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Technical Trading and Trends in the Dollar-Euro Exchange Rate

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November 2009

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AUSTRIAN INSTITUTE OF ECONOMIC RESEARCH

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Austrian Institute of Economic Research

Final report to the "Jubiläumsfonds der Oesterreichischen Nationalbank", Grant No 11898
(Project Co-ordinator: Stefan Schleicher)

Internal review: Franz R. Hahn • Research assistance: Eva Sokoll

Abstract

The study explores the pattern of exchange rate dynamics based on the dollar-euro rate. It documents the performance of technical trading systems in this market, and it analyses the impact of technical trading on exchange rate dynamics. The main results are as follows: First, exchange rates fluctuate around "underlying" short-term trends. Over a extended period of time, short-term trends last longer in one direction than in the other. The accumulation of these runs result in long-term appreciation or depreciation trends. Second, the 2,265 technical models based on daily data would have produced an average gross rate of return of 4.2 percent per year when trading the dollar-euro rate between 1999 and 2006. The 2,466 models based on 30-minutes data perfom worse than the daily models. However, those 25 models, which performed best over the most recent sub-period, would have produced over the subsequent period a gross return of 8.2 percent per year. Third, the aggregate transactions as well as open positions of technical models exert an excessive demand (supply) pressure on currency markets. When the models produce trading signals, they are either buying or selling, when they maintain open positions, almost all of them are on the same side of the market, either long or short.

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2009/295-1/S/WIFO project no: 10205

Medieninhaber (Verleger), Herausgeber und Hersteller: Österreichisches Institut für Wirtschaftsforschung,
Wien 3, Arsenal, Objekt 20 • Postanschrift: A-1103 Wien, Postfach 91 • Tel. (+43 1) 798 26 01-0 • Fax (+43 1) 798 93 86 • http://www.wifo.ac.at/ •
Verlags- und Herstellungsort: Wien

Verkaufspreis: 40,00 € • Kostenloser Download: http://www.wifo.ac.at/wwa/jsp/index.jsp?fid=23923&id=37582&typeid=8&display_mode=2

Stephan Schulmeister

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Content

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Study of the Austrian Institute of Economic Research supported by the Anniversary Fund of the Austrian National Bank (Project code 11989)

0. Executive Summary

The purpose of the study is threefold. First, the study investigates the pattern of exchange rate dynamics in an exploratory (inductive) manner. It measures the path of exchange rate movements and elaborates those elements of non-randomness in exchange rate dynamics which account for the accumulation of (very) short-term runs to medium-term and long-term trends. Second, the study documents the performance of a wide range of technical trading rules and examines the components of their profitability. Third, the study explores the relationship between the use of technical trading systems in the foreign exchange market and exchange rate dynamics.

The main results of the investigation into the pattern of exchange rate movements (chapter 3) can be summarized as follows:

- Exchange rates fluctuate most of the time around "underlying" short-term trends. This phenomenon is more pronounced on the basis of daily and 30-minutes data than on the basis of 1-minute data.
- Over a extended period of time (i. e., up to several years) these short-term trends (monotonic movements or runs on the basis of smoothed data) last longer in one direction than in the other.
- The accumulation of upward runs lasting longer than downward runs brings about a "bull market" in a stepwise process.
- In the same manner, the sequence of downward runs lasting longer than upward runs causes the exchange rate to depreciate during a "bearish" period.
- The difference in the slope of upward and downward runs contributes to the development of "bull markets" and "bear markets". Upward (downward) runs being steeper over an extended period of time than "counter-runs" runs cause short-term trends (runs on the basis of smoothed data) to become more persistent.
- Short lasting ups and downs of exchange rates occur more frequently than expected if the exchange rate followed a random walk, i.e., the observed short-term volatility is even higher than expected under the "random walk hypothesis((RWH). However, as the

exchange rate fluctuates around "underlying" trends most of the time, there occur less short runs and more persistent runs than under the RWH when the exchange rate series is smoothed by moving averages.

- The average slopes of exchange rate runs tend to be smaller than expected if the exchange rate followed a random walk. This tendency is particularly pronounced on the basis of intraday data.

These observations conflict with the basic assumptions of the "efficient market hypothesis". According to this concept any asset price reflects the fundamental equilibrium value of the respective asset (rational market participants permanently keep the price at this level). If new information arrives, actors will drive the price instantaneously to its new equilibrium. This (rational) behaviour assures that asset prices follow a random walk which in turn implies that one cannot systematically make trading profits from exploiting just the information contained in past prices ("weak market efficiency").

In order to investigate this issue, the profitability of technical trading systems in the dollar/euro market (1999/2006) and in the dollar/deutschmark market (1987/1999) is analyzed in chapter 4. The analysis covers 2265 models based on daily exchange rates and 2466 models based on 30-minutes exchange rates. All these models derive buy and sell signals exclusively from the information contained in past prices. The main results of the analysis of the profitability of technical currency trading are as follows:

- The 2265 technical models based on daily data would have produced an average gross rate of return of 4.2% per year when trading the dollar/euro rate between 1999 and 2006. The net rate is only slightly smaller (3.9% per year). Only 2.6% of all models would have made losses.
- The daily models would have been profitable on average in each of four sub-periods lasting 2 years between 1999 and 2006. The annual gross return would have been highest over the sub-period 1999/2000 (8.7%) and lowest over the sub-period 2005/2006 (0.6%).
- The in-sample-profitability of the 25 best performing models would have been three times higher than the average return of all 2265 models. Such an ex-post performance might attract potential (amateur) traders. However, the out-of-sample-performance of the 25 (ex post) best perfoming models is rather poor.
- The 2466 models trading the dollar/euro exchange rate at 30-minute intevals perfom worse than the daily models, they would have produced an annual gross rate of return of only 1.1% on average. Due to the high number of transactions the annual net rate of return would be strongly negative (-6.1%).
- The 25 (ex post) best 30-minutes models would have been profitable also out of sample. Over the entire out-of-sample period 2001/2006, those 25 models which performed best over the most recent sub-period would have produced ex-ante (i. e., over the subsequent period) a gross return of 8.2% per year and a net return 4.6% per year.

- The pattern of profitability is the same for all types of models and for all periods. The number of single losses exceeds the number of single profits, the average loss per day (per 30-minutes interval) during unprofitable positions is higher than the average profit per trading interval during profitable positions. Hence, the overall profitability is exclusively due to profitable positions lasting several times longer than unprofitable positions.
- This "universal" structure of the profitability of technical models is less pronounced when trading is done on the basis of 30-minutes data as compared to daily data. The difference is particularly pronounced with respect to the sole profit source of technical trading, i. e., the duration of profitable positions. When trading is based on daily data, profitable positions last roughly four times longer than unprofitable positions but only twice as long when 30-minutes data are used.
- The results for trading the dollar/deutschmark exchange rate between 1987 and 1998 are similar to those found for dollar/euro trading between 1999 and 2006.

One can conclude from these results that the profitability of technical currency trading in general, and of the best performing models in particular, is sufficiently high to have caused more and more market partcipants to use technical analysis as one basis of their trading decisions. The last chapter therefore explores the impact of aggregate trading signals on exchange rate movements. The main results can be summarized as follows:

- The aggregate transactions as well as open positions of technical models exert an excessive demand (supply) pressure on currency markets. When the models produce trading signals they are either buying or selling, when they maintain open positions almost all of them are on the same side of the market, either long or short.
- There prevails a strong simultaneous interaction between exchange rate movements and the transactions triggered off by technical models. When these models change their open positions at a certain speed then the exchange rate changes much stronger than on average in the direction congruent with the models' transaction.
- After a certain part of technical models has reversed open positions at a certain speed, the exchange rate continues to move in the same direction as implied by the models' transactions. A rising exchange rate, for example, causes increasingly more technical models to produce buy signals, which in turn strengthens and lengthens the appreciation trend.
- After 90% of the models have already changed their open positions from short to long (long to short) the exchange rate continues to rise (fall) over the subsequent days.
- The continuation of exchange rate trends after most technical models have opened positions congruent with the trend has to be attributed to the transactions of non-technical traders, perhaps amateurs. At the same time, these "latecoming bandwagonists" are probably the most important losers in currency trading.

1. Introduction: Scope and Structure of the Study

Over the first ten years of its existence, the euro has fluctuated widely vis-à-vis the other most important currencies. This is particularly true for the US dollar/euro exchange rate (figure 1). In early 1999 one euro was worth 1.17$, then the exchange rate fell until October 2000 to 0.83$, it started to rise again in February 2002 and reached 1.36$ by December 2004. After falling back to 1.17$ during 2005, the euro appreciated strongly up to 1.60$ in mid 2008. By the end of 2008, the euro exchange rate fell again to roughly 1.30$.

The exchange rate cycle between 1999 and 2005 developed in a sequence of upward and downward trends. For example, the euro depreciation between January 1999 and October 2000 was brought about in three downward trends, interrupted by only small counter-movements (figure 1). In a similar manner, the euro appreciation between February 2002 and December 2004 developed in a sequence of several trends each lasting some months (figure 1). Between October 2000 and January 2002 the exchange rate level was roughly the same. The two upward and the two downward trends, which occurred over this period, compensated each other. Also these movements were persistent as the four trends lasted for several months (figure 1).

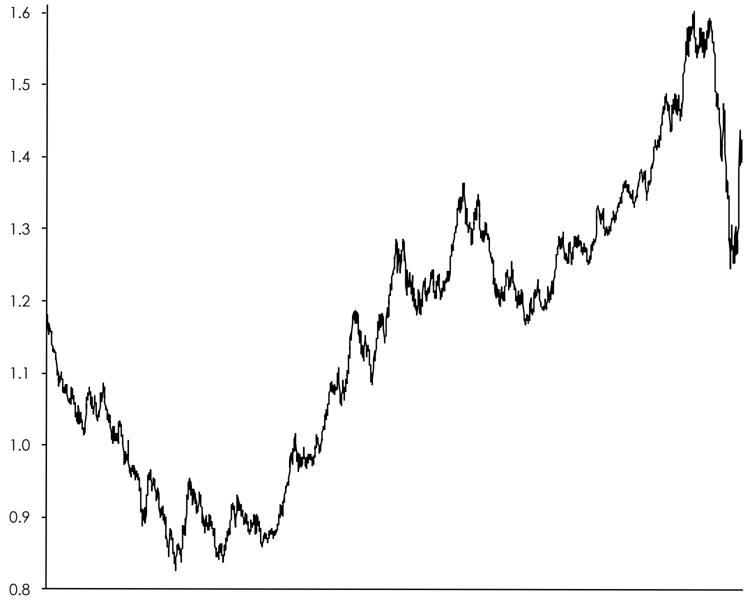
Around these medium-term trends the daily exchange rate fluctuates in a seemingly erratic manner. It is unclear, e. g., if an upward trend is brought about by upward movements being steeper or lasting longer than counter-movements (and vice versa in the case of medium-term downward trends).

The pattern of exchange rate dynamics as a sequence of trends, sometimes interrupted by non-directional movements ("whipsaws") seems to repeat itself across different time scales. Figure 2 displays exchange rate movements based on 5-minute data over six business days in June 2003 (this sample covers roughly the same amount of data points as the seven-year period displayed in figure 1). Inspection reveals that the exchange rate fluctuates also over the very short run in a sequence of trends, sometimes interrupted by "whipsaws" as during afternoon trading (GMT) on June, 6, and on June, 11.

The present study addresses three main questions:

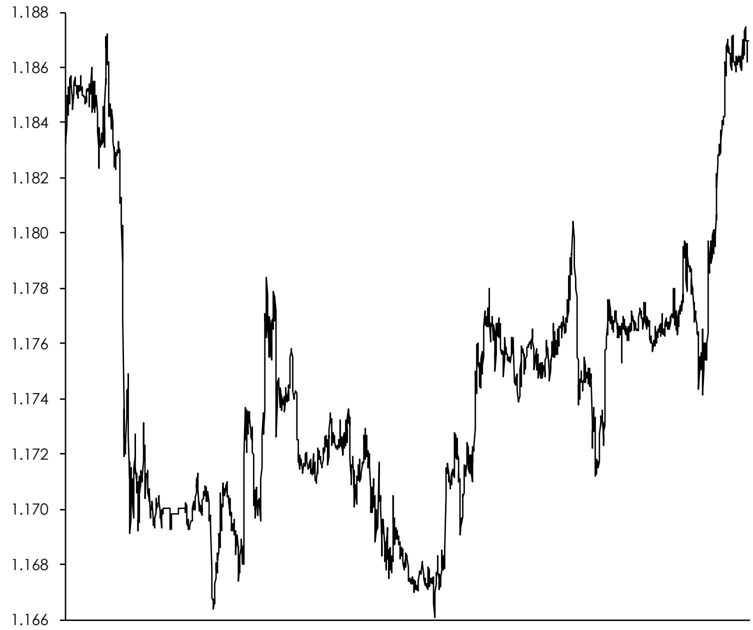
- Which types of trading behaviour cause the exchange rate to move in a sequence of short-term upward and downward trends most of the time?
- Why does this pattern of exchange rate dynamics repeat itself across different time scales?
- What causes short-term trends to last longer or be steeper in one direction rather than in the other for several years, resulting in a medium-term to long-term trend of euro depreciation (1999/2000) or euro appreciation (2002/2004 and 2005/mid 2008)?

Figure 1: The cycle of the dollar/euro exchange rate 1999 – 2008
Daily data



S: Olsen Ltd.

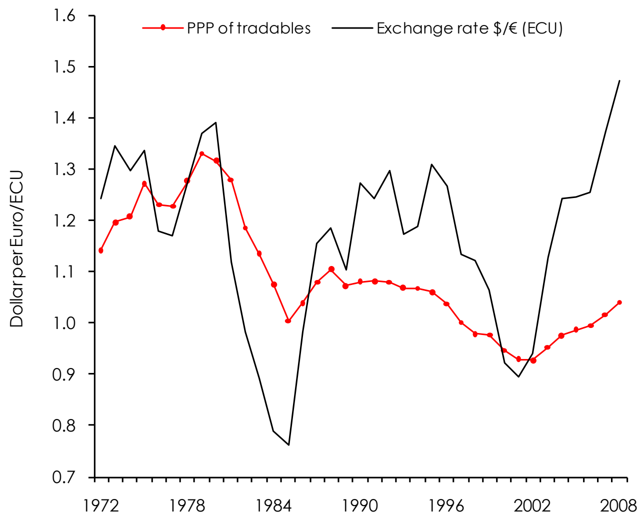
Figure 2: Movements of intraday dollar/euro exchange rates, June, 6-13, 2003
5-minutes data



S: Olsen Ltd.

Empirically founded answers to these questions could contribute to a better understanding of the wide and persistent fluctuations of the exchange rate from its fundamental goods market equilibrium, e. g., purchasing power parity (PPP). Figure 3 demonstrates the extent of the overshooting of the dollar/euro exchange rate using PPP of internationally traded goods and services (tradables) as the fundamental benchmark (see Schulmeister, 2005, for a discussion of PPP concepts).

