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Do Price Trends Exist in Speculative Markets?
A Case Study

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Abstract

The concept of price trends in speculative markets has been known and used by market practitioners for more than a century. It appears, however, that trends and their existence have not yet been subject to scientific scrutiny, and are not accepted as facts by science. This paper is an attempt at objective investigation of one particular trend in share prices of an actual company.
The hypothesis is that if systematic elements such as trends do in fact influence the otherwise stochastic price movements in the market, this will have to be reflected in the statistic frequencies of market price movements.
The analysis confirms the hypothesis with unexpected clarity. A Kolmogorov-Smirnov test is significant on the 10%, 5% and 1% levels. It is thus strongly probable that the investigated trend does in fact exist, and that it has a tangible effect on price.

The findings may indicate a resolution of the apparent contradiction between the trend concept and the “random walk” hypothesis.

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The Question at Issue

Price movements in financial markets are closely watched. A question of special interest is whether current price movements can give clues as to future price behavior.

More than one hundred years ago Charles H Dow introduced the *trend* as a key forecasting instrument, based upon the conviction that a price movement in a certain direction would tend to persist in the same direction until demonstrably broken. There is considerable empirical material to indicate that this might be true. However, this conception lacks scientific legitimacy. It seems that so far there has been no serious attempt made to scientifically ascertain whether such trends are objective facts, and not merely optical illusions. The present working paper is an attempt to approach this question analytically, based upon a company case.

Appendix 1 shows price fluctuations for the Volvo B share in a ”high-low-close” chart, month by month, from January 1984 til now, October 2001. As shown we can draw a line A that with considerable accuracy touches a number of extreme values, indicated on the chart. From 1984 to 1993 the price stays below this line, and at one occasion seems to be turned down by the line. In January 1994 the trendline is demonstrably broken. Thereafter, on several occasions and with considerable accuracy, the same line again turns the price back up. In recent months the line is again penetrated, now on the downside.

To the observer it might appear as if this line, trendline as it might be called, has a curious power of influencing price movements. There are more such lines with the same apparent power, cisely parallell to line A. And, - as such trendlines appear to stretch over years - may they also extend their influence into the future?

Is this the case of an optical illusion, or do such systematic elements in price movements in fact exist?

Method

This phenomenon, the curious precision with which lines can be drawn through extreme points in charts, seems not to have been object to scientific scrutiny.

The curious precision is briefly mentioned by Edwards & Magee (1948, 16th reprint 1997, p.235), and it is indicated by a great number of empirical examples. The reason why it has not so far aroused scientific interest may be that it is hard to see any intuitive/logic explanation for the phenomenon. But, if all initially inexplicable phenomena had been disregarded on such grounds, we would have missed many new insights.

There is, however, an abundance of studies on price movements generally. The research follows two main directions. In the first place there are studies based upon the serial correlation of price movements, such as Alexander (1961 and 64), Kendall (1953), Osborne (1959), Roberts (1959), Working (1934) and others. Then there are investigations of the efficiency of different trading strategies, such as Allen & Karjalainen (1999), Blume, Easley & O'Hara (1994), Brock, Lakonishok & LeBaron (1992), Jegadeesh & Titman (1993), Neely, Weller & Dittmar (1997), Neftci (1991) and recently Lo, Mamaysky & Wang (2000), and others.

It appears that none of the methods used in the past are well suited for the task at hand. The question under study requires a new and different approach. The one I use is very much an engineer's way of concretizing abstractions. It might be termed *the projection method*:

The point of departure is the line A,"the master trendline", appendix 1[1]. All "high" and "low" points[2], are given coordinates in time (month number *M*) and value (Swedish crowns *K*). These

[1] Here must be distinguished between "trend" and "trendline". A *trend* is solely defined by its inclination. For each trend there are normally several *trendlines* with the same inclination.

points are projected on a baseline which runs perpendicular to the master trendline. This means that all points on the masterline will have the same projected value. This also goes for all points on any line parallell to the masterline.

