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## Changes of German share prices, random or not random?

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Changes of German Share Prices<sub>1970-74</sub>

Random or not Random ?

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Gerd Ronning

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## Changes of German Share Prices - Random or not Random ?

Gerd Ronning

1. In a recent paper Conrad and Jüttner [1] analysed time series of the kind

$$(1) \quad v_t^{(j)} = p_t^{(j)} - p_{t-1}^{(j)},$$

where  $p_t^{(j)}$  is the price of the  $j$ -th share at time  $t$ . Contrary to results for stock markets in other countries (see [3] and [4]) for Germany they found strong evidence against the random walk hypothesis for the series  $(v_t^{(j)})$ . In their paper they applied four non-parametric run tests ("total number of runs" = TN-test, "runs up and down" = UD-test, "difference sign test" = DS-test, "Wallis-Moore test" = WM-test) and a test on first order serial correlation (SC-test).

Though the authors claimed that all the tests were of the same hypothesis, this is not the case: Only the TN-test and the SC-test were used to test the random walk model for  $(v_t^{(j)})$ <sup>0)</sup> whereas the three other tests (as applied by Conrad and Jüttner) were only relevant for the question, whether or not the series of prices  $(p_t^{(j)})$  is random, which is irrelevant for the discussion of most types of random walk models (see [3]).

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0) Although the authors used changes in log prices for the SC-test, the results of this test refer (at least approximately) to the above mentioned hypothesis ([3]).

From the results obtained by Conrad and Jüttner using the last three tests (UD,DS,WM) one can only conclude (as we show in § 2) that series of prices are not random. Nobody would really be surprised to hear this, especially if daily quotations are analysed as was done in [1]. But even these series are "more random" when the time interval between quotations is enlarged. This will be demonstrated by some numerical results which were obtained in a larger study [7] of the behaviour of changes of German share prices. See § 4 .

2. If one uses the run tests UD, DS or WM to test the randomness of the series  $(v_t^{(j)})$  it is the sign of differences of this series which is important; more precisely, let the differences be defined by

$$(2) \quad q_t^{(j)} = v_t^{(j)} - v_{t-1}^{(j)},$$

then "runs" in these tests are determined by the sign of  $q_t$  . ([6],[8]) Conrad and Jüttner however considered "price movements" or "price changes" ([1] pp. 582,584,586) in applying these tests, i.e. they used the series of price differences  $(v_t^{(j)})$  defined in (1).

From comparison of (1) and (2) it is clear that this approach is a test of independence of the series of prices  $(p_t^{(j)})$  and not of the series of price changes  $(v_t^{(j)})$  . Therefore only the two correctly applied tests (TN and SC) are relevant to the random walk hypothesis. The results in [1] reflect

this discrepancy<sup>1)</sup>: Between 15% and 60% of the shares analysed are nonsignificant in the tests TN and SC whereas all shares had to be rejected in the tests UD and WM<sup>2)</sup>.

The confusion seems to be caused by the following: In contrast to UD, DS and WM which refer to the variable  $q_t$  the TN-test refers directly to the series  $(v_t^{(j)})$  whose elements are divided into three categories ( $> a$ ,  $= a$ ,  $< a$ ) where  $a$  is usually taken to be the median estimate ([9] chap. 18.4.1). For price changes however  $a = 0$  is also a reasonable choice ([4] pp. 168-169). If we take  $a = 0$ , runs for the TN-test can be determined by checking whether the price changes are positive, zero or negative. Therefore in this special case ( $a = 0$ ) the TN-test considers differences as do the three other run tests (UD,DS,WM). But for these tests the hypothesis of randomness no longer refers to the series  $(v_t^{(j)})$  but to the series  $(p_t^{(j)})$ .

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1) The results in [1] can be summarized as follows: 54 shares were analysed in total. The number of cases in which the random walk hypothesis was accepted (at different levels of significance) can be read from the following table:

level of significance	TN	UD	DS	WM	SC
0.05	6	0	35	0	26
0.01	15	0	41	0	31
0.001	25	0	47	0	32

2) The high number of nonsignificant cases in the DS-test may perhaps be explained by the low efficiency of this test ([5] p. 26). The same situation occurs when price changes are analysed [7]. See also § 4 below.