Figure 3: Dollar/euro exchange rate and purchasing power parity



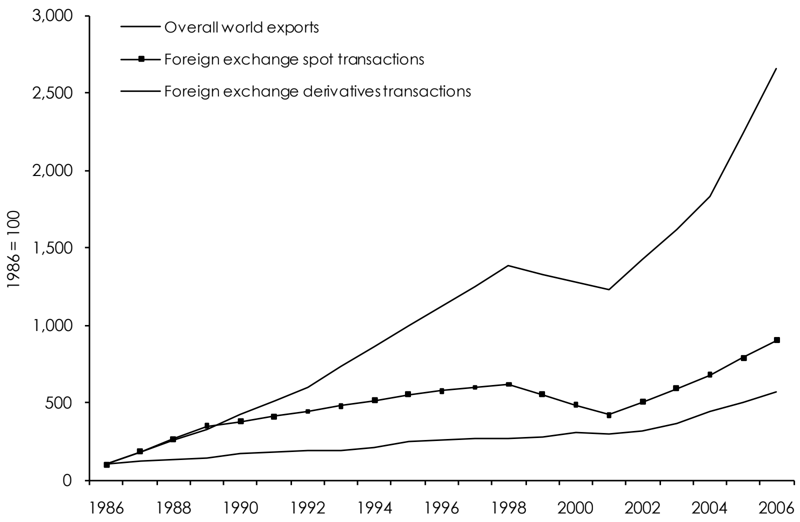
S: OECD, WIFO, Schulmeister (2005).

Mainstream theory cannot explain the overshooting of the exchange rate (in particular its extent). Therefore this phenomenon is mostly attributed to "shocks". However, such an interpretation conflicts with three other empirical regularities. First, the deviations of the exchange rate from its fundamental equilibrium are brought about in persistent trends, often lasting for several years (note that the famous Dornbusch model can only account for overshooting over the short run – *Dornbusch*, 1976). Second, also the reversion of the exchange rate towards PPP takes several years. Third, the reversion process does usually not lead to a convergence of the exchange rate towards PPP but rather to a "shooting through" of the PPP level followed by a new overshooting process in the opposite direction (figure 3 – for a discussion of the "PPP puzzle" see *Froot - Rogoff*, 1995; *Rogoff*, 1996; *Sarno - Taylor*, 2002; *Taylor - Taylor*, 2004).

The present study attempts to shed light on the PPP puzzle by investigating the interaction between trading behaviour and price dynamics in the foreign exchange market over the (very) short run as well as over the medium and long run. Hence, the study is based on daily data as well as on intraday data.

Due to this "microstructure approach" the study also addresses a second puzzle as regards currency markets, namely, the huge and growing discrepancy between trading activities in theses markets and transaction volume in the "underlying" goods markets, e. g., in international trade. Between 1986 and 2006 overall world trade (goods and services) expanded by a factor of roughly 5, spot transactions in the foreign exchange market rose by a factor of 9 and derivatives trading by a factor of almost 27 (figure 4).

Figure 4: World trade and foreign exchange transactions

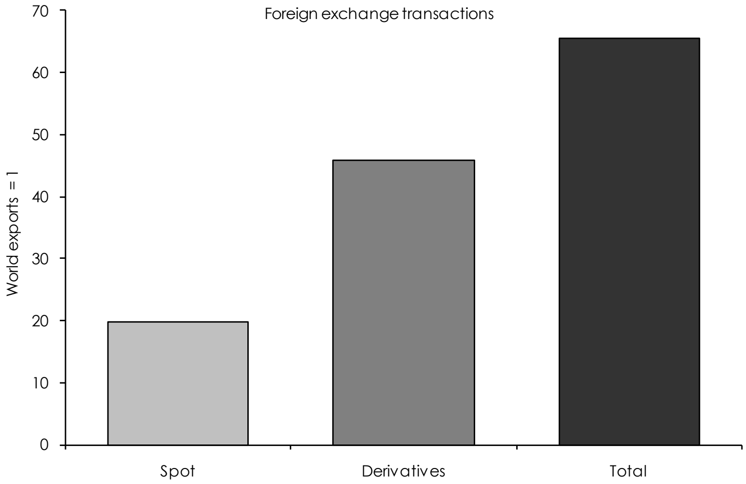


S: BIS, WFE, OECD, Oxford Economic Forecasting (OEF).

The level of overall foreign exchange trading was roughly 66 times higher than total world trade of goods and services. Due to the much higher expansion of transactions of currency derivatives, the volume of the latter is more than twice as large as the volume of spot transactions (figure 5).

The coincidence of the PPP puzzle and the "trading volume puzzle" represents an additional challenge for mainstream economics. This is so because high liquidity (e. g., trading volume) should facilitate the price discovery process and should therefore dampen deviations of the exchange rate from its fundamental equilibrium. In fact, however, exchange rate overshooting coincides with a tremendous rise in trading activity, in particular in currency derivatives.

Figure 5: Volume of overall trade and foreign exchange transactions in 2006



S: BIS, WFE, OECD, Oxford Economic Forecasting (OEF).

Since traditional equilibrium models cannot explain the exchange rate puzzles, the research project followed an inductive or exploratory approach. This approach included not only a careful data inspection but also investigations in the market place through visiting foreign exchange trading desks and interviewing professional traders. From this "field research" I derived a first hypothesis about exchange rate dynamics as the outcome of the interaction of different trading strategies. This "bull-bear-hypothesis" can be sketched as follows:

- Exchange rate runs are triggered by economic or political news if traders believe that the news will cause other traders to open a new position in the market.
- Once a run has gained momentum, technical trading systems open a position congruent with the direction of the ongoing price movement.
- Amateur speculators, who jump on the bandwagon later than professional traders, extend the exchange rate trend.
- The longer an upward (downward) trend lasts, the fewer buy (sell) orders are given by technical traders and by "latecoming bandwaggonists", so that, the trend looses momentum.
- In such a situation technical and non-technical "contrarians" jump in, hoping to profit from an imminent reversal of the trend.
- Contrarian trading together with cash-in-transactions bring any short-term exchange rate trend to an end, often initiating a new trend in the opposite direction.
- Technical currency trading (trend-following as well as contrarian) is practiced at different time scales, the data used range from tick and minute data up to daily data. This practice contributes to the self-similarity of exchange rate dynamics across time scales.

- Exchange rate trends in one direction last longer than counter-movements for several years because there prevails an expectational bias in favour or against a currency ("bullishness" or "bearishness"). If a current run is in line with the bias, traders put more money into an open position and/or hold such a position longer than in the case of a trend against the bias.

The research project focuses on those components of this hypothesis which concern the interaction between exchange rate dynamics and technical trading systems. The main reason for that lies in the importance of technical trading in currency markets as survey studies reveal.[1]) First, roughly 90% of market participants base their trading at least in part on technical analysis. Second, between 30% and 40% of professionals use technical analysis as their most important trading technique. Third, the importance of technical analysis has increased more strongly over the 1990s than other trading practices like the orientation on fundamentals or on customer orders.

The purpose of the study is threefold. First, the study investigates the pattern of exchange rate dynamics in an exploratory (inductive) manner. It measures the path of exchange rate movements and elaborates those elements of non-randomness in exchange rate dynamics which account for the accumulation of (very) short-term runs to medium-term and long-term trends. Second, the study documents the performance of a wide range of technical trading rules and examines the components of their profitability. Third, the study explores the relationship between the use of technical trading systems in the foreign exchange market and exchange rate dynamics. More specifically, the objectives of the study are as follows:

- Summarize the key assumptions underlying the mainstream theory of asset price dynamics ("fundamentalist hypothesis") and compare them to the inductively derived assumptions of the "bull-bear-hypothesis" (section 2).
- Investigate the pattern of exchange rate movements based on different data frequencies, e. g., daily, 30-minutes and 1-minute data (section 3). In particular, elaborate how long-term appreciations (depreciations) of the euro exchange rate are brought about. Are these trends (mainly) due to upward (downward) movements lasting longer than counter-movements, or are they (mainly) caused by upward (downward) movements being steeper than counter-movements? How are monotonic exchange rate movements distributed by their duration?
- Analyze the ex-post-profitability (in sample) as well as the ex-ante-profitability (out of sample) of a great number of popular technical trading systems, e. g., roughly 2.500 moving average models, momentum models and relative strength models (section 4). Special attention shall be given to the components of the profitability of technical currency trading and how they are related to the pattern of exchange rate movements.

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[1]) For survey studies see Group of Thirty, 1985; Taylor-Allen, 1992; Menkhoff, 1997 and 1998; Lui-Mole, 1998; Cheung-Chinn-Marsh, 2004; Cheung-Wong, 2000; Cheung-Chinn, 2001; Oberlechner, 2001; Gehrig-Menkhoff; 2004, 2005A and 2005B.

In addition, the following questions shall be addressed: If a technical trader selects from many different models those performing best over a certain "test period" in the past, and if he then follows these models over the subsequent period, would he make "abnormal" profits? Or would this optimization strategy produce losses due to "model mining"?

- Provide an analysis of the impact of technical trading systems on exchange rate dynamics (section 5). This concerns in particular the following questions. How are the trading signals produced by different models distributed (clustered) over time? How many technical models hold the same - long or short - position at any point in time? How do aggregate transactions and/or open positions of technical models and their change over time relate to subsequent exchange rate movements?

The study focuses on the most important euro exchange rate, i. e., vis-à-vis the US dollar. For a comparison between the euro-era and the pre-euro-era the study investigates the above sketched relationships also for the period 1987/1999 (in this case, only the single most active currency market is considered, i.e., the dollar/ deutschmark market).

2. The "fundamentalist hypothesis" and the "bull-bear-hypothesis" of asset price dynamics

According to mainstream economic theory, asset prices are determined by the respective equilibrium conditions, i. e., by the so-called market fundamentals. In the case of exchange rates, two conditions represent the basic fundamentals, interest parity as the money market equilibrium and purchasing power parity as the goods market equilibrium. Assuming rational expectations and instantaneous price adjustment, interest parity should always hold true (deviations from the monetary equilibrium could only be due to risk premia under imperfect foresight). Purchasing power parity, however, is assumed to only hold over the medium and long run. Over the short run, the exchange rate will deviate from PPP due to sticky price adjustment in the goods markets (*Dornbusch*, 1976; for surveys of exchange rate models see *Rogoff*, 1996; *Sarno-Taylor*, 2002; *Taylor-Taylor*, 2004).

Traditional models of exchange rate determination represent just special cases of the equilibrium theory of asset price determination in general. The basic proposition of this concept is as follows. Asset prices are determined by market fundamentals so that destabilizing speculation will influence prices at best over the very short run (if at all). In this chapter, I shall at first summarize the main assumptions of this theoretically (deductively) derived concept of asset price formation which I term "fundamentalist hypothesis". I will then discuss the key elements of the alternative "bull-bear-hypothesis" which is rather empirically oriented. [2])

The main assumptions and propositions underlying the "fundamentalist hypothesis" can be summarized as follows (see also figure 6 and table 1):

[2]) The first part of this chapter draws on chapter 2 in Schulmeister, 2009A.

- The theoretical benchmark model of the "fundamentalist hypothesis" is an ideal, frictionless market where all participants are equipped with perfect knowledge and where no transaction costs exist. In this "world 0" there is no need for trading and, hence, for liquidity because prices would instantaneously jump to their new equilibrium in reaction to new information.
- The model underlying the "fundamentalist hypothesis" relaxes the assumptions of perfect knowledge and of no transaction costs. Also in this "world" actors are fully rational and use the same information set and the same "true" model, but do not know the expectations of other actors. Hence, in "world I" prices cannot reach a new equilibrium instantaneously but only through a gradual price discovery process (*Habermeier – Kirilenko,* 2003).
- The high transaction volumes in modern financial markets stem mainly from the activities of market makers. The latter provide just the liquidity necessary for facilitating and smoothing the movements of asset prices towards their fundamental equilibria.
- Speculation is an indispensable component of both, the price discovery process as well as the distribution of risks. As part of the former, speculation is essentially stabilizing, i.e., it moves asset prices smoothly and quickly to their equilibria (*Friedman*, 1953).
- An endogenous overshooting caused by excessive speculation does not exist. Any deviation of asset prices from their fundamental equilibrium is due to exogenous shocks and, hence, is only a temporary phenomenon.
- The emergence of news and shocks follows a random walk and so do asset prices. Therefore, speculation techniques based on past prices cannot be systematically profitable (otherwise a market cannot even be considered "weakly efficient" – *Fama*, 1970).

The "bull-bear-hypothesis" perceives trading behaviour and price dynamics in asset markets as follows ("World II"):

- Imperfect knowledge is a general condition of social interaction and, hence, is characteristic also for the market place. As a consequence, actors use different models and process different information sets when forming expectations and making decisions.[3])
- As human beings, actors' expectations and transactions are governed not only by rational calculations, but also by emotional und social factors (the latter two factors are particularly important in financial markets since these markets are often characterized by "manic" or "depressive" phases as the asset prices themselves).

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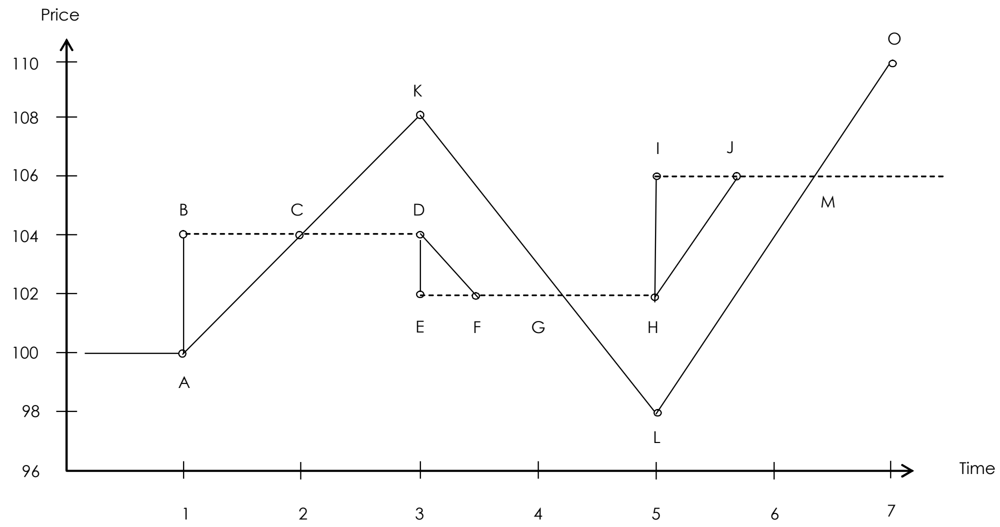
[3]) In a recent, pathbreaking book, *Frydman - Goldberg* (2007) demonstrate that recognizing the importance of imperfect knowledge is key to understanding outcomes in financial markets and that the difficulties encountered by neoclassical theory and behavioral finance models to explain financial market behaviour stem from their disregard of this insight.

- Not only are expectations heterogeneous but they are often formed only qualitatively, i. e., as regards the direction of a price movement. In financial markets, e. g., traders react to news by just forming qualitative expectations about the direction of the imminent price move (not only due to time pressure but also because one cannot know the expectations of other traders).
- Upward (downward) price movements – usually triggered by news - are lengthened by "cascades" of buy (sell) signals stemming from trend-following technical trading systems since "technical analysis" is the most widely used technique in short-term trading in financial markets.
- The "trending" behaviour of short-term asset price movements (based on daily or intraday data) is fostered by the dominance of either a "bullish" or a "bearish" bias in expectations. News which are in line with the prevailing "market mood" gets higher recognition and reaction than news which contradict the "market mood".
- In addition, traders put more money into an open position and hold it longer if the current run is in line with the "bullish" or "bearish" sentiment than in the case of a run against the "market mood".
- In the aggregate, this behaviour of market participants cause price runs in line with the "market mood" to last longer than counter-movements. In such a way short-term runs accumulate to long-term trends, i. e., "bull markets" and "bear markets". The sequence of these trends then constitutes the pattern in long-term asset price dynamics: Prices develop in irregular cycles around the fundamental equilibrium without any tendency to converge towards this level.
- Long-term price trends do not represent "bubbles", i. e., non-fundamental equilibrium paths, since market participants know in advance that any "bull market" and "bear market" will end, and that there occur also significant counter-movements during long-term trends.