It is expected that the distribution of the original price data approximate some known probability function according to the "random walk" hypothesis. And if so, the projected values will also be randomly distributed according to some known probability distribution. We will thus have instrument for calculating the theoretical cumulative distribution for any point on the baseline.

It may now be made use of the fact that a concentration of points on the baseline will signal the possible existence of a trendline. Such concentrations should emerge as *irregularities* to the "pure" probability distribution.

The test described in this paper is based on the classical trendline definition, that *at least three extreme points should touch the line*. Identical calculations have also been made for alternative trendline definitions[3].

The Data

The raw data, plus some of the computations carried out on these data, are collected in a separate appendix. The data are referred to by columns A to P.

According to appendix 1 there are monthly price data for 214 months, numbered from 1 to 214. For each month we have two extreme values, one "high" and one "low". That makes alltogether 428 points. Each point is given coordinates in time (M, month number, column B) and value (K, Swedish crowns, kolumn C). Kolumn D shows the ln$K$, the logarithmic value of K.

The list is sorted by "projected price" ln$K$, which is defined in a separate chapter. Column A numbers the points in the same order and represents the cumulative frequency distribution. These numbers also serve as the identification of each point.

The Trend

The trend is given by the inclination of the masterline, line A, appendix 1. This line in turn is defined by two points, $(m_1, \ln k_1)$ and $(m_2, \ln k_2)$. Trend inclination is expressed as the *trend multiplier T*, that is the factor by which a trendline value has to be multiplied in order to obtain the trendline value one year hence:

1) $$T^{\frac{m_2 - m_1}{12}} = \frac{k_2}{k_1} \quad \text{which gives} \quad T = \exp\left(\frac{12}{m_2 - m_1} \ln \frac{k_2}{k_1} \right)$$

Given the points (71, 107,285) and (202, 138) from appendix 1, the calculation gives a trend multiplier **T=1,02315,** or roughly 2% per year.

The Projected Price *K**

The high/low points are defined by their coordinates in time and value, columns B and C in the data appendix. For reasons that will later become apparent, the values are also expressed in their logarithmic form, column D.

These points will be projected on a baseline, perpendicular to the masterline A. The frequencies of the projected values are independent of the location of the baseline, which may therefore be arbitrarily positioned. This also means that the projected values as such do not have any absolute interpretation. The baseline location is defined by an arbitrarily chosen point $(m_{0,} \ln k_0)$, in this case (50, ln240).

We have now three points as basis for computing projected values, $(m_1, \ln k_1)$, $(m_2, \ln k_2)$ defining the trend, and $(m_0, \ln k_0)$ defining the location of the baseline. Appendix 2 shows a geometric consideration of two congruent triangles with sides A, B, C and a, b, c respectively. We now define the projected position of the first two points on the $\ln K$ -axis (the baseline) as $\ln k = \ln k_0 + a$ where we have $a = b\frac{A}{B}$. The expressions may be simplified by interpreting α as a physical angle with tangent $\tan\alpha = \frac{\ln k_2 - \ln k_1}{m_2 - m_1}$.

We then obtain:

$$\ln k_1 = \ln k_0 + \left(\left(\tan\alpha\left(m_0 - m_1\right) + \left(\ln k_1 - \ln k_0\right)\right)\cos\alpha\right)$$

For the i-th point $(m_i, \ln k_i)$ we get:

2) $$\ln k_i = \ln k_0 + \left(\left(\tan\alpha\left(m_0 - m_i\right) + \left(\ln k_i - \ln k_0\right)\right)\cos\alpha\right)$$

The values for k_i and $\ln k_i$ are recorded in the data appendix, columns F and G for the total of all 428 points. The points are sorted and identified by their consecutive number in order of increasing $\ln k$ value[4]. Column E shows the cumulative relative frequencies of $\ln k^*$ in percent.

The Distribution Functions.

What mathematical distribution functions may now prove appropriate to our data?