3. Moore and Wallis [6] discuss the fact that the hypothesis of randomness of the series of differences is much more likely to be accepted than the corresponding hypothesis referring to the original series. This can be demonstrated quite impressively by the following example: Figure 1 shows a series  $(z_t)$  of size 300 which has been generated by setting

$$Z_{t+1} = Z_t + Y_t \quad ,$$

where  $Z_0 = 0$  and  $(Y_t)_1^{299}$  is a series of independent identically distributed random variables which take on the values  $+1$  and  $-1$ , each with probability  $1/2$ . The series  $(Z_t)$  therefore generates a simple random walk (without barriers) ([2] chap. III). It is worth noting that the simple random walk is a fairly good description of share prices, at least for the USA ([4] p. 171). The median estimate for the series (which equals zero in our example) is given by the dashed line.

(Abbildung 1 ungefähr hier)

Results of the run tests and the SC-test for the series  $(z_t)$  (which corresponds to tests for the series  $(p_t^{(j)})$  in the above discussion) are given in table 1. For all but the DS-test the value of the test statistics far exceeds the 0.001 critical level.<sup>3)</sup> Since the DS-test is not very efficient

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3) The critical value at the 0.001 (0.01, 0.05) level for UD, DS and SC is (approximately) 3.29 (2.58, 1.96) and for WM the critical value is 15.1 (10.3, 6.9). See [5] p. 90, [6], [8].

compared with other tests used (see footnote 2) the hypothesis that the series  $(z_t)$  itself is random clearly has to be rejected.

Table 1

Tests of randomness for the series  $(z_t)$

Test:	TN	UD	DS	WM	SC (raw)	SC (standard.)
value of the test statistic:	-14.7	-8.8	1.4	59.1	0.99	17.1

4. We now consider the series of prices themselves  $(p_t^{(j)})$  and give some results concerning their stochastic behaviour. We applied the three run tests concerning differences of a series (UD,DS,WM). For these tests the results in Conrad and Jüttner's paper [1] also refer to the series of share prices (see § 2). Their results based on daily quotations are shown in column 1 of table 2. The remaining columns contain the results from our own computations for increasing quotation intervals starting with one week<sup>4)</sup>. The results are given only for those shares which were used in both studies ([1] and [7]).

(Tabelle 2 ungefähr hier)

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4) Conrad and Jüttner used data from the time interval 2/1/68 - 22/4/71 while we considered the interval 4/1/67 - 16/5/73. For weekly intervals we have about 300 observations and for intervals of 7 weeks about 40; the sample size in [1] is 825.

Table 2 shows that most values of the test statistics (for all three tests) are reduced in (absolute)<sup>5)</sup> magnitude if weekly quotations instead of daily quotations are used.<sup>6)</sup> This tendency continues for greater time intervals. If one uses seven weeks as the interval unit then at the 0.01 level only in 2 cases for the UD-test, 2 cases for the DS-test and 1 case for the WM-test is the hypothesis of randomness for the series of share prices rejected. This is in accordance with theoretical considerations that the farther apart the observations are, the "more independent" they become.

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5) Our test statistics are defined symmetrically [7] while some in [1] are not which causes the differences of sign, especially in the DS-test.

6) For the WM-test the expected number of runs longer than 2 given in [1] p. 585 is incorrect. The correct expression is (in Conrad and Jüttner's own terminology)

$$\bar{u}_3 = \frac{4N - 21}{60} + \frac{2}{N!} ,$$

which follows from the fact that  $\bar{u}_1$ ,  $\bar{u}_2$  and  $\bar{u}_3$  must add up to the expected total number of runs. In computations the term  $2/N!$  may be neglected. See for example [5], (2-18).