In order to clarify the theoretical differences between the "fundamentalist hypothesis" and the "bull-bear-hypothesis", it is useful to distinguish between three (theoretical) paths of asset prices, depending on the assumptions made about market conditions. "World 0" represents the case of an ideal, frictionless market where all participants are equipped with perfect knowledge and where no transaction costs exist (as usually assumed in theoretical models of asset pricing under rational expectations). In this world, prices would instantaneously jump to their new equilibrium in reaction to new information (*Habermeier – Kirilenko*, 2003). In "world I" all actors are also fully rational, but do not know the expectations of other participants. For that reason and also because transactions are costly, prices cannot jump instantaneously to the new equilibrium due to fundamental news but follow a gradual price discovery process towards the equilibrium. In "world II" there operate also "bounded-rational" or even irrational traders who drive the price beyond its fundamental equilibrium.

Figure 6: Three stylized paths of asset prices



A simple chart stylizes the three paths of asset prices over the short run (figure 6):

- In "world 0" new information at the point in time = 1 causes the asset price to jump instantaneously from the old equilibrium at P = 100 (at point A) to the new equilibrium at P = 104 (B). The price stays there until news in t = 3 cause the price to jump to P = 102 (E). Finally in t = 5 new information once again causes an instantaneous price adjustment to P = 106 (I).
- In "world I" prices adjust only gradually, i.e., it takes a series of transactions to move the price from P = 100 to P = 104, i.e., from A to C. However, since there are only rational traders in this world, the price movement will stop at the new fundamental equilibrium level and stay there until t = 3 (then the price starts to move from D to F, and later from H to J).
- In "world II" there exist traders who form their price expectations according to the most recent movements, i.e., when prices move persistently up (down) they expect the respective run or short-term trend to continue. Hence, they buy (sell) when prices are rising (falling), which in turn strengthens the trend.

As a consequence of this "trending", rational investors (in the sense of profit-seeking) will try to systematically exploit this non-randomness in price dynamics. The conditions of "world II" will therefore almost inevitably emanate from those of "world I": If prices move smoothly from one fundamental equilibrium to the next, and if this price discovery process takes some time, then profit-seeking actors will develop trend-following trading strategies. The use of these strategies will in turn increase the momentum of price movements which will then hardly stop exactly at the new fundamental equilibrium (for models dealing with the interaction of heterogeneous actors see *DeLong et al.*, 1990A and 1990B; *Frankel – Froot*, 1990; *De Grauwe – Grimaldi*, 2006; *Hommes*, 2006; *Frydman – Goldberg*, 2007).

Over more than 100 years people have developed and used a great variety of "technical" trading systems. All models of "technical analysis" have in common that they attempt to exploit price trends and by doing so they reinforce the pattern of asset price dynamics as a sequence of upward and downward trends (for a comprehensive treatment of technical analysis see *Kaufman*, 1987; the interaction between technical trading and price dynamics is explored in *Schulmeister*, 2006, 2009B).

Table 1: Features of three hypothetical "worlds" of financial markets

	World 0	**World I**	**World II**
General characteristic	Perfect knowledge and foresight. Rational expectations. No transaction costs (frictionless markets).	As in world 0 with two exceptions: – Transaction costs matter – Expectations of other actors due to news have to be discovered in a gradual adjustment process.	Imperfect knowledge as general condition of social interaction: Actors process different information sets using different models. Actors are human beings: Expectations and transactions are governed by rational, emotional und social factors.
Expectations	Homogeneous.	In general homogeneous, but heterogeneous during the price discovery/adjustment process.	Heterogeneous.
Expectations formation	Quantitative.	Quantitative.	Often only directional (qualitative).
Price adjustment to news	Instantaneous jumps to the new fundamental equilibrium.	Gradual price movement towards the new fundamental equilibrium.	Price movement overshoots the ("region" of) the new fundamental equilibrium. Short-term trending of asset prices accumulates to medium-term trends due to optimistic or pessimistic biases in expectations ("bullishness/bearishness").
Transaction volume	Low (counterpart of the "underlying" transaction in goods markets).	"Basic" liquidity necessary for the price discovery process => Trading volume higher than the "underlying" goods markets transactions, moving in tandem with the latter over time.	"Excessive" trading causes transaction volumes to grow significantly faster than the "underlying" transactions in goods markets.
Trading is based on	Fundamentals.	Fundamentals.	Fundamentals, technical models as well as on psychological factors on the individual level (e.g. emotions) as well as on the social level (e.g. market moods, herding).

In our stylized example those transactions (in "world II") which cause the price to overshoot (driving it from C to K, from G to L and from M to O) have to be considered "excessive" (as in "world I" price movements are triggered by news also in "world II"). These overshooting price changes amount to 12 between t = 1 and t = 7. The overall price changes over this period amount to 30 (8 + 10 + 12), whereas only cumulative price changes of 10 (4 + 2 + 4) would be fundamentally justified.

This stylized example shows that once prices start to overshoot, their overall price path becomes much longer and the related transaction volumes get much bigger than under purely rational expectations (as in "world I"). At the same time the trending of asset prices provides opportunities for technical (i. e., non-fundamental) speculation, and the use of these speculation systems in turn strengthens asset price trends.

Table 1 summarizes the main features of the three different "worlds" of financial markets ("world 0" is also covered since it serves as benchmark model in asset pricing theory – even though the assumptions made for this "world" are extremely unrealistic). Based on the "stylistic" differentiation between "world I" and "world II" one could derive some support for the "bull-bear-hypothesis" from the following empirical observations (and vice versa for the "fundamentalist hypothesis" if these observations cannot be made):

- First, the discrepancy between the level and growth of transaction in (financial) asset markets (including derivatives) and in the underlying (physical) spot markets is extremely high (i. e., hedging is of little importance, most transactions occur between speculators with different expectations).
- Second, asset prices overshoot their fundamental equilibrium values most of the time. The respective long-term over-appreciations (over-depreciations) are primarily brought about by monotonic upward (downward) movements (i. e., price runs) lasting longer than counter-movements, and less by upward (downward) runs being steeper than counter-movements (the latter case would point at quick reactions of "fundamentalists" to news, the former case would reflect the persistence of price movements).
- Third, technical trading systems are widely used in financial markets and produce "abnormally" high profits over extended periods of time (i. e., several years).
- Fourth, the use of technical trading systems feeds back upon asset price trends, e. g., the aggregate trading signals of a great variety of technical models strengthen and lengthen price trends.

The present study evaluates the empirical relevance of the "bull-bear-hypothesis" in comparison to the "fundamentalist hypothesis" with respect to the pattern of price dynamics and the role of technical trading systems in the dollar/euro market and in the dollar/DM market. Observations concerning the size of financial transactions relative to transactions in the underlying goods markets are documented and evaluated in *Schulmeister – Schratzenstaller – Picek*, 2008, and in *Schulmeister*, 2009A.

3. Pattern of exchange rate fluctuations

This chapter explores the specific shape of exchange rate movements. In particular, I shall investigate how short-term runs bring about long-term overshooting. Hence, this chapter addresses the relationship between the following two phenomena:

- Exchange rates, but also stock prices and commodity prices, move in a sequence of upward trends ("bull markets") and downward trends ("bear markets") which last for several years. As a consequence, exchange rates - and asset prices in general - do not converge towards their fundamental equilibrium but overshoot it most of the time.
- Trading volume in financial markets has expanded enormously, at present it is almost 100 times higher than nominal GDP of industrial countries. The main driver of this expansion is the increase in the speed of trading: The time horizon of most transactions is shorter than a few hours.

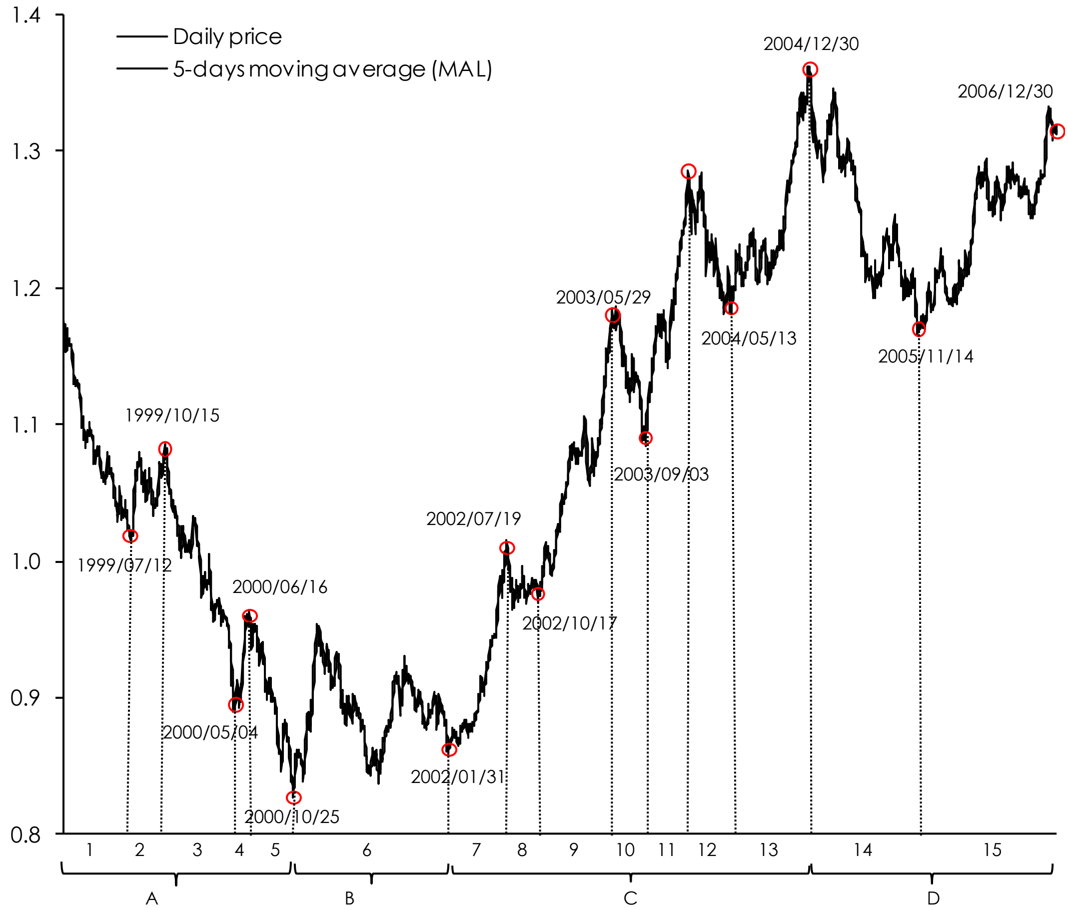
The coincidence of both developments constitutes a puzzle. How can very short-term transactions generate asset price movements which accumulate to long-term "bull markets" and "bear markets"? To put it differently: Which properties of asset price dynamics cause asset prices to move in long-term irregular cycles, i. e., in a sequence of upward and downward trends?

In this chapter I shall try to find some answers to these questions by exploring the movements of the dollar/euro exchange rate across different time scales, e. g., based on data at 1 day, 30-minutes as well as on 1-minute intervals. As alternative to the standard assumptions of the efficient market hypothesis, I sketch the following hypothetical picture of exchange rate dynamics. This picture fits into the more general picture of the "bull-bear-hypothesis":

- Over the short run, asset prices fluctuate almost always around "underlying" trends (sideways movements occur comparatively seldom). If one smoothes the respective price series with simple moving averages, one can easily identify the "underlying" trends.
- The phenomenon of "trending" repeats itself across different time scales. E. g., there occur trends based on 1-minute-data as well as trends based on daily data. However, the volatility of fluctuations around the trend is higher the higher is the data frequency.
- Long-term upward or downward trends ("bulls and bears") are the result of the accumulation of price runs based on daily data which last for several years longer in one direction than the counter-movements.

In order to examine the empirical relevance of this hypothesis, I shall at first look at the "Gestalt" of exchange rate movements taking the dollar/euro rate as example. Then I present some general relations between short-term monotonic price movements ("runs") and long-term price trends. The chapter concludes with a quantification of these relationships based on the development of the dollar/euro exchange rate between 1999 and 2006 and of the dollar/deutschmark rate between 1987 and 1998.

Figure 7: Subperiods in the development of the US dollar/euro exchange rate 1999-2006

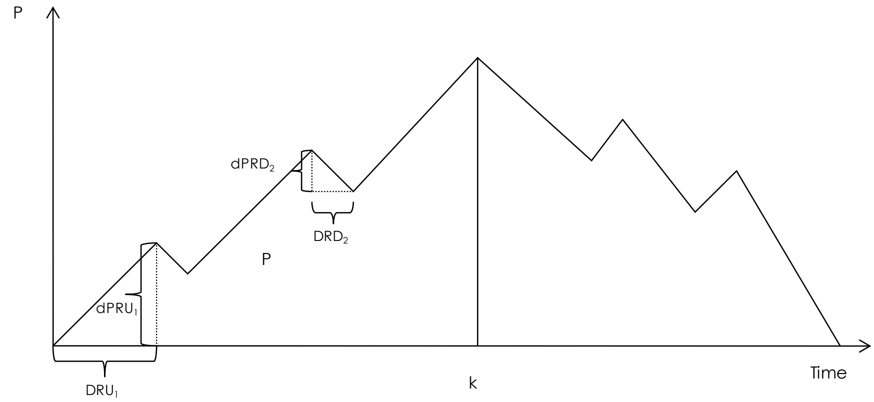


The (irregular) cycle of the dollar/euro exchange rate between 1999 and 2005 was shaped by two pronounced long-term trends, a downward trend lasting from January 1999 to October 2000, and an upward trend lasting from January 2002 to December 2004 (marked by A and C in figure 7).

Both long-term trends were realised in a sequence of shorter (medium-term) trends. For example, the euro depreciation over period A was brought about in three downward trends which were interrupted by only small counter-movements (figure 7). In a similar manner the euro appreciation during period C was realised in a sequence of several trends, each lasting some months. Only between October 2000 and January 2002 did the trending behaviour of the dollar/euro exchange rate not result in a long-term appreciation or depreciation (the two upward and downward trends - each lasting several months - roughly "compensated" each other).

In order to analyze the interaction between short-term runs and long-term trends across different time scales (data frequencies), the study divides the overall sample period into 4 long-term sub-periods and 15 medium-term sub-periods (figure 7 and table 2).

Figure 8: Stylized relationship between runs and trends of asset prices



The basic relationsships between monotonic price movements (runs) upward (RU) and downward (RD), their slopes upward and downward (SRU, SRD) and their duration in time units (DRU, DRD) are as follows.

Slope of upward run$_i$ and of downward run $_i$:

$SRU_i = dPRU_i/DRU_i$

$SRD_j = dPRD_j/DRD_j$

where $dPRU_i$ and $dPRD_j$ indicate the absolute price change realized during upward run *i* and downward run j, respectively.

The overall price rise (fall) realized during a medium-term or long-term upard (downward) trend as between 0 and k in figure 7 is the sum over all single price changes realized during all upard (downward) runs which can be conceived as the product of duration and slope:

$P_k - P_0 = \Sigma\, dPRU_i - \Sigma\, dPRD_j = \Sigma\, DRU_i * SRU_i - \Sigma\, DRD_j * SRD_j$

The average duration of upward and downward runs between 0 and k ($ADRU_{0,k}$ $ADRD_{0,k}$) is

$ADRU_{0,k} = (\Sigma\, DRU_i)/NRU_{0,k}$

$ADRD_{0,k} = (\Sigma\, DRD_j)/NRD_{0,k}$

where NRU indicate the number of runs between 0 and k.