The lognormal distribution offers an obvious first choice. This distribution describes elementary deviations combined in a *multiplicative* process, whereas the straight normal distribution combines elementary deviations in a corresponding *additive* process. The underlying processes that create growth and change in economic matters appear to be of an overwhelmingly multiplicative kind. Aitchison & Brown pointed out this as a fact in their standard work on the subject (1957). Lawrence has an excellent summary of its application in business and economics in Crow & Shimizu (1988, p. 229). One relevant example is that the Black & Scholes algoritm for option calculation is based upon just this distribution.

A normally distributed stochastic variable Y with mean μ and standard deviation σ has the frequency function:

$$f_N\left(y \middle| \mu, \sigma\right) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{(y-\mu)^2}{2\sigma^2}\right] \quad \text{for} \quad -\infty < y < +\infty$$

The corresponding distribution function is:

3) $$F_N\left(y \middle| \mu, \sigma\right) = P(Y \le y) = \int_{-\infty}^{y} f_N\left(y \middle| \mu, \sigma\right) dy$$

A non-negative stochastic variable X is said to be lognormally distributed with parameters (μ,σ) if its natural logarithm Y=lnX is normally distributed with parameters (μ,σ). Consequently the distribution function for X is:

4) $$F_L(x|\mu,\sigma) = P(Y \le \ln x) = \int_{-\infty}^{\ln x} f_N(y|\mu,\sigma)\,dy \qquad \text{for} \qquad x>0$$

Derivation with respect to X gives:

5) $$f_L(x|\mu,\sigma) = \frac{1}{x} f_N(\ln x|\mu,\sigma) = \frac{1}{x}\frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(\ln x-\mu)^2}{2\sigma^2}\right) \quad \text{for } x>0$$

Data may be graphically fitted to the normal and the lognormal distributions. A perfectly normally distributed empirical set of figures will appear as a straight line in a diagram with one axis with Gaussian scale and the other with a linear scale. Deviations from this straight line is a measure of the quality of the fit. Similarly, a perfectly lognormally distributed empirical set of figures will appear as a straight line in a diagram with one axis with Gaussian scale, and the other with a logarithmic scale.

The raw data (*K* och ln*K*, columns C and D, the data appendix) have been graphically tested both against the normal distribution (appendix 3) and the lognormal distribution (appendix 4). Evidently the lognormal fit is the better of the two. The fit is rather good in the interval 10% to 90%. In the tail areas <10% and >90%, however, the extreme values are strongly underrepresented[5].

Appendix 5 shows the same test for lognormality performed on projected data (columns F and G, the data appendix). For some reason the fit is considerably better than for the raw data, with parameters $\mu = 4{,}84$ and $\sigma = 0{,}49$. The dispersion of the distribution is also lower, with a standard deviation decreasing from $\sigma = 0{,}61$ to $\sigma = 0{,}49$. Measured by the variance, which is a more relevant comparison, the reduction is more than one third. It is hard to see the reason for this remarkable improvement in fit and dispersion. It could be that even with a trend multiplier as low as

[5] Truncations of this sort have been observed as a rather common phenome-

102% it is a result of the better fit to the tendency of the data.[6] As for the tails of the distribution we find that extreme values are underrepresented, in the same way as for the raw data.

Trend Analysis

The analysis so far indicates that price movements are mainly stochastic and lognormally distributed. The question is whether there is a trend effect that may cause deviations from a purely stochastic behavior.

A first visual indication is obtained by drawing a simple histogram for the projected values in logarithmic form ($\ln k$, column F, the data appendix). Such a histogram is drawn in appendix 6 for the total of all of the 428 points. Instead of obtaining an even curve, we get a curve broken by a great number of steps of different depth. Appendix 7 shows an enlarged part of the curve, where these steps emerge more clearly.