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Figure 1 - A Simple Random Walk

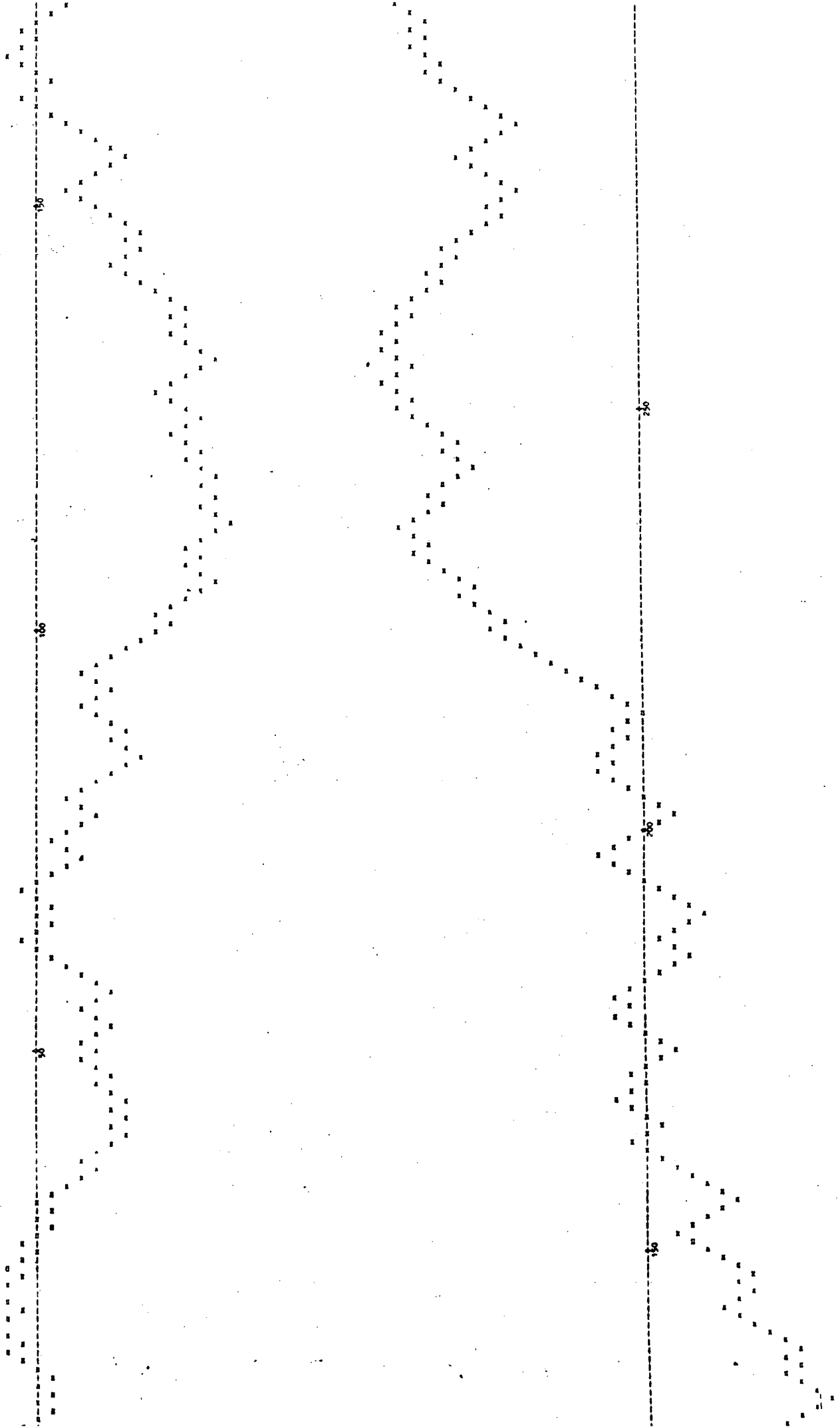


Table 2

Tests of randomness for series of share prices

TEST	STOCKS	1 day	1 week	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks
RUNS UP AND DOWN	AEG	-14.4**	-8.26**	-7.12**	-3.07**	-2.25*	-3.48**	-0.91	-2.01*
	BASF	-13.6**	-7.87**	-4.59**	-4.68**	-2.99**	-3.67**	- .69	-2.79**
	DEGUSSA	-15.1**	-9.19**	-5.32**	-3.42**	-3.06**	-4.45**	-2.16*	+2.34*
	Klöckner Werke	-13.3**	-4.84**	-4.76**	-4.90**	-2.82**	-2.68**	-2.23*	-2.56*
	Linde	-14.1**	-8.22**	-5.60**	-6.00**	-5.08**	-3.40**	-2.68**	-1.28
	MAN	-12.5**	-7.46**	-4.54**	-4.70**	-3.56**	-1.59	-1.77*	-1.08
	Mannesmann	-15.7**	-5.27**	-5.26**	-1.60	-2.25*	-1.49	-2.37*	-1.77*
	Audi/NSU	- 9.8**	-7.04**	-4.74**	-3.43**	-0.96	-2.65**	-1.86*	-1.77*
	Schering	-14.2**	-7.64**	-5.43**	-4.55**	-2.65**	-2.42*	-0.19	-2.33*
	Siemens	-14.2**	-8.53**	-6.73**	-4.55**	-5.55**	-2.16*	-2.37*	-0.99
	Südzucker	- 6.8**	-8.10**	-4.17**	-4.30**	-2.53*	-1.78*	-2.80**	-3.34**
	Volkswagenwerk	-14.1**	-6.09**	-6.33**	-4.90**	-4.55**	-4.14**	-2.16*	-1.77*
	Wintershall	-10.8**	-8.37**	-3.86**	-4.58**	-3.57**	-2.53*	-3.09**	-2.31*
	Deutsche Bank	-15.9**	-8.80**	-6.05**	-5.28**	-2.42*	-3.01**	-1.87*	-1.23
DIFFERENCE SIGN TEST	AEG	3.44**	-1.60	-0.72	0.53	-0.41	0.24	-0.78	0.27
	BASF	3.97**	-1.39	-1.99*	-1.24	0.41	0.24	-1.79*	-2.47**
	Degussa	0.42	-1.20	0.43	0.71	0.63	0.97	-0.26	0.47