The average slope of upward and downward runs between 0 and k ($ASRU_{0,k}$ $ASRD_{0,k}$) is:

$ASRU_{0,k} = (\Sigma\, dPRU_i)/(\Sigma\, DRU_i)$

$ASRD_{0,k} = (\Sigma\, dPRD_j)/(\Sigma\, DRD_j)$

Based on these relations the overall price rise (fall) realized during a medium-term or long-term upard (downward) trend between 0 and k can be represented as result of six components, the number of upward and downward runs, the average duration of upward and downward runs and the average slope of upward and downward runs:

$P_k - P_0 = NRU_{0,k} * ADRU_{0,k} * ASRU_{0,k} - NRD_{0,k} * ADRD_{0,k} * ASRD_{0,k}$

These relations shall now be quantified for the dollar /euro exchange rate, based on daily data, on 30-minutes data and on 1-minute data.

3.1 Exchange rate dynamics based on daily data

At first, I measure the path of the daily $/€ exchange rate movements as depicted in figure 7. The results are shown in table 2.

In period A the euro depreciated in 471 (trading) days by 34.4 (dollar) cents. This translates into a depreciation "speed" of 0.07 cents per day (column 4 in table 2). As there were many ups and downs, the path of the cumulated movements was several times longer than the change in level, namely, 226.0 cents (column 3) or 0.48 cents per day (column 6).

The ratio of column 2 and column 3 measures the degree of monotonicity (column 6). There are two extreme values. A value of one (in absolute terms) would indicate a pure monotonic path like a (deterministic) bubble. A value of zero would indicate "whipsaws", i.e., price oscillations around a constant level. Hence, this ratio indicates the importance of counter-movements during a price trend.

During the euro "bear market" (period A) daily exchange rate movements were slightly "more monotonic" than during the "bull market" in period C (the respective values of column 6 are -0.15 and 0.12, respectively). At the same time, the average change in price per day was the same in both periods (0.07 cents). This implies that the average slope of exchange rate runs was smaller in absolute terms during period A as compared to period C (figure 3 shows that this was true for upward runs as well as for downward runs).

The relations between duration, (average) change in price and length of price path differ significantly across the 15 sub-periods. However, exchange rate movements tend to be steeper and "more monotonic" during comparatively shorter periods (as sub-period 4 or subperiod 11 – table 2).

If one carries out the same measurement exercise based on daily exchange rates smoothed by a 5-days moving average, then the length of the actual price path shrinks in all sub-periods to less than half of the original price path. This holds true for the four main sub-periods A to D as well as for the 15 shorter sub-periods. There are two reasons for that result. First, most fluctuations of the daily dollar/euro exchange rate are small in size and last only one day. Second, and more important, the exchange rate fluctuates most of the time around an "underlying" trend as is shown in figure 7.

As next step, I explore how the accumulation of monotonic movements (runs) of the daily dollar/euro rate brings about exchange rate trends lasting several years (as during period A and C). Table 3 shows that the euro depreciation during the "bear market" in period A was primarily due to downward runs lasting longer by one third than upward runs (2.38 days versus 1.79 days). The average slope of upward and downward runs was approximately the same (0.47 and -0.48, respectively). During the "bull market" in period C, upward runs lasted 1.95 days on average, roughly by 20% longer than downward runs (1.66 days). However, during this period also differences in the slope between upward and downward runs did contribute to the overall appreciation as upward runs were by roughly 10% steeper than downward runs (0.56 and -0.51, respectively – table 3).

Table 2: Pattern of exchange rate movements: Daily dollar/euro rates 1999- 2006

	Period	Duration	Change in price	Length of actual price path	Change in price per day (slope)	Length of actual price path per day	Change in price per length of actual path
		Days	Cents	Cents 1)	Cents	Cents	
		(1)	(2)	(3)	(4)	(5)	(6)
Based on original data							
1999/01/01 - 1999/07/12	1	135	-15.5	57.4	-0.11	0.425	-0.27
1999/07/12 - 1999/10/15	2	68	6.9	33.1	0.10	0.486	0.21
1999/10/15 - 2000/05/04	3	143	-19.3	70.7	-0.13	0.494	-0.27
2000/05/04 - 2000/06/16	4	30	6.7	18.5	0.22	0.617	0.36
2000/06/16 - 2000/10/25	5	91	-13.4	45.0	-0.15	0.494	-0.30
2000/10/25 - 2002/01/31	6	324	2.8	156.4	0.01	0.483	0.02
2002/01/31 - 2002/07/19	7	120	15.4	46.7	0.13	0.390	0.33
2002/07/19 - 2002/10/17	8	63	-3.8	32.7	-0.06	0.519	-0.12
2002/10/17 - 2003/05/29	9	156	21.7	72.0	0.14	0.461	0.30
2003/05/29 - 2003/09/03	10	68	-9.2	39.1	-0.14	0.575	-0.24
2003/09/03 - 2004/01/09	11	90	19.5	52.2	0.22	0.580	0.37
2004/01/09 - 2004/05/13	12	88	-9.8	70.3	-0.11	0.798	-0.14
2004/05/13 - 2004/12/30	13	164	17.5	88.9	0.11	0.542	0.20
2004/12/30 - 2005/11/14	14	224	-18.7	123.0	-0.08	0.549	-0.15
2005/11/14 - 2006/12/30	15	293	15.0	132.7	0.05	0.453	0.11
1999/01/01 - 2000/10/25	A	471	-34.4	226.0	-0.07	0.480	-0.15
2000/10/25 - 2002/01/31	B	324	2.8	156.4	0.01	0.483	0.02
2002/01/31 - 2004/12/30	C	755	50.1	405.3	0.07	0.537	0.12
2004/12/30 - 2006/12/30	D	518	-3.4	256.0	-0.01	0.494	-0.01
1999/01/01 - 2006/12/30	T	2079	15.0	1045.4	0.01	0.505	0.01
Based on 5-days moving averages							
1999/01/01 - 1999/07/12	1	131	-15.2	25.9	-0.12	0.198	-0.59
1999/07/12 - 1999/10/15	2	64	5.4	16.9	0.08	0.264	0.32
1999/10/15 - 2000/05/04	3	139	-17.5	33.0	-0.13	0.238	-0.53
2000/05/04 - 2000/06/16	4	26	5.6	7.9	0.22	0.306	0.71
2000/06/16 - 2000/10/25	5	87	-11.0	21.9	-0.13	0.252	-0.50
2000/10/25 - 2002/01/31	6	318	2.2	60.5	0.01	0.190	0.04
2002/01/31 - 2002/07/19	7	114	13.5	17.2	0.12	0.151	0.78
2002/07/19 - 2002/10/17	8	55	-0.7	5.4	-0.01	0.099	-0.12
2002/10/17 - 2003/05/29	9	148	19.5	31.5	0.13	0.213	0.62
2003/05/29 - 2003/09/03	10	58	-8.4	11.1	-0.14	0.192	-0.75
2003/09/03 - 2004/01/09	11	80	14.4	18.2	0.18	0.228	0.79
2004/01/09 - 2004/05/13	12	76	-6.6	12.0	-0.09	0.158	-0.55
2004/05/13 - 2004/12/30	13	152	13.8	24.4	0.09	0.161	0.56
2004/12/30 - 2005/11/14	14	210	-12.5	30.1	-0.06	0.144	-0.41
2005/11/14 - 2006/12/30	15	279	14.2	32.3	0.05	0.116	0.44
1999/01/01 - 2000/10/25	A	467	-33.5	110.0	-0.07	0.236	-0.30
2000/10/25 - 2002/01/31	B	320	2.1	70.2	0.01	0.219	0.03
2002/01/31 - 2004/12/30	C	751	49.3	183.0	0.07	0.244	0.27
2004/12/30 - 2006/12/30	D	514	-1.6	114.8	0.00	0.223	-0.01
1999/01/01 - 2006/12/30	T	2067	14.3	482.9	0.01	0.234	0.03

1) Cumulative absolute value of the daily changes in exchange rate levels.

Table 3: Exchange rate runs: Daily dollar/euro rate 1999 - 2006

	Period	Upward runs			Downward runs			Ratio between upward and	
		Number	Average Duration Days	Average slope 1)	Number	Average Duration Days	Average slope 1)	Duration	Slope 2)
				Based on original data					
1999/01/01 - 1999/07/12	1	32	1.63	0.402	32	2.59	- 0.439	0.63	0.92
1999/07/12 - 1999/10/15	2	17	2.06	0.570	16	2.06	- 0.397	1.00	1.44
1999/10/15 - 2000/05/04	3	35	1.57	0.467	36	2.44	- 0.511	0.64	0.91
2000/05/04 - 2000/06/16	4	8	2.38	0.664	8	1.38	- 0.536	1.73	1.24
2000/06/16 - 2000/10/25	5	20	1.95	0.405	21	2.48	- 0.561	0.79	0.72
2000/10/25 - 2002/01/31	6	79	1.97	0.510	79	2.13	- 0.457	0.93	1.12
2002/01/31 - 2002/07/19	7	35	1.91	0.463	34	1.56	- 0.296	1.23	1.56
2002/07/19 - 2002/10/17	8	20	1.55	0.466	21	1.52	- 0.570	1.02	0.82
2002/10/17 - 2003/05/29	9	38	2.37	0.520	37	1.78	- 0.381	1.33	1.37
2003/05/29 - 2003/09/03	10	20	1.45	0.515	21	1.86	- 0.619	0.78	0.83
2003/09/03 - 2004/01/09	11	24	2.42	0.617	23	1.39	- 0.511	1.74	1.21
2004/01/09 - 2004/05/13	12	23	1.78	0.737	24	1.96	- 0.852	0.91	0.86
2004/05/13 - 2004/12/30	13	50	1.80	0.591	49	1.51	- 0.483	1.19	1.22
2004/12/30 - 2005/11/14	14	57	1.74	0.527	58	2.16	- 0.567	0.81	0.93
2005/11/14 - 2006/12/30	15	81	1.85	0.492	81	1.77	- 0.412	1.05	1.20
1999/01/01 - 2000/10/25	A	113	1.79	0.474	113	2.38	- 0.484	0.75	0.98
2000/10/25 - 2002/01/31	B	79	1.97	0.510	79	2.13	- 0.457	0.93	1.12
2002/01/31 - 2004/12/30	C	210	1.95	0.557	209	1.66	- 0.513	1.18	1.08
2004/12/30 - 2006/12/30	D	139	1.80	0.505	139	1.93	- 0.484	0.93	1.04
1999/01/01 - 2006/12/30	T	541	1.88	0.520	540	1.95	- 0.490	0.97	1.06
				Based on 5-days moving averages					
1999/01/01 - 1999/07/12	1	14	2.64	0.145	15	6.27	- 0.219	0.42	0.66
1999/07/12 - 1999/10/15	2	7	5.57	0.286	6	4.17	- 0.230	1.34	1.25
1999/10/15 - 2000/05/04	3	13	3.15	0.189	14	6.93	- 0.261	0.46	0.73
2000/05/04 - 2000/06/16	4	3	6.00	0.377	2	4.00	- 0.146	1.50	2.57
2000/06/16 - 2000/10/25	5	6	3.67	0.250	7	9.29	- 0.253	0.39	0.99
2000/10/25 - 2002/01/31	6	20	6.95	0.226	20	8.95	- 0.163	0.78	1.38
2002/01/31 - 2002/07/19	7	11	8.09	0.172	10	2.50	- 0.075	3.24	2.28
2002/07/19 - 2002/10/17	8	5	5.40	0.088	6	4.67	- 0.109	1.16	0.81
2002/10/17 - 2003/05/29	9	8	14.38	0.222	7	4.71	- 0.182	3.05	1.22
2003/05/29 - 2003/09/03	10	4	3.25	0.106	4	11.25	- 0.217	0.29	0.49
2003/09/03 - 2004/01/09	11	7	9.29	0.251	6	2.50	- 0.128	3.71	1.96
2004/01/09 - 2004/05/13	12	5	5.60	0.096	6	8.00	- 0.193	0.70	0.50
2004/05/13 - 2004/12/30	13	7	16.14	0.169	6	6.50	- 0.136	2.48	1.24
2004/12/30 - 2005/11/14	14	9	8.44	0.116	10	13.40	- 0.159	0.63	0.73
2005/11/14 - 2006/12/30	15	18	9.83	0.131	18	5.67	- 0.089	1.74	1.48
1999/01/01 - 2000/10/25	A	44	3.80	0.229	45	6.64	- 0.240	0.57	0.95
2000/10/25 - 2002/01/31	B	37	3.97	0.246	36	4.75	- 0.199	0.84	1.24
2002/01/31 - 2004/12/30	C	70	6.77	0.245	68	4.06	- 0.242	1.67	1.01
2004/12/30 - 2006/12/30	D	56	4.36	0.232	56	4.82	- 0.216	0.90	1.08
1999/01/01 - 2006/12/30	T	207	5.02	0.239	205	5.00	- 0.229	1.00	1.05

1) Average change in exchange rate level per day in cents. - 2) In absolute terms.

The relation between slope and duration of monotonic exchange rate movements is less clear over the 15 (shorter) subperiods marked in figure 7. However, in 11 out of 15 cases did runs in line with the short-term trend last longer than counter-runs. Hence, the difference in the average duration between upward and downward runs did contribute to the overall appreciation or depreciation, respectively, realized during the trend (table 3). At the same time, also the differences in the average slope between upward and downward runs contributed to the overall short-term trends: During an appreciation (depreciation) period, upward (downward) runs were in most cases steeper than counter-runs (table 3).

This pattern is particularly pronounced on the basis of 5 days moving averages of the original price series (table 3): The long-term appreciation (depreciation) trend of the $/€ exchange rate in period A (C) is primarily brought about by upward (downward) runs lasting longer than "counter-runs". The differences in the slopes of upward and downward runs play only a minor role, mainly because steeper upward (downward) runs during an appreciation (depreciation) trend turn into more persistent price movements when the original data are smoothed by a moving average.

To sum up: A long-term appreciation (depreciation) is realized in two ways. First, during a "bullish" ("bearish") period upward (downward) runs are steeper than counter-runs. Second, during a "bullish" ("bearish") period upward (downward) runs last longer than counter-runs. The first phenomenon could be attributed to traders reacting stronger to news which are in line with the prevailing "market mood" than to "counter-news". The second phenomenon might reflect "bandwagon behavior", in particular based on technical trading systems. The use of the latter is fostered by the fact that the differences in slope as well as in duration of runs cause price movements which are in line with the long-term trend to become more persistent than conter-movements when moving averages are used (hence, moving average models are probably the most popular tools of technical traders).[4])

I will now document the distribution of upward and downward runs according to their length for two periods, first, for the period of a long-term depreciation trend of the euro (period A), and, second, for the period of an appreciating euro (period C).

Over the depreciation phase A, short upward runs occurred more frequently than short downward runs (93 runs compared to 69 runs; short runs are defined as lasting up to 2 days). By contrast, within the set of medium runs (between 3 and 6 days) and long runs (longer than 6 days), downward runs occurred more frequently than upward runs (table 4).

[4]) Similar results were already obtained in a study which elaborated the pattern of exchange rate dynamics by measuring the path of the daily deutschmark/dollar exchange rate during the "bull market" 1980/85 as well as during the "bear market" 1985/86 (Schulmeister 1987). The results are confirmed in a recent study on price dynamics in commodity futures markets (Schulmeister, 2009A).

Table 4: Non-random components in duration and slope of exchange rate runs
Daily dollar/euro rates

	Run length	Upward runs						Downward runs					
		Number			Slope 1)			Number			Slope 1)		
		observed		RW-Simulation	observed		RW-Simulation	observed		RW-Simulation	observed		RW-Simulation
		Period A: 1999/01/01 - 2000/10/25											
Original data	1-2	93	-	88.7	0.491	-	0.501	69	***	88.8	-0.515	-	-0.501
	3-6	20	**	27.7	0.445	*	0.501	42	***	27.5	-0.478	-	-0.502
	≥ 7	0	*	1.8	-	-	0.508	2	-	1.8	-0.343	*	-0.505
	All	113	-	118.2	0.474	-	0.501	113	-	118.2	-0.484	-	-0.502
5-days moving averages 2)	1-6	37	-	35.9	0.179	-	0.162	27	*	36.0	-0.148	-	-0.162
	7-14	5	**	10.4	0.250	-	0.261	11	-	10.4	-0.267	-	-0.262
	≥ 15	2	-	2.0	0.342	-	0.286	7	***	2.0	-0.265	-	-0.286
	All	44	-	48.4	0.229	-	0.224	45	-	48.4	-0.240	-	-0.224
20 days moving averages 2)	1-14	16	-	18.0	0.032	**	0.051	11	*	18.0	-0.058	-	-0.052
	15-34	3	-	4.1	0.165	**	0.124	5	-	4.1	-0.101	-	-0.123
	≥ 35	0	*	1.4	-	-	0.150	4	***	1.4	-0.147	-	-0.151
	All	19	-	23.5	0.117	-	0.110	20	-	23.5	-0.122	-	-0.110
		Period C: 2002/01/31 - 2004/12/30											
Original data	1-2	163	**	141.9	0.585	-	0.558	177	***	141.8	-0.510	*	-0.557
	3-6	43	-	44.3	0.532	-	0.558	32	***	44.3	-0.519	-	-0.559
	≥ 7	4	-	2.9	0.475	-	0.563	0	**	2.9	-	-	-0.562
	All	210	***	189.0	0.557	-	0.559	209	***	189.1	-0.513	**	-0.558
5-days moving averages 2)	1-6	44	**	57.2	0.176	-	0.181	53	-	57.1	-0.180	-	-0.180
	7-14	18	-	16.6	0.279	-	0.292	15	-	16.8	-0.305	-	-0.291
	≥ 15	8	***	3.3	0.262	-	0.319	0	**	3.2	-	-	-0.320
	All	70	-	77.1	0.245	-	0.250	68	*	77.1	-0.242	-	-0.249
20 days moving averages 2)	1-14	29	-	28.7	0.058	-	0.057	31	-	28.7	-0.050	-	-0.058
	15-34	4	-	6.5	0.129	-	0.138	6	-	6.6	-0.141	-	-0.138
	≥ 35	5	**	2.4	0.181	-	0.168	0	**	2.3	-	-	-0.169
	All	38	-	37.5	0.144	-	0.125	37	-	37.5	-0.096	**	-0.124

1) Average change in exchange rate level per day in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective moving average.

Notes: The table compares the observed numbers and slopes of exchange rate runs by duration to their expected means under the random-walk-hypothesis. These means are derived from a Monte-Carlo-simulation based on 1000 random walk series. The random walks were constructed with an expected zero mean of the first differences and with an expected standard deviation of the first differences as observed in the original exchange rate series over the respective period. * (**, ***) indicate the significance of the difference between the observed means and the expected means under the random-walk-hypothesis at the 10% (5%, 1%) level.

By the same token, short downward runs occurred more frequently than short upward runs over the appreciation phase C. At the same time, medium and long runs were more often upward directed than downward directed (table 4).

In order to test for the robustness of these results, I generate 1000 random series ("random walks without drift"). I then compare the observed distribution of monotonic price movements to the expected distribution under the random walk hypothesis (RWH). This comparison shall reveal in which class of runs (by length) and based on which smoothing parameters (length of moving average = MA) does the observed number of runs as well as their slope deviate (most) significantly from the respective values according to the RWH.

Based on the original data (MA = 1), there occurred significantly more short runs than under the RWH over the appreciation period C. This results holds to a larger extent true for short downward runs as compared to short upward runs. At the same time there occurred significantly less medium and long downward runs (table 4). Over the depreciation period A, by contrast, there occurred significantly less short downward runs, but significantly more medium downward runs, and less medium and long upward runs than under the RWH (table 4).

Based on smoothed series (both, the observed exchange rate series as well as the random series are smoothed by a 5 days and 20 days moving average), the most significant deviations of the observed number of runs from their expected values under the RWH concern the most persistent runs (lasting longer than 14 days in the case of a 5 days MA, and longer than 34 days in the case of a 20 days MA – table 4). Over the depreciation period A, e. g, there occurred many "abnormally" long lasting monotonic downward movements (many more than upward movements). In an analogous way, over the appreciation period C there occurred many "abnormally" long lasting upward movements (many more than downward movements).

In general, the observed slopes of exchange rate runs deviate from their expected values under the RWH to a lesser extent than the number of runs. E. g., during the appreciation period C the average slope of downward runs (in absolute terms) is only in three cases significantly smaller than the values expected under the RWH. In three cases are upward runs on average (insignificantly) steeper than expected (table 4). The picture is even more unclear for the depreciation period A. In only three cases are upward runs significantly less steep than under a random walk, in one case, however, the opposite is true. In only four cases are downward runs (insignificantly) steeper than according to the RWH.

The tables A/1 and A/2 in the annex document the distribution of the upward and downward runs according to their length more in detail. Table A/1 reports the observed number and slope for each single run length up to 6 days as well as the respective values under the RWH. The table also documents the contribution of the single run classes to the overall change in the exchange rate. It turns out that the greatest part of any overall appreciation or depreciation is realized by relatively few persistent price movements. E. g., based on 5 days moving averages, the dollar/euro exchange rate fell by 33.5 cents over period A (table 2).

Table 5: Classification of all exchange rate runs by duration 1999 – 2006
Daily dollar/euro rates

	Number			Slope 1)		
	Observed	RW-Simulation		Observed	RW-Simulation	
			Original data			
1	561.0	520.5	*	0.501	0.523	*
2	276.0	259.6	-	0.510	0.528	-
3	122.0	129.8	-	0.509	0.525	-
4	65.0	64.6	-	0.526	0.526	-
5	28.0	32.3	-	0.499	0.526	-
6	19.0	16.0	-	0.506	0.525	-
≥ 7	10.0	15.8	*	0.415	0.527	***
All	1081.0	1038.7	**	0.505	0.526	***
			5-days moving average			
1-6	305.0	314.8	-	0.170	0.169	-
7-14	85.0	88.1	-	0.276	0.273	-
≥ 15	26.0	22.4	-	0.275	0.297	*
All	416.0	425.2	-	0.234	0.235	-
			10 days moving average			
1-9	228.0	212.8	-	0.088	0.087	-
10-24	72.0	74.3	-	0.190	0.191	-
≥ 25	13.0	11.7	-	0.229	0.222	-
All	313.0	298.8	-	0.168	0.166	-
			20 days moving average			
1-14	147.0	160.4	-	0.045	0.054	**
15-34	33.0	36.3	-	0.121	0.128	-
≥ 35	17.0	13.0	*	0.160	0.159	-
All	197.0	209.7	-	0.118	0.117	-
			40 days moving average			
1-14	69.0	110.4	**	0.028	0.026	-
15-39	15.0	17.7	-	0.059	0.064	-
≥ 40	18.0	18.7	-	0.113	0.107	-
All	102.0	146.8	**	0.089	0.083	-

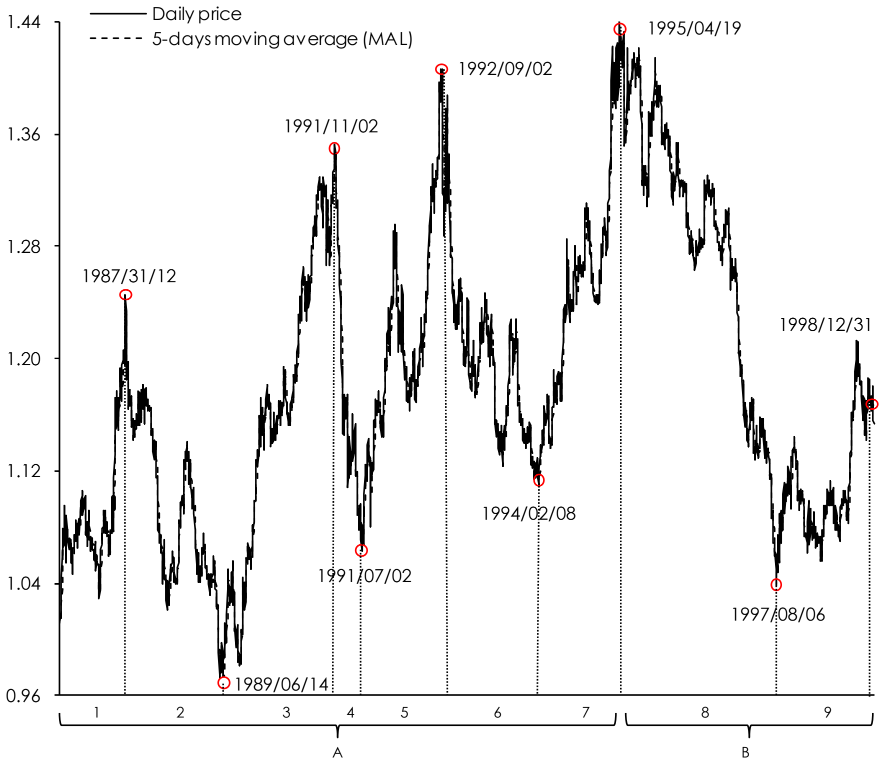
1) Average change in exchange rate level per day in cents in absolute terms. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by 5 (10, 20, 40) days moving averages.

This "net" depreciation was the result of an cumulative rise by 38.3 cents and an cumulative fall by 71.1 cents (table A/1). 56.6% of the cumulative rise and 86.4% of the cumulative fall were brought about in only 7 upward runs and only 18 downward runs lasting 7 days or more. During the "bull market" of period C 80.4% of the "gross" appreciation by 93.4 cents was realized in only 15 persistent upward runs (out of a total of 68 upward runs – table A/1).

Table A/2 accomplishes the calculations already contained in table 4. E. g., the table also includes the expected values of the number and slopes of runs under a random walk with drift. In addition, also the results für the sub-periods B and C are reported in table A/2. Furthermore, this table includes the results for 10-days and 40-days moving averages. The deviations of the observed number and slope of runs by duration from the expected values under a random walk with drift are smaller than from a random walk without drift. Of course, this result holds true in particular for the "bearish" period A and the "bullish" period C.

Table 5 displays the distribution of exchange rate runs by their length for the overall period 1999 to 2006. Since the dollar/euro rate followed roughly a cycle over this period, the observed duration and slope of runs deviate much less from the respective values according to the RWH than over the "bearish" period A and the "bullish" period C (table 4). Based on the original data, there occur significantly more runs than under te RWH, i. e., the empirical short-term volatility is even higher than expected if the exchange rate followed a random walk. At the same time, the average slopes of runs are less steep than in the case of a random walk. Smoothing the original series as well as the 1000 random series reduces the number of runs for the observed runs to a larger extent than for the random walk series. This result is due to the fact that the exchange rate fluctuates most of the time around "underlying" short-term trends.

Figure 9: Subperiods in the development of the US dollar/deutschmark rate 1987 -1998



In the last part of this section I shall explore the pattern of exchange rate dynamics for the dollar/DM rate between 1987 and 1998. In order to facilitate the comparison of the results with the results for the dollar/euro rate between 1999 and 2006, the dollar/DM rate is chained with the dollar/euro rate on January 2, 1999. Hence, this "artificial" dollar/DM rate differs from the "true" rate by a constant factor (with respect to foreign exchange trading, the DM was the genuine forerunner of the euro).

Table 6: Pattern of exchange rate movements: Daily dollar/deutschmark rates 1987 - 1998

	Period	Duration	Change in price	Length of actual price path	Change in price per day (slope)	Length of actual price path per day	Change in price per length of actual path
		Days	Cents	Cents 1)	Cents	Cents	
		(1)	(2)	(3)	(4)	(5)	(6)
				Based on original data			
1987/01/01 - 1987/12/31	1	248	22.6	134.3	0.09	0.542	0.17
1987/12/31 - 1989/06/14	2	371	-26.9	182.8	-0.07	0.493	-0.15
1989/06/14 - 1991/02/11	3	421	38.5	239.6	0.09	0.569	0.16
1991/02/11 - 1991/07/02	4	100	-28.3	82.3	-0.28	0.823	-0.34
1991/07/02 - 1992/09/02	5	301	33.7	215.8	0.11	0.717	0.16
1992/09/02 - 1994/02/08	6	368	-27.3	248.2	-0.07	0.674	-0.11
1994/02/08 - 1995/04/19	7	310	32.9	195.1	0.11	0.629	0.17
1995/04/19 - 1997/08/06	8	593	-37.4	316.3	-0.06	0.533	-0.12
1997/08/06 - 1998/12/31	9	362	12.8	180.3	0.04	0.498	0.07
1987/01/01 - 1995/04/19	A	2125	42.3	1303.4	0.02	0.613	0.03
1995/04/19 - 1998/31/12	B	956	-23.9	497.3	-0.03	0.520	-0.05
1987/01/01 - 1998/31/12	T	3082	15.4	1803.6	0.01	0.585	0.01
				Based on 5 days moving averages			
1987/01/01 - 1987/12/31	1	244	20.9	62.1	0.09	0.255	0.34
1987/12/31 - 1989/06/14	2	367	-22.7	87.6	-0.06	0.239	-0.26
1989/06/14 - 1991/02/11	3	417	36.2	109.1	0.09	0.262	0.33
1991/02/11 - 1991/07/02	4	96	-25.3	40.8	-0.26	0.425	-0.62
1991/07/02 - 1992/09/02	5	297	32.3	95.7	0.11	0.322	0.34
1992/09/02 - 1994/02/08	6	362	-26.8	103.5	-0.07	0.286	-0.26
1994/02/08 - 1995/04/19	7	304	29.2	74.7	0.10	0.246	0.39
1995/04/19 - 1997/08/06	8	585	-36.4	110.0	-0.06	0.188	-0.33
1997/08/06 - 1998/12/31	9	354	10.8	54.5	0.03	0.154	0.20
1987/01/01 - 1995/04/19	A	2121	40.8	613.0	0.02	0.289	0.07
1995/04/19 - 1998/31/12	B	952	-25.4	222.7	-0.03	0.234	-0.11
1987/01/01 - 1998/31/12	T	3078	15.1	836.9	0.00	0.272	0.02

1) Cumulative absolute value of the daily changes in exchange rate levels.

Table 7: Exchange rate runs: Daily dollar/deutschmark rates 1987 - 1998

	Period	Upward runs			Downward runs			Ratio between upward and	
		Number	Average duration	Average slope 1)	Number	Average duration	Average slope 1)	Duration	Slope 2)
			Days			Days			
				Based on original data					
1987/01/01 - 1987/12/31	1	58	2.12	0.638	58	2.16	- 0.447	0.98	1.43
1988/01/01 - 1989/06/14	2	91	1.93	0.443	92	2.12	- 0.538	0.91	0.82
1989/06/15 - 1991/02/11	3	104	2.31	0.579	103	1.76	- 0.556	1.31	1.04
1991/02/12 - 1991/07/02	4	22	1.68	0.730	23	2.74	- 0.878	0.61	0.83
1991/07/03 - 1992/09/02	5	78	2.23	0.717	78	1.63	- 0.717	1.37	1.00
1992/09/03 - 1994/02/08	6	92	1.74	0.690	92	2.26	- 0.662	0.77	1.04
1994/02/09 - 1995/04/19	7	78	2.26	0.648	77	1.74	- 0.605	1.30	1.07
1995/04/20 - 1997/08/06	8	165	1.62	0.522	165	1.98	- 0.542	0.82	0.96
1997/08/07 - 1998/12/31	9	98	1.79	0.552	97	1.93	- 0.448	0.93	1.23
1987/01/01 - 1995/04/19	A	524	2.08	0.618	524	1.98	- 0.609	1.05	1.02
1995/04/20 - 1998/31/12	B	263	1.68	0.534	262	1.96	- 0.508	0.86	1.05
				Based on 5 days moving averages					
1987/01/01 - 1987/12/31	1	24	5.83	0.297	23	4.43	- 0.202	1.32	1.47
1988/01/01 - 1989/06/14	2	29	5.14	0.218	30	7.23	- 0.254	0.71	0.86
1989/06/15 - 1991/02/11	3	42	6.07	0.285	42	3.83	- 0.227	1.58	1.26
1991/02/12 - 1991/07/02	4	8	3.50	0.276	9	7.56	- 0.486	0.46	0.57
1991/07/03 - 1992/09/02	5	32	6.09	0.328	31	3.26	- 0.314	1.87	1.05
1992/09/03 - 1994/02/08	6	26	6.42	0.230	27	7.22	- 0.334	0.89	0.69
1994/02/09 - 1995/04/19	7	27	7.11	0.271	26	4.31	- 0.203	1.65	1.33
1995/04/20 - 1997/08/06	8	36	6.72	0.152	36	9.53	- 0.213	0.71	0.71
1997/08/07 - 1998/12/31	9	27	6.96	0.174	27	6.15	- 0.131	1.13	1.32
1987/01/01 - 1995/04/19	A	208	5.40	0.291	208	4.77	- 0.288	1.13	1.01
1995/04/20 - 1998/31/12	B	103	4.20	0.228	102	5.08	- 0.239	0.83	0.95

1) Average change in exchange rate level per day in cents. - 2) In absolute terms.

Figure 9 shows that the deutschmark appreciated between January 1987 and April 1995 by 42.3 cents. However, this period A cannot be considered one single "bull market" since it comprises several appreciation or depreciation trends each lasting between one year and two years. Figure 9 and table 6 specify – somewhat arbitrarily – five "bullish" and four "bearish" sub-periods between the beginning of 1987 and the end of 1998. The movements of the dollar/DM exchange rate over each of these subperiods (with the exception of the comparatively short subperiod 4) is similar to those of the dollar/euro "bear market" 1999/2000 and to the dollar/euro "bull market" 2002/2005, respectively. This similarity concerns the average slope of price movements, their length per day as well as the degree of monotonicity (compare the respective values in columns 4, 5 and 6 of table 6 to those in table 2). As in the case of the dollar/euro exchange rate, smoothing the original data by means of a 5 days moving average reduces the length of the dollar/DM exchange rate path by more than 50%, mainly because the daily rates fluctuate around short-term trends most of the time (table 6, figure 9).

Table 8: Non-random components in duration and slope of exchange rate runs
Daily dollar/deutschmark

	Run length	Upward runs						Downward runs					
		Number			Slope 1)			Number			Slope 1)		
		observed		RW-Simulation	observed		RW-Simulation	observed		RW-Simulation	observed		RW-Simulation
Period A: 1987/01/01 - 1995/04/19													
Original data	1-2	*378*	-	*397.9*	0.612	***	0.665	*396*	-	*398.0*	-0.585	***	-0.665
	3-6	*135*	-	*124.3*	0.633	*	0.665	*123*	-	*124.1*	-0.636	*	-0.666
	≥ 7	*11*	-	*8.5*	0.565	*	0.662	*5*	-	*8.6*	-0.628	-	-0.664
	All	*524*	-	*530.7*	0.618	***	0.665	*524*	-	*530.7*	-0.609	***	-0.665
5-days moving averages 2)	1-6	*146*	-	*160.0*	0.209	-	0.215	*155*	-	*160.0*	-0.228	-	-0.215
	7-14	*52*	-	*47.3*	0.336	-	0.348	*45*	-	*47.1*	-0.315	**	-0.347
	≥ 15	*10*	-	*9.3*	0.355	-	0.379	*8*	-	*9.6*	-0.366	-	-0.378
	All	*208*	-	*216.7*	0.291	-	0.298	*208*	-	*216.7*	-0.288	-	-0.298
20 days moving averages 2)	1-14	*68*	-	*81.1*	0.086	***	0.067	*67*	-	*81.0*	-0.062	-	-0.067
	15-34	*12*	**	*18.6*	0.172	-	0.163	*18*	-	*18.6*	-0.144	*	-0.163
	≥ 35	*12*	***	*6.7*	0.183	-	0.202	*6*	-	*6.8*	-0.220	-	-0.204
	All	*92*	*	*106.4*	0.158	-	0.149	*91*	*	*106.4*	-0.147	-	-0.150
Period C: 1995/04/19 - 1998/12/31													
Original data	1-2	*220*	***	*179.4*	0.512	**	0.568	*196*	*	*179.4*	-0.472	***	-0.569
	3-6	*41*	***	*56.0*	0.579	-	0.569	*63*	-	*55.9*	-0.545	-	-0.567
	≥ 7	*2*	-	*3.7*	0.527	-	0.568	*3*	-	*3.7*	-0.549	-	-0.569
	All	*263*	***	*239.1*	0.534	**	0.569	*262*	***	*239.1*	-0.508	***	-0.568
5-days moving averages 2)	1-6	*82*	-	*72.8*	0.174	-	0.184	*73*	-	*72.6*	-0.162	*	-0.183
	7-14	*19*	-	*21.1*	0.296	-	0.297	*22*	-	*21.1*	-0.271	-	-0.295
	≥ 15	*2*	-	*4.2*	0.261	*	0.324	*7*	*	*4.3*	-0.294	-	-0.324
	All	*103*	-	*98.0*	0.228	**	0.254	*102*	-	*98.0*	-0.239	-	-0.253
20 days moving averages 2)	1-14	*34*	-	*36.2*	0.066	-	0.058	*31*	-	*36.2*	-0.061	-	-0.058
	15-34	*9*	-	*8.3*	0.112	*	0.139	*10*	-	*8.3*	-0.136	-	-0.139
	≥ 35	*2*	-	*3.0*	0.184	-	0.174	*4*	-	*3.0*	-0.159	-	-0.172
	All	*45*	-	*47.5*	0.113	-	0.127	*45*	-	*47.5*	-0.131	-	-0.127

1) Average change in exchange rate level per day in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective moving average.

Notes: See Table 4.

Table 7 shows how the accumulation of exchange rate runs brought about long-term appreciation and depreciation trends of the dollar/DM exchange rate. In almost all cases did upward (downward) runs last longer during "bull markets" ("bear markets") than "counter-runs", in most cases did the difference in duration between upward and downward runs contribute more to the overall appreciation or depreciation than the difference in the slope between upward and downward runs. This pattern is particularly pronounced if the dollar/DM rates are smoothed by a 5-days moving average.

The distribution of upward and downward runs of the dollar/DM exchange rate displays a similar pattern as in the case of the dollar/euro rate (table 8). Over the appreciation period between 1987 and 1995, there occurred less short upward runs than short downward runs, but more medium and long upward runs than downward runs. The opposite was the case over the depreciation period between 1995 and 1998. Hence, these two very long-term exchange rate changes were primarily brought about by persistent upward (downward) runs occurring comparatively more frequently during the appreciation (depreciation) phase.

The deviations of the duration and the slope of runs from the respective values expected under the RWH are less pronounced for the appreciation and depreciation period of the dollar/DM exchange rate than for the periods C and A of the dollar/euro exchange rate (tables 8 and 4). This different result is mainly due to the fact that the DM appreciation 1987/95 as well as the DM depreciation 1995/98 does not represent one single long-term upward trend and downward trend, respectively, whereas the periods C and A in the development of the euro can be considered one single "bull market" and "bear market", respectively (see figures 7 and 9).[5])

3.2 Exchange rate dynamics based on intraday data

This section reports at first the results of the same "measurement exercises" based on 30-minutes data. The frequency of these data is higher by a factor of 48 than the frequency of daily data since the data base comprises 24 hours of trading per day (except for weekends). For this reason, moving averages with longer length than in the case of daily data are used for smoothing the 30-minutes data.

Table 9 displays the non-random components in the duration of monotonic exchange rate movements during the depreciation period of the euro (period A) as well as during the appreciation period C. The most important results for the original (unsmoothed) 30 minutes exchange rates are as follows (table 9):

- Short lasting exchange rate runs occurred significantly more frequently than expected under the RWH. At the same time, persistent runs i. e., monotonic exchange rate

[5]) Tables A/3 and A/4 in the annex document the distribution of runs of the dollar/DM exchange rate in an analogous manner as tables A/1 and A/2 for the dollar/euro rate. The main characteristics of the distribution of exchange rate runs are very similar. E. g., also in the case of the dollar/DM rate did relatively few but persistent runs based on 5 day moving averages account for most of the cumulative "gross" appreciation and depreciation (see table A/3).

movements lasting longer than nine 30-minutes intervals, occurred less often than under the RWH. Both results hold true for the depreciation period A as well as for the appreciation period C.

- The overall number of observed exchange rate runs is significantly higher than is to be expected if 30 minutes exchange rates followed a random walk.
- The average slopes of upward and downward runs are significantly smaller (In absolute terms) than under a random walk. This result holds true for all run classes over the "bear market" 1999/2000 as well as over the "bull market" 2002/2004.

When the 30 minutes data are smoothed by a 50-period MA and by a 100-period MA, respectively, a very different picture emerges (table 9):

- Over the depreciation period A there occurred (insignificantly) less short exchange rate runs than under the RWH. At the same time, there occurred significantly more long downward runs, but significantly less upward runs than under the RWH (long lasting runs are defined as those lasting more than 34 periods).
- Also over the appreciation period C is the number of short lasting runs smaller than expected under the RWH (this result is significant for the 50-period MA but insignificant for the 100-period MA). In an analogous way to the depreciation period A, there occurred significantly more long lasting upward runs than under the RWH. At the same time there occurred less persistent downward runs (this result is significant for the 100-period MA but insignificant for the 50-period MA).
- The overall number of upward and downward runs is in all but one case (period A/50-period MA) smaller than expected under the RWH (in the case of period C/50-period MA, this result is significant).
- Exchange rate runs based on smoothed data remain signfificantly less steep than expected under the RWH.

One can conclude from these results that the short-term volatility of exchange rates, i. e., the frequency of short lasting ups and downs, is much higher when measured on the basis of intraday data than on daily data. In both cases (i. e., data frequencies) is the observed short-term volatility higher than expected under the RWH. However, in both cases does the exchange rate fluctuate around an "underlying" trends. As a consequence, there occur less short lasting runs and more long lasting (persistent) runs when the exchange rate series is smoothed by moving averages. Persistent upward (downward) runs last longer during an appreciation (depreciation) phase than the counter-movements. Hence, the sequence of these runs results in a stepwise appreciation (depreciation) process, i. e., in long-term exchange rate trends.

Table 9: Non-random components in duration and slope of exchange rate runs
Dollar/euro rates at 30-minutes intervals

	Run length	Upward runs: Number observed		Upward runs: Number RW-Simulation	Upward runs: Slope 1) observed		Upward runs: Slope 1) RW-Simulation	Downward runs: Number observed		Downward runs: Number RW-Simulation	Downward runs: Slope 1) observed		Downward runs: Slope 1) RW-Simulation
							Period A: 1999/01/01 - 2000/10/25						
	< 3	*4571*	***	*4037*	0.071	***	0.085	*4611*	***	*4037*	-0.074	***	-0.085
Original data	3 - 9	*1234*	***	*1325*	0.071	***	0.085	*1196*	***	*1324*	-0.075	***	-0.085
	>= 10	*3*	***	*10*	0.068	***	0.086	*2*	***	*11*	-0.073	**	-0.086
	Total	*5808*	***	*5372*	0.071	***	0.085	*5809*	***	*5372*	-0.074	***	-0.085
5 period moving averages 2)	< 7	*1907*	***	*1631*	0.023	***	0.027	*1863*	***	*1631*	-0.023	***	-0.027
	7 - 14	*468*	-	*477*	0.039	***	0.044	*495*	-	*479*	-0.040	***	-0.044
	>= 15	*52*	***	*93*	0.046	**	0.048	*69*	***	*92*	-0.051	**	-0.048
	Total	*2427*	***	*2202*	0.031	***	0.038	*2427*	***	*2202*	-0.033	***	-0.038
20 period moving averages 2)	0	*978*	***	*830*	0.007	***	0.009	*925*	***	*830*	-0.007	***	-0.009
	< 3	*194*	-	*188*	0.020	-	0.021	*228*	***	*189*	-0.020	-	-0.021
	3 - 9	*41*	***	*69*	0.022	***	0.026	*60*	-	*68*	-0.023	***	-0.026
	>= 10	*1213*	***	*1087*	0.016	***	0.019	*1213*	***	*1087*	-0.017	***	-0.019
50 period moving averages 2)	Total	*492*	-	*516*	0.003	**	0.003	*488*	-	*515*	-0.003	**	-0.003
	< 7	*85*	**	*69*	0.006	***	0.008	*63*	-	*70*	-0.007	**	-0.008
	7 - 14	*91*	**	*103*	0.014	*	0.015	*117*	***	*102*	-0.013	***	-0.015
	>= 15	*668*	-	*688*	0.011	***	0.012	*668*	-	*688*	-0.011	*	-0.012
							Period C: 2002/01/31 - 2004/12/30						
	< 3	*7105*	***	*6594*	0.069	***	0.082	*7203*	***	*6594*	-0.067	***	-0.082
Original data	3 - 9	*2118*	*	*2164*	0.072	***	0.083	*2019*	***	*2162*	-0.071	***	-0.083
	>= 10	*6*	***	*16*	0.066	***	0.084	*6*	***	*18*	-0.086	-	-0.083
	Total	*9229*	***	*8773*	0.070	***	0.083	*9228*	***	*8773*	-0.069	***	-0.083
5 period moving averages 2)	< 7	*3040*	***	*2664*	0.023	***	0.027	*3054*	***	*2664*	-0.022	***	-0.027
	7 - 14	*789*	-	*779*	0.039	***	0.043	*788*	-	*782*	-0.038	***	-0.043
	>= 15	*101*	***	*152*	0.051	***	0.047	*88*	***	*150*	-0.044	***	-0.047
	Total	*3930*	***	*3596*	0.033	***	0.037	*3930*	***	*3596*	-0.031	***	-0.037
50 period moving averages 2)	< 15	*772*	**	*843*	0.003	***	0.003	*785*	*	*841*	-0.003	***	-0.003
	15 - 34	*87*	***	*112*	0.005	***	0.007	*114*	-	*115*	-0.006	***	-0.007
	>= 35	*205*	***	*169*	0.014	-	0.015	*164*	-	*167*	-0.015	-	-0.015
	Total	*1064*	*	*1124*	0.012	-	0.012	*1063*	*	*1124*	-0.011	*	-0.012
100 period moving averages 2)	< 15	*559*	-	*595*	0.001	***	0.002	*575*	-	*596*	-0.001	***	-0.002
	15 - 34	*63*	*	*75*	0.003	***	0.004	*77*	-	*77*	-0.003	***	-0.004
	>= 35	*145*	***	*128*	0.009	-	0.010	*114*	*	*125*	-0.010	-	-0.010
	Total	*767*	-	*798*	0.008	-	0.008	*766*	-	*798*	-0.008	*	-0.008

1) Average change in exchange rate level per 30-minutes interval in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective moving average.

Notes: See table 8.

Also the fact that exchange rate runs are significantly less steep than according to the RWH points to some persistence in price dynamics, probably in part due to comparatively slow reaction to news, in part due to the use of trend-following trading techniques.

Figure 10: "Bearish" and "bullish" sub-periods in the development of the dollar/euro exchange rate

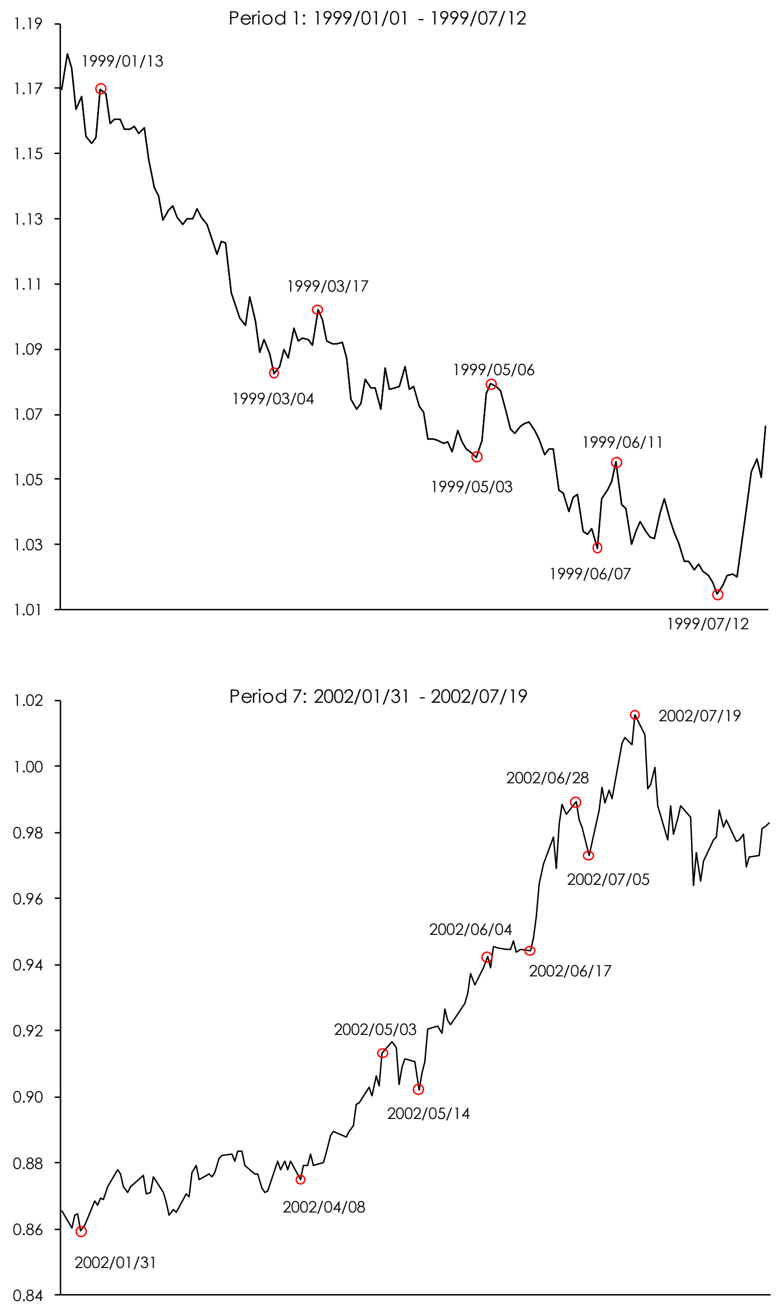


Table 10: Non-random components in duration and slope of exchange rate runs
Dollar/euro rates at 1-minute intervals

	Run length	Upward runs: Number observed		Upward runs: Number RW-Simulation	Upward runs: Slope 1) observed		Upward runs: Slope 1) RW-Simulation	Downward runs: Number observed		Downward runs: Number RW-Simulation	Downward runs: Slope 1) observed		Downward runs: Slope 1) RW-Simulation
						Period 1: 1999/01/01 - 1999/07/12							
Original data	< 3	32705	***	23763	0.027	***	0.029	33028	***	23767	-0.027	***	-0.029
	3 - 9	5842	***	7869	0.021	***	0.029	5529	***	7865	-0.022	***	-0.029
	>= 10	23	***	66	0.012	***	0.029	13	***	65	-0.022	***	-0.029
	Total	38570	***	31698	0.025	***	0.029	38570	***	31698	-0.026	***	-0.029
50 period moving averages 2)	< 15	6176	***	3019	0.001	***	0.001	6182	***	3026	-0.001	***	-0.001
	15 - 34	506	***	406	0.002	***	0.003	444	**	408	-0.002	***	-0.003
	>= 35	511	***	616	0.003	***	0.005	567	***	607	-0.003	***	-0.005
	Total	7193	***	4041	0.002	***	0.004	7193	***	4041	-0.002	***	-0.004
100 period moving averages 2)	< 15	4433	***	2129	0.000	***	0.001	4484	***	2141	0.000	***	-0.001
	15 - 49	482	***	366	0.001	***	0.002	394	*	365	-0.001	***	-0.001
	>= 50	314	***	374	0.002	***	0.004	350	*	364	-0.002	***	-0.004
	Total	5229	***	2870	0.001	***	0.003	5228	***	2870	-0.002	***	-0.003
200 period moving averages 2)	< 15	3045	***	1521	0.000	***	0.000	3048	***	1526	0.000	***	0.000
	15 - 49	320	***	254	0.000	***	0.001	304	***	254	0.000	***	-0.001
	>= 50	261	*	279	0.001	***	0.002	273	-	274	-0.001	***	-0.002
	Total	3626	***	2054	0.001	***	0.002	3625	***	2054	-0.001	***	-0.002
400 period moving averages 2)	< 15	2036	***	1083	0.000	***	0.000	2021	***	1086	0.000	***	0.000
	15 - 49	183	-	181	0.000	***	0.000	185	-	179	0.000	***	0.000
	>= 50	203	-	198	0.001	***	0.002	215	*	198	-0.001	***	-0.002
	Total	2422	***	1462	0.001	***	0.001	2421	***	1462	-0.001	***	-0.001
						Period 7: 2002/01/31 - 2002/07/19							
Original data	< 3	36305	***	26869	0.017	***	0.018	36469	***	26857	-0.017	***	-0.018
	3 - 9	6715	***	8842	0.016	***	0.018	6558	***	8852	-0.016	***	-0.018
	>= 10	17	***	73	0.017	-	0.018	10	***	74	-0.018	-	-0.018
	Total	43037	***	35783	0.017	***	0.018	43037	***	35783	-0.017	***	-0.018
50 period moving averages 2)	< 15	7382	***	3443	0.001	***	0.001	7408	***	3429	-0.001	***	-0.001
	15 - 34	576	***	462	0.001	***	0.002	586	***	467	-0.001	***	-0.002
	>= 35	573	***	679	0.002	***	0.003	537	***	687	-0.002	***	-0.003
	Total	8531	***	4583	0.002	***	0.003	8531	***	4583	-0.001	***	-0.002
100 period moving averages 2)	< 15	5220	***	2415	0.000	***	0.000	5262	***	2409	0.000	***	0.000
	15 - 49	534	***	407	0.001	***	0.001	516	***	412	-0.001	***	-0.001
	>= 50	382	***	415	0.002	***	0.002	358	***	417	-0.001	***	-0.002
	Total	6136	***	3237	0.001	***	0.002	6136	***	3237	-0.001	***	-0.002
200 period moving averages 2)	< 15	3555	***	1771	0.000	***	0.000	3578	***	1766	0.000	***	0.000
	15 - 49	380	***	285	0.000	***	0.000	363	***	289	0.000	***	0.000
	>= 50	318	-	314	0.001	***	0.001	312	-	315	-0.001	***	-0.001
	Total	4253	***	2370	0.001	***	0.001	4253	***	2370	-0.001	***	-0.001
400 period moving averages 2)	< 15	2318	***	1255	0.000	***	0.000	2298	***	1262	0.000	***	0.000
	15 - 49	225	-	202	0.000	***	0.000	247	***	196	0.000	***	0.000
	>= 50	238	-	235	0.001	***	0.001	237	-	233	-0.001	***	-0.001
	Total	2781	***	1691	0.001	***	0.001	2782	***	1691	0.000	***	-0.001

1) Average change in exchange rate level per minute in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by 50 (100, 200, 400) period moving average.

Notes: See table 8.

Tables A/5 and A/6 in the annex document the distribution of runs of the dollar/euro exchange rate based on 30-minutes data in an analogous manner as tables A/1 and A/2 for daily rates. The main characteristics of the distribution of exchange rate runs are very similar. In particular, also in the case of exchange rates based on 30-minutes data do relatively few but persistent runs based on 5 periods or on 50 periods moving averages (MA5 and MA50, respectively) account for most of the cumulative "gross" appreciation and depreciation. E. g., 71.6% of the "gross" depreciation (404.2 cents) during period A based on MA5 are brought about by downward runs lasting more than six 30-minutes intervals (23.2% of all downward runs - table A/5). When a 50-periods MA is used, the concentration of the overall "gross" appreciation or depreciation on relatively few persistent runs is even greater (runs lasting longer than 6 intervals account for almost 99% of the overall "gross" exchange rate change).

Tables A/7 and A/8 in the annex have the same structure as tables A/2, A/4 and A/6. They show the distribution of runs of the dollar/euro exchange rate based on 30-minutes data for the sub-periods 1, 3 and 5 during the "bear market" of period A (table A/7) and for the sub-periods 7, 9, 11 and 13 during the "bull market" of period C (table A/8). The results obtained for the overall period A and period C (table 9) are confirmed: "Bearish" sub-periods are mainly due to persistent downward (upward) runs occurring more (less) frequently than according to the RWH (table A/7). Similarly, "bullish" sub-periods are characterized by persistent upward (downward) runs occurring more (less) frequently than under a random walk (table A/8).

Finally, the same "measurement exercise" is done for the dollar/euro exchange rate at 1 minute intervals. Due to the enormous amount of data the calculations are carried out only for one "bullish" sub-period and for one "bearish" sub-period, i. e., for the sub-periods 1 and 7. Each of the two periods is further subdivided into four "sub-sub-periods" (figure 10). The run distribution prevailing in these "bullish" and "bearish" periods is documented in the annex in table A/9 and table A/10, rspectively.

The features of the distribution of upward and downward runs of the dollar/euro exchange rate at 1-minute intervals can be summarized as follows (see table 10 as well as tables A/9 and A/10 in the annex):

- The number of runs is significantly higher than under the RWH. The deviations from a random walk are even greater than in the case of 30-minutes data (compare table 10 to table 9).
- Even when smoothing the data with comparatively long moving averages (up to 400 periods) does the overall number of runs exceed the expected number according to the RWH.
- The pattern of persistent runs accumulating to an overall appreciation or depreciation is much less pronounced on the basis of 1-minute data than on the basis of daily data and 30-minutes data. Only over shorter "bullish" ("bearish") sub-periods do persistent upward

(downward) runs occur more frequently than persistent downward (upward) runs (see, e. g., the distribution of runs during the "bullish" period between June, 17 and June 28, 2002 – table A/10).

- The average slopes of runs are significantly less steep than according to the RWH.

One reason for why the distribution of upward and downward runs based on 1-minute data differs from the respective distribution of runs based on 30-minutes data might be the following. The periods for which exchange rate movements based on 1-minute data are investigated are comparatively "longer" (in the sense of the amount of data points) than those used for 30-minutes data. As a consequence, the average change per time unit and, hence, the trend component, is particularly small in our sample periods of 1-minute data.

The results of chapter 3 can be summarized as follows:

- Exchange rates fluctuate most of the time around "underlying" short-term trends. This phenomenon is more pronounced on the basis of daily and 30-minutes data than on the basis of 1-minute data.
- Over a extended period of time (up to several years) these short-term trends (runs on the basis of smoothed data) last longer in one direction than in the other. The accumulation of upward runs lasting longer than downward runs brings about a "bull market" in a stepwise process (and vice versa for a "bear market").
- The difference in the slope of upward and downward runs contributes to the development of "bull markets" and "bear markets". Upward (downward) runs being steeper over an extended period of time than "counter-runs" runs cause short-term upward (downward) trends to become more persistent.
- The average slopes of exchange rate runs tend to be smaller than expected if the exchange rate followed a random walk. This tendency is particularly pronounced on the basis of intraday data.

This pattern of exchange rate dynamics conflicts with the basic assumptions of the "efficient market hypothesis". According to this concept any asset price reflects the fundamental equilibrium value of the respective asset (rational market participants permanently keep the price at this level). If new information arrives, actors will drive the price instantaneously to its new equilibrium. This (rational) behaviour assures that asset prices follow a random walk which in turn implies "weak market efficiency" (*Fama*, 1970; 1998). This concept means that one cannot systematically make trading profits from exploiting just the information contained in past prices (as do the popular trading rules of technical analysis).[6])

In contrast to efficient market theory the empirical analysis presented above shows that the dynamics of exchange rates (and most probably of asset prices in general) is characterised by price fluctuations around underlying trends. The phenomenon of "trending" can be

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[6] Recent contributions to the debate about the efficiency of asset markets are *LeRoy* (1989), *Shiller* (2003), and *Lo* (2004).

observed on the basis of daily data as well as of intraday data. The "abnormally" frequent occurrence of persistent price movements represents the most important link between the short run and the long run in the dynamics of asset prices. This is so because short-term price runs accumulate to long-term trends.

The most popular trading technique in financial markets, the so called "technical analysis", is based on the (assumed) exploitability of asset price trends. The next chapter invetsigates therefore the profitability of technical trading systems in the dollar/euro market (1999/2006) and in the dollar/DM market (1987/1998).

4. Performance of technical currency trading

In this chapter, I shall first present an overview of the literature on technical trading in the foreign exchange market. I will then introduce into the basics of technical trading and explain the functioning of those types of models tested in the present study. The last sections document the performance of 2265 models based on daily exchange rates and of 2466 models based on 30-minutes exchange rates.

4.1 Extant research on technical currency trading

According to survey studies, technical analysis is the most widely used trading technique in foreign exchange markets. Over the 1990s the importance of technical analysis increased stronger than other trading practices like the orientation on fundamentals or on customer orders. Nowadays between 30% and 40% of professional currency traders use technical systems as their most important trading technique (for recent survey studies see *Cheung-Chinn-Marsh*, 2004; *Cheung-Wong*, 2000; *Cheung-Chinn*, 2001; *Oberlechner*, 2001; *Gehrig-Menkhoff*; 2004, 2005A and 2005B; the best survey of survey studies is *Menkhoff-Taylor*, 2007).

The results of the survey studies cast doubt on the conventional assumptions about trading behaviour in the foreign exchange market. Hence, many researchers investigated if trading rules were actually profitable in this market (see, e.g., *Sweeney*, 1986; *Schulmeister*, 1988; *Levich-Thomas*, 1993; *Menkhoff-Schlumberger*, 1995; *Neely-Weller-Dittmar*, 1997; *Curcio-Goodhart-Guillaume-Payne*, 1997; *Gencay-Stengos*, 1998; *Chang-Osler*, 1999; *Neely-Weller*, 1999; *Gencay*, 1999; *LeBaron*, 1999; *Osler*, 2000; *Schulmeister*, 2000; *Maillet-Michel*, 2000; *Neely-Weller*, 2003; *Ohlson*, 2004; *Schulmeister*, 2008A and 2008B).

All of these studies have found technical trading systems to be profitable when tested in sample based on daily exchange rates. However, their performance out of sample was in most cases found to be significantly worse. Some authors also found that the profitability of trading rules has declined over time (*Marsh*, 2000; *Ohlson*, 2004). Studies on the performance of technical currency trading based on intraday data arrive at mixed results. *Dempster-Jones* (2002) and *Gencay-Dacarogna-Olsen-Pictet* (2003) find this type of trading to be profitable, *Curcio-Goodhart-Guillaume-Payne* (1997) and *Neely-Weller* (2003) arrive at the opposite result (for an excellent survey of all types of studies on technical analysis in different asset markets see *Park-Irwin*, 2004).

Several problems remain unexplained by the extant research.

First, the decline in the profitability of technical currency trading based on daily data is mostly attributed to an increase in market efficiency. It is argued that the information and communication technologies have improved the access to information, lowered transaction costs and increased liquidity in the currency markets (hypothesis 1). However, the new technologies also enable traders to use technical models on the basis of high frequency (intraday) data instead of daily data. This development might have caused intraday exchange rate movements to become more persistent and, hence, exploitable by technical models. At the same time, exchange rate changes on the basis of daily data have become bigger and more erratic which in turn causes technical trading to become less profitable on the basis of daily exchange rates (hypothesis 2). An evaluation of the two competing hypotheses necessitates an analysis of the profitability of technical currency trading on the basis of daily as well as of intraday data. This has not yet been done for a great variety of technical models actually used in practice.

Second, the relationship between the pattern of exchange rate dynamics, the performance of technical trading systems and their aggregate trading behaviour has not yet been analyzed on the basis of intraday data. Such an investigation is of high priority since most currency transactions are done in intraday trading. An analysis of the aggregate trading behaviour of a great variety of technical models will contribute to a better understanding of two characteristics in exchange rate dynamics. The first property concerns the trending behaviour of the exchange rate over the long run (*Engel-Hamilton*, 1990), as well as over the short run (*Dewachter*, 2001; *Neely-Dueker*; 2005). The second property concerns the phenomenon of price cascades in currency markets (*Osler*, 2003 and 2005).

Third, the extant research on the relationship between order flows and exchange rate movements has neglected the role of technical currency trading. Proponents of the microstructure approach hold that order flows are only driven by new (still private) information on fundamentals (*Evans-Lyons*, 2002; 2005). However, to the extent that news impact on exchange rates, they do also cause technical models to produce a sequence of buy or sell signals which in turn induce additional order flows.

Fourth, the interaction between exchange rate dynamics and technical analysis has not yet been analyzed for the exchange rates of the euro vis-à-vis the other most important currencies.

The present study tries to fill this gap by exploring the performance of technical trading systems in the dollar/euro market based on daily data as well as on 30-minutes data in sample and out of sample.

4.2 Basics on technical trading systems

Technical analysis tries to derive profitable buy and sell signals by isolating upward and downward price trends or runs around which the price fluctuates from oscillations around a stable level, called "whipsaws" in the traders' jargon (*Kaufman*, 1987; *Murphy*, 1986; "technical day trading" is dealt with in *Deel*, 2000, and *Velez-Capra*, 2000).

One can classify technical trading systems in two different ways. First, according to the method of processing price data one can distinguish between qualitative and quantitative approaches. Second, according to the timing of trading signals one can distinguish between trend-following strategies and contrarian strategies. Trend-following systems produce buy (sell) signals in the early stage of an upward (downward) trend whereas contrarian strategies produce sell (buy) signals at the end of an upward (downward) trend, e. g., contrarian models try to identify "overbought" ("oversold") situations.[7])

The qualitative approaches rely on the interpretation of some (purportedly) typical configurations of the ups and downs of price movements like head and shoulders, top and bottom formations or resistance lines (most of these approaches are contrarian, e. g., they try to anticipate trend reversals). The chartist trading techniques contain therefore an important subjective element.

The quantitative approaches try to isolate price runs from non-directional movements using statistical transformations of the series of past prices. Consequently, these models produce clearly defined buy and sell signals, which can be accurately tested. The most common quantitative trading systems are moving average models, momentum models and the so-called relative strength index. These types of models are tested in the study. For a simple explanation of how these models work it is in the following assumed that the models are applied to daily data (in the empirical part of this study also intraday data will be used, namely, exchange rates at 30-minutes intervals).

4.3 Types of technical models and types of trading signal generation

The first type of model consists of a short-term moving average (MAS_j) and an long-term moving average (MAL_k) of past prices. The length j of MAS usually varies between 1 day (in this case the original price series serves as the shortest possible MAS – see figures 1 and 2 as examples) and 10 days, the length k of MAL usually lies between 10 and 40 days.

The basic trading rule of average models is as follows (signal generation 1):

Buy (go long) when the short-term (faster) moving average crosses the long-term (slower) moving average from below and sell (go short) when the converse occurs. Or equivalently: Open a long position when the difference (MAS_j-MAL_k) becomes positive, otherwise open a

[7]) In the behavioral finance literature trend-following approaches are called "momentum strategies", however, in this study they are termed "trend-following" since in the terminology of technical analysis "momentum" refers to a specific type of model which can be trend-following as well as contrarian.

short position. If one expresses this difference as percentage of MAL_k one gets the moving average oscillator:

$MAO(j,k)_t = [(MAS_{j,t}-MAL_{k,t})/MAL_{k,t}]*100$

This type of representation facilitates a (graphical) comparison of the signal generation between moving average models and momentum models (see figures 1 and 2).

The second type of model works with the relative difference (rate of change in %) between the current price and that i days ago:

$M(i)_t = [(P_t - P_{t-i})/ P_{t-i}]*100$

The basic trading rule of momentum models is as follows (signal generation 1):

Buy (go long) when the momentum M(i) turns from negative into positive and sell (go short) in the opposite case.

The variables MAO(j,k) or M(i) are called "oscillators" because they fluctuate around zero (see figures 11 and as empirical example figure 12).

The basic trading rule of moving average models and momentum models (SG 1) is trend-following since $MAS_{j,t}$ (P_t) exceeds (falls below) $MAL_{k,t}$ (P_{t-i}) only if an upward (downward) price movement has persisted for some days (depending on the lengths of the moving averages and the time span i in the case of momentum models, respectively).

There exist many modifications of the basic version of moving average and momentum models (see, e. g., Kaufman, 1987, chapters 5 and 6). The most common consists of a band with varying width around zero combined with different rules of opening a long, short or neutral position when the moving average oscillator or the momentum oscillator cross the upper bound, lower bound or the zero line. These rules – termed SG 2 to 6 in this study – are either trend-following or contrarian.

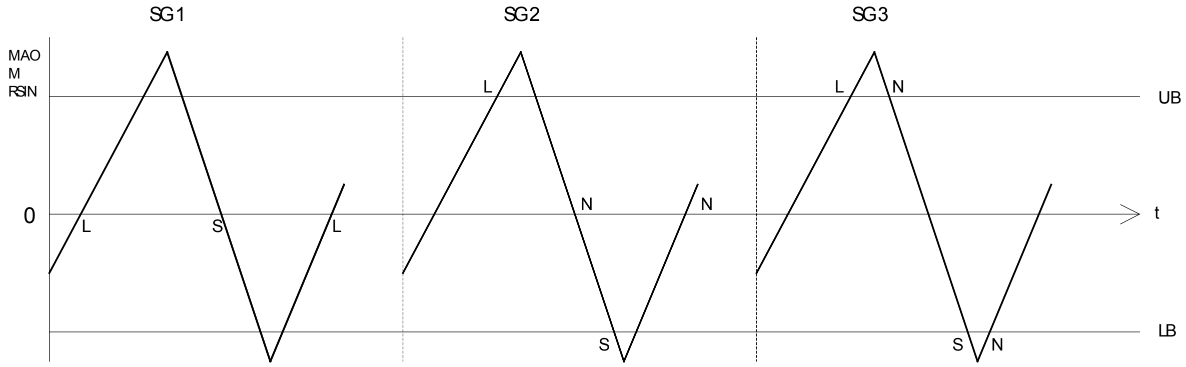
According to signal generation 2 one opens a long (short) position whenever the oscillator crosses the upper (lower) bound from below (above). When the model holds a long (short) position and the oscillator crosses the zero line from above (below) then the model switches to a neutral position. Figure 11 clarifies the meaning of this rule by comparing it to SG 1.

Rule SG 2 is "more" trend-following than SG 1 since it opens a long or short position at a later stage of a price trend (dependent on the width of the band). At the same time SG 2 is more "cautious" than SG 1 since it always holds a neutral position between switching from long to short and vice versa. Holding a neutral position as long as a price movement has not gained some persistence aims at avoiding losses during "whipsaws".

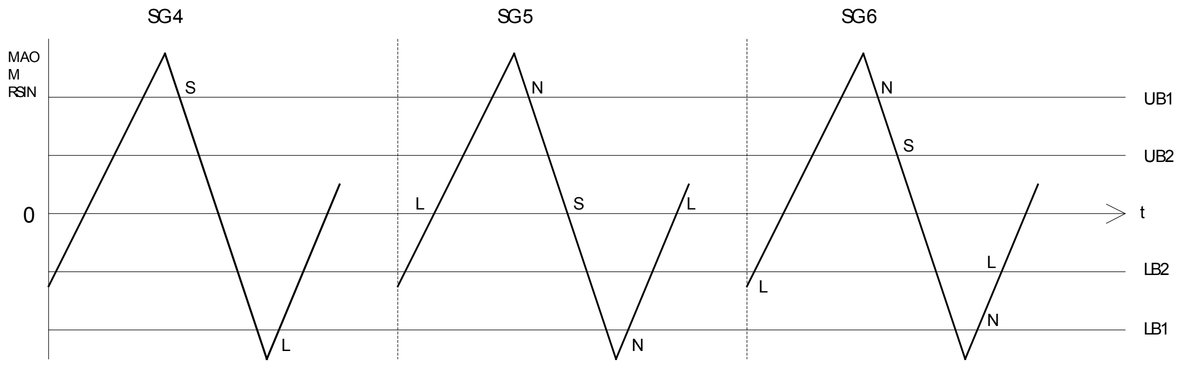
Rule SG 3 differs from SG 2 insofar as the former switches from an open to a neutral position earlier than the latter. Whenever the oscillator crosses the upper (lower) band from above (below) rule SG 2 turns from long (short) to neutral. Hence, when following SG 2 a trader holds a neutral position as long as the oscillator remains within the band around the zero line. This means in the case of a momentum oscillator, e. g., that one closes a long position even if the current price still exceeds the price i days ago, provided that the (positive) rate of change $[(P_t - P_{t-i})/ P_{t-i}]*100$ is declining and falls below the level of the upper bound.

Figure 11: Signal generation of technical trading systems

Trend-following systems



Contrarian Systems



SG	Signal generation
L	Open a long position (buy)
S	Open a short position (sell)
N	Go neutral (close the long position = sell; close the short position = buy)
MAO	Moving average oscillator
M	Momentum oscillator
RSIN	Relative strength oscillator (normalized)
UB	Upper bound
LB	Lower bound

The trading rules SG 4 to 6 can be considered contrarian since they try to identify "overbought" ("oversold") situations. A price configuration is believed to indicate an overbought situation when the moving average (momentum) oscillator is falling below a certain – still positive – level (marked by the upper bound of the band). If the oscillator is rising – though still negative – the situation is considered oversold once the oscillator crosses the lower bound from below. Figure 11 shows the differences between the 3 contrarian trading rules:

Rule SG 4 is always either long or short (as is the trend-following rule SG 1). According to SG 4 a trader switches from a long (short) to a short (long) position once the moving average or momentum oscillator crosses the upper (lower) bound from above (below). Hence, even if the rate of price change in the case of a momentum model is still positive the model SG 4 switches from a long to a short position once the rate of price change falls below the level of the upper bound.

Rule SG 5 is more "cautious" than SG 4 insofar as the former goes at first neutral when the oscillator penetrates the upper (lower) bound from above (below), and switches to a short (long) position only if the oscillator penetrates the zero line.

Rule SG 6 operates with a second (inner) band marked by UB2 and LB2 (UB1>UB2>LB2>LB1). This model holds a neutral position whenever a falling (rising) oscillator lies between UB1 and UB2 (LB1 and LB2) and, hence, is less often neutral as compared to SG 5. Model SG 6 opens a new long (short) position later than SG 4 but earlier that SG 5, SG 6 can therefore be considered a combination of SG 4 and SG 5. At the extreme values of UB2 (LB2) the model SG 6 is identical either with SG 4 (when UB2=UB1 and LB2=LB1) or with SG 5 (when UB2=LB2=0).

One of the most popular indicators for identifying overbought and oversold conditions is the so-called Relative Strength Index (RSI). Since the strategy of following this index is contrarian only the trading rules SG 4 to SG 5 can be applied. The n-day Relative Strength Index is defined as follows (*Kaufman*, 1987, p. 99).

$RSI(n)_t = 100 – \{100/1+[Up_t(n)/Down_t(n)\}$

Where

$Up_t(n) = 1/n\Sigma D_i$ for $D_i>0$

$Down_t(n) = 1/n\Sigma D_i$ for $D_i<0$

and D_i is the (daily) priced change:

$D_i = P_{t-i+1} - P_{t-I}$ for i = 1…….n

The size of the RSI(n) oscillator does not only depend on the overall price change $P_t – P_{t-n}$ (as the momentum oscillator) but also the persistence (degree of monotonicity) of this change, e. g., the less counter-movements occur during an upward (downward) trend the higher (lower) is RSI(n) for any given price change $P_t – P_{t-n}$. If the RSI(n) falls (rises) again below (above) a certain level (the upper/lower bound of the RSI oscillator) the situation is considered overbought (oversold).

The original RSI fluctuates between 0 and 1. To make this oscillator comparable to the moving average and the momentum oscillator, respectively, one can calculate a normalized RSI (=RSIN) which fluctuates around zero:

$RSIN(n)_t = 1/100\ [RSI(n)_t – 0,5]*2$

The contrarian trading rules SG 4, SG 5 and SG 6 can then be applied to this normalized index in the same way as to the moving average oscillator and the momentum oscillator, respectively.

4.4 Model selection

The study investigates a great variety of technical models. When testing the performance of trading based on 30-minutes data the length of the short-term and long-term moving average (MAS and MAS, respectively) as well as the time span *i* in the case of momentum models are greater than when trading is based on daily data. This reason for that differentiation is simple: As the data frequency of 30-minutes exchange rates is 48 times higher than of daily rates, the "underlying" trends comprise in general more time units when 30-minutes data are used that when daily data are used. However, in order to avoid the suspicion of "model mining", the parameters of the daily models and of the 30-minutes models differ not "too" much from each other. [8])

More specifically, the following models are selected for testing the profitability of currency trading based on daily data:

- Bands: As wider upper and lower bound (UB1 and LB1, respectively) a value of 0.3 and -0,3, respectively