The steps implies a condensation of points around certain $\ln k$*-values, in other words, possible trends. Thus these steps give an initial visual indication in favour of our hypothesis. The biggest step, appendix 7, we find around $\ln k$*=5 which is the location of our masterline

The classical definition of a trendline, three points on a line, corresponds to the requirement that three consecutive k*-values (column G, the data appendix) should be equal or close to equal[7]:

$$\Delta = k_i - k_{i-2} \quad 0$$

Now, because K* is a stochastic variable, the interval Δ will also be a stochastic variable. By the same token this holds true also for the *expected number of points (B)* within the interval:

$$b = n \quad P(k_{i-2} \le K \le k_i | \mu, \sigma) = n \int_{k -2}^{k_i} f_N (\ln k | \mu, \sigma) d \ln k$$

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[6] This demonstrates that option prices computed considering price tendencies (trends) give better results, quite different from the ones obtained by computations based upon raw data alone.

[7] In fact the difference can hardlv ever be exactlv zero. because K is a dis-

6)

$$b = n\frac{1}{\sigma\sqrt{2\pi}}\left[\int_0^{k_i}\frac{1}{k}\exp\left(-\frac{(\ln k-\mu)^2}{2\sigma^2}\right)dk-\int_0^{k_{i-2}}\frac{1}{k}\exp\left(-\frac{(\ln k-\mu)^2}{2\sigma^2}\right)dk\right]$$

Where n is the total number of points (428-2), with $\mu = 4{,}84$ and $\sigma = 0{,}49$ according to appendix 5. The value of the variable *B* computed for all k_i is recorded in column H in the data appendix.

Being a stochastic variable, *B* will have a corresponding distribution function:

7) $$P(b \le b_0 | \mu,\sigma) = \frac{1}{\sigma\sqrt{2\pi}}\int_0^{b_0}\frac{1}{b}\exp\left(-\frac{(\ln b-\mu)^2}{2\sigma^2}\right)db$$

My hypothesis now says that if we have a trend effect, this will manifest itself in the form of a *deviation* from this "pure" stochastic distribution. If we have a condensation of points around certain constant values (steps), the corresponding intervals will be narrower (with lower *B* values) than predicted by the distribution function, and we will thus expect to find *an overrepresentation* of low expected *B* values.

In the data appendix, columns I, J, K, L and M, the intervals have been sorted in order of increasing *B* value, together with their accumulated relative frequency. Appendix 8 shows the resulting lognormal diagram.

<u>As expected, there is a clear overrepresentaton of low *B* values.</u>

Appendix 8 shows a mixture of two lognormal distributions, both with a remarkably good fit of the empirical data[8]. This means that our empirical data are drawn from *two different populations*, with b=0,9 as the dividing-line between the two.

The dominant (primary) distribution $b\ ?\ 0{,}9$ represents 75% of the observations, with $\mu = 0{,}3507$ and $\sigma = 0{,}7141$. The theorethical average of the *B* values for this distribution is computed according to:

[8] This excellent fit holds true even at the utmost tails of the distributions.

$$\bar{B} = E(B) = E(\exp(\ln B)) = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{+\infty} \exp(\ln b) \exp\left(-\frac{(\ln b - \mu)^2}{2\sigma^2}\right) d(\ln b)$$

$$= \exp(\mu + 0{,}5\sigma^2) \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{+\infty} \exp\left(-\frac{\left(\ln b - (\mu + \sigma^2)\right)^2}{2\sigma^2}\right) d(\ln b)$$

8) $$= \exp(\mu + 0{,}5\sigma^2)$$

$$E(B) = \exp\left(\ln 1{,}42 + 0{,}5\left(\ln \frac{2{,}90}{1{,}42}\right)^2\right) = 1{,}8323$$

The computed value of *E(B)* comes very close to the arithmetic mean of 1,88 of the computed *B* values (column H, row 431 and 432, the data appendix). This would then be, or come very close to, what we have termed the "pure" stochastic distribution.

The second (secondary) distribution $b \le 0{,}9$, representing 25% of the observations, has totally different parameters: $\mu = 0{,}6575$ - and -$\sigma = 1{,}1342$ with an average $E(B) = \exp(0{,}6575 + 0{,}5 * 1{,}1342^2) = 3{,}6720$.

The accumulated frequencies for this secondary distribution are considerably higher than those that would have been obtained by the primary distribution in the same interval. This in a very clear way demonstrates the expected overrepresentation of low *B* values, and thus confirms our hypothesis.