	Klöckner Werke	0.48	-1.20	-1.86*	0.00	-0.41	0.93	1.28	1.66*
	Linde	1.45	1.31	0.29	0.54	-0.85	0.74	1.06	-0.57
	MAN	2.23*	-0.51	0.15	0.55	0.00	-1.25	-1.66*	0.00
	Mannesmann	2.35*	-0.10	1.85*	0.36	-1.04	0.00	0.52	0.00
	Audi/NSU	1.02	-1.03	0.45	-0.55	0.65	1.01	0.27	0.00
	Schering	0.36	0.50	2.75**	2.73**	0.21	4.08**	2.87**	1.71*
	Siemens	2.23*	1.60	0.14	0.18	0.83	-0.71	0.78	2.22*
	Südzucker	0.18	0.95	1.61	1.33	2.11*	3.22**	1.85*	2.71**
	Volkswagenwerk	3.02**	-0.89	0.14	-0.36	0.41	0.24	-0.26	0.00
	Wintershall	0.12	-0.74	0.61	1.16	1.59	1.83*	0.29	1.24
	Deutsche Bank	0.12	0.10	1.58	-0.18	-0.41	1.40	1.03	0.27
WALLIS-MOORE TEST	AEG	177**	50.5**	31.9**	6.1	4.7	15.8**	0.5	3.9
	BASF	158**	45.7**	19.3**	12.8**	8.1*	9.2*	5.1	12.6**
	Degussa	210**	68.5**	32.6**	11.5**	20.0**	25.1**	8.9*	8.8*
	Klöckner Werke	159**	29.2**	18.5**	22.2**	23.4**	13.0**	6.1	5.7
	Linde	137**	52.6**	12.7**	31.2**	24.0**	10.6**	11.7**	2.1
	MAN	153**	36.5**	37.4**	20.2**	12.2**	11.4**	6.9	4.9
	Mannesmann	182**	24.8**	27.8**	1.3	7.3	3.2	8.3*	9.0*
	Audi/NSU	89**	55.3**	25.2**	9.2*	2.7	12.2**	3.5	2.5
	Schering	182**	38.0**	44.0**	17.9**	6.1	3.1	2.2	3.8
	Siemens	174**	49.1**	46.4**	17.5**	24.2**	7.1*	3.0	0.5
	Südzucker	185**	42.6**	11.1**	10.9**	4.6	7.8*	5.0	4.4
	Volkswagenwerk	182**	46.0**	33.7**	30.4**	17.4**	14.2**	5.8	4.8
	Wintershall	132**	77.0**	21.6**	13.2**	11.5**	6.6	16.6**	7.5*
	Deutsche Bank	210**	58.6**	46.7**	26.8**	4.9	10.4**	0.9	3.0

level of significance: \* = 0.05 , \*\* = 0.01 (see footnote 3)