of the executive board were less influenced by political interests. The second aspect is the raised probability of a (hostile) takeover. It relates closely to the reduction of influence of public institutions on the company, since protective influence is reduced.

At the same time when exclusive voting rights for public share holders were ended, in 1998, the electricity market was liberalized. In the following years several investments and disinvestments took place, as for example in water supply and

distribution where two large companies were acquired in 2001 and 2003 and sold in 2006 and 2009 respectively.

In Figure 6 stock returns as well as R/S-statistics are shown. Several four, eight, and sixteen-year periods ending between 2000 and 2003 are antipersistent. In addition, some four year periods ending 2007 and 2008 are antipersistent. Some periods ending in between can be considered persistent at the 5% level. A possible explanation is antipersistent behavior during political reorganization of the energy market and voting rights within RWE, Gaussian and even persistent behavior during reduction of shares in public hands and reversion to antipersistent behavior during upcoming danger of (hostile) takeover.

In all four examples antipersistent periods pertained to periods of substantial changes in fundamental determinants of related companies. Remarkably, all four companies have in common that a large part of decision rights or ownership is concentrated in few hands. In addition, all companies underwent changes in long-term strategy or political playing field during or in the vicinity of antipersistent periods. Hoechst and Karstadt additionally faced financial distress and a change in ownership at the same time, while in the case of BMW financial distress was combined with a stable structure of ownership. RWE did not suffer from financial problems but underwent changes in ownership and political influence.

5 Conclusions

Antipersistence has been attributed mostly to volatilities of stock returns and not stock returns themselves. This study consists of a quantitative and a qualitative part. The quantitative part rigorously determines four companies with periods in which the null-hypothesis 'no antipersistence' must be rejected at the 5 % level using the modified Lo estimator with a lag of five days. In the qualitative part evolution of company strategy, ownership structure, etc. have been compared to the evolution of the R/S statistics.

Three of four companies inspected in detail underwent substantial changes in ownership structure. In addition all four companies saw essential changes in strategy. One company underwent financial distress in connection with a powerful principal shareholder. With necessary caution it can be stated that detection of antipersistent periods has pointed towards synchronous special circumstances for the companies.

This article is the first to connect antipersistent behavior of stock return series to fundamental information concerning related companies. Therefore, many aspects have been neglected. Neither did trading volume nor manipulative actions e.g. by hedge fonds or due to distortions in the derivatives market (e.g. Volkswagen) play a role. Furthermore, a relatively small sample of shares in one single market has been investigated. Finally, simultaneity of fundamentals and antipersistent periods has been interpreted amply. This is justified by the relatively coarse instrument

of rolling analysis with fixed time window size. Future directions of research are widening of the scope of companies under study and deeper understanding of the mechanisms that transmit especially owner structure to time series behavior.

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6 Appendix – Tables

In the following detailed tables of results are presented.
Tables 2, 3: The information left of the hyphen pertains to the window size, right of the hyphen to the lag.

Table 2: Number of antipersistent time windows at 5% level

Title	4J-L0	4J-L5	4J-L21	8J-L0	8J-L5	8J-L21	16J-L0	16J-L5	16J-L21
Deutsche Bank	0	0	0	0	0	0	0	0	0
BASF	730	209	80	109	34	45	0	0	0
BMW	540	268	31	952	793	2	226	186	1
DEGUSSA	551	222	385	237	175	171	0	0	134
Continental	177	166	52	155	233	45	719	258	428
Bayer	297	160	15	285	64	0	0	0	0
Hoechst	662	560	271	657	288	3	0	0	0
MAN	1177	324	319	1204	444	210	859	27	70
Karstadt-Quelle	610	537	278	736	724	695	349	305	362
Linde	778	393	336	706	386	1	225	99	165
GEA Group	305	131	43	73	0	0	223	173	197
RWE	724	680	392	215	220	99	777	647	86
Daimler	0	21	0	0	6	9	0	0	0
Bayer-Schering	0	0	23	32	9	0	0	0	0
Siemens	0	0	2	67	55	57	0	0	0
Metro	111	82	39	0	0	0	0	16	1
Thyssen Krupp	23	0	1	0	0	0	7	0	0
HVB	194	4	0	230	200	6	0	0	3
Commerzbank	21	40	8	10	0	0	0	0	0
Allianz	150	119	40	48	2	1	0	0	0
TUI	21	31	37	0	0	0	0	0	0

Table 3: Maximum number of adjacent antipersistent time windows at 5% level

Title	4J-L0	4J-L5	4J-L21	8J-L0	8J-L5	8J-L21	16J-L0	16J-L5	16J-L21
Deutsche Bank	0	0	0	0	0	0	0	0	0
BASF	260	37	23	30	19	23	0	0	0
BMW	145	43	10	310	308	2	53	44	1
DEGUSSA	148	72	117	66	65	62	0	0	29
Continental	27	51	18	33	82	25	261	39	89
Bayer	60	43	5	242	33	0	0	0	0
Hoechst	445	350	140	341	120	3	0	0	0
MAN	649	112	112	727	263	55	561	7	33
Karstadt-Quelle	115	84	37	492	478	460	263	232	229
Linde	242	188	105	432	144	1	148	60	77
GEA Group	34	28	13	45	0	0	159	121	159
RWE	288	322	314	45	70	70	223	206	39
Daimler	0	9	0	0	3	4	0	0	0
Bayer-Schering	0	0	11	22	3	0	0	0	0
Siemens	0	0	2	29	23	22	0	0	0
Metro	15	22	9	0	0	0	0	7	1
Thyssen Krupp	11	0	1	0	0	0	2	0	0
HVB	54	2	0	59	27	2	0	0	2
Commerzbank	8	20	2	8	0	0	0	0	0
Allianz	128	62	23	18	2	1	0	0	0
TUI	14	17	18	0	0	0	0	0	0

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