Identical calculations based upon stricter and even less strict trend definitions produce similar secondary distributions, see appendix 9[9]

Significance and confidence

The empirical approximations to the mathematical distributions may be tested for significance and confidence according to the Kolmogorov-Smirnov criteria. This is done for the N=2 case (the traditional trend definition)

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[9] It was expected that the trend effect would manifest itself in the statistic frequencies of prices. This has been confirmed, and with unexpected clarity. It was not, however, equally expected that this confirmation appears in the form of a separate lognormal distribution. The "systematic elements" that cause the deviation from the "pure" distribution are themselves a sto-

The test is based upon the maximum deviation that may be found in an empirical sample value and the corresponding value of a mathematical distribution *F(x)*:

9) $$D_n = \sup_x |F(x) - S_n(x)|$$

where n is the size of the sample, and $S_n(x)$ is the empirical distribution of the sample.

As $S_n(x)$ is a function of a random sample, D_n is a stochastic variable. Suppose now that D_n is known. It will then be possible to find a value D_n^α such that:

10) $$P(D_n \le D_n^\alpha) = 1 - \alpha$$

where α is the level of significance. This means that we have a probability equal to $(1-\alpha)$ that the critical value D_n^α is equal to or greater than D_n. Critical values D_n^α have been computed as functions of n and α .

From the definition of D_n^α follows that:

$$1-\alpha = P\left\{\sup_x |F(x) - S_n(x)| \le D_n^\alpha\right\}$$

$$= P(|F(x) - S_n(x)| \le D_n^\alpha) \quad \text{for all x}$$

11) $$= P(S_n(x) - D_n^\alpha \le F(x) \le S_n(x) + D_n^\alpha) \quad \text{for all x}$$

The latter equation shows that we have a probability $(1-\alpha)$ that the unknown probability function *F(x)* lies within the interval $(S_n(x) - D_n^\alpha)$ and $(S_n(x) + D_n^\alpha)$. The breadth of this interval is a measure for the precision with which $S_n(x)$ estimates F(x).

A similar confidence interval can also be used to test the hypothesis:

12) $$H_0 : F(x) = F_0(x)$$

where $F_0(x)$ is some specified mathematical distribution function.

it is rejected (Hoel, Port & Allen 1971, p. 169). The Kolmogorov-Smirnov test is performed for computed values of B, alternative N=2, appendix 8, according to my hypothesis.

The hypothesis may now be formulated as the predication that $S_{426}(b)$ is an estimate of the lognormal distributions $F_L(b|0,6098:1,1130)$ and $F_L(b|0,3507:0,7141)$, appendix 8. The first function is valid for b values up to b=0,9 (the secondary distribution). The second function (the primary distribution) is valid for b values from b= 0,9 and up, see appendix 8.

Computations of b for all k_i values according to equation 6) and and sorted on increasing b are recorded in column L. Corresponding $|F(b)-S_n(b)|$ differences are recorded in column M.

The same differences are sorted in falling order in column P. The largest differences are 0,0560, 0,0558 and 0,0540 for k_i, i equal 108, 419 and 210 respectively. Consequently we have a maximum difference $D_{426}=0{,}0560$

The critical values are computed according to:

13) $$D_n^{\alpha}=\frac{t}{\sqrt{n}+0{,}12+0{,}11/\sqrt{n}}$$

where n total number of events (=428-N), and t is a function of α, with values 1,628, 1,358 and 1,224 for $\alpha=0{,}01$ - $\alpha=0{,}05$ and $\alpha=0{,}10$ respectively, according to Bickel & Docksum (2001, p. 220). That gives us the following critical values:

$$D_{426}^{0,01}=0{,}0784$$
$$D_{426}^{0,05}=0{,}0654$$
$$D_{426}^{0,10}=0{,}0589$$

This means that with $D_{426}=0{,}0560$ the hypothesis is accepted on all given significance levels. Appendix 10 shows confidence limits for $\alpha=0{,}01$ and $\alpha=0{,}10$ according to equation 11)[10].

[10] Because of the construction of the test, confidence limits are sprawling at

The conclusion is that our empirical B distributions are valid estimates of the $F_L(b|\mu,\sigma)$ distributions, appendix 8, on 10%, 5%- and 1% levels of significance. It is thus strongly probable that the investigated trend does in fact exist, and that it materially influences prices.

Reflections

The core of the matter, as illustrated in appendix 8, is that we have a *dual* distribution, implying that prices are emerging from *two different* populations; one due to the effect of the trend, and the other to the random price variations.

In a wider perspective this duality may have interesting implications. Are we approaching the resolution of an old inconsistency? It goes far back in time, to the beginning of the last century:

-On one hand we have Louis Bachelier and his postulate that "the mathematical expectation of the speculator is zero", brilliant in its simplicity and the foundation of the "random walk" hypothesis.

-On the other hand we have Charles Dow with "Dow theory" and the trend concept.

These two concepts are in apparent contradiction, and have generated a controversy that has persisted to this day. But if we have *two different* populations, and *two different* probability distributions, Bachelier and Dow might both be right. Maybe we could see an end to "the hundred years war" between the two?

Appendix 1 Volvo B, "high-low-close" monthly price chart, from and including January 1984 to and including October 2001.

Appendix 2 Computation of projected prices ($\ln k_i$). Geometric illustration.

Appendix 3 Normal distribution, graphical test of raw price data (k) according to appendix 1.

Appendix 4 Lognormal distribution, graphical test of raw price data ($\ln k$) according to appendix 1.

Appendix 5 Lognormal distribution, graphical test of projected prices ($\ln k_i$) according to the data appendix, column F.

Appendix 6 Histogram of projected prices ($\ln k_i$), points 1 to 428 ("the step curve"), according to column F, the data appendix.

Appendix 7 Histogram of projected prices ($\ln k_i$), points 201 to 300 ("the step curve"), according to column F, the data appendix.

Appendix 8 The lognormal distribution, test of computed cumulative expected number of points per interval, N=2, according to column L in the data appendix.

Appendix 9 Alternative Trendline Definitions

Appendix 10 Confidence intervals for the Kolmogorov-Smirnov-test, significance levels $\alpha = 0{,}01$ and $\alpha = 0{,}10$, N=2.

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Data Appendix

to

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Data Appendix
Column Definitions

(Actual tables in separate file *Volvo-casestudy-data.pdf)*

Sorted according to projected price

Column A	Cumulative frequency for projected prices ($\ln k_i$, column F). Also used to identify each separate point.
Column B	Number of month, according to appendix 1.
Column C	Price (*K*), i.e. the extreme values (”high” or ”low”) per per month, according to appendix 1.
Column D	Prices in logarithmic form (ln*K*)
Column E	Cumulative relative frequencies for projected prices (*K**) in percent (=100%*(kol.A)/428)
Column F	Projected price in logarithmic form $\left(\ln k\right)$ according to equation 2).
Column G	Projected price $\left(k = \exp\left(\ln k\right)\right)$
	Column HExpected number of points *(b)* per interval and *N*=2 according to equation 6)

Sorted according to expected number of points per interval (*b*), kolumn L.

Column I	Point number (as column A, but in a different order)
Column J	Cumulative frequency for *b* (simple serial number).
Column K	Cumulative relative frequency for *b* in percent (=100%*(kol.J)/426)
Column L	Expected number of points (*b*) per interval, N=2, According to equation 6 (Same as column H, but in order of increasing value).
Column M	Cumulative relative expected number of points (b) per interval in percent, according to equation 7 (With $\mu = 0{,}6098$ and $\sigma = 1{,}1130$ up to *b*=0,90 and with $\mu = 0{,}3507$ and $\sigma = 0{,}7141$ for *b*=0,90 and up.. See appendix 8).
Column N	”The Kolmogorov-Smirnov-difference” in decimal percent (Equal to the absolute difference between columns K and M)

Sorted according to the “Kolmogorov-Smirnov difference”, column N, in falling order

Column O	Point number, as columns A and I

falling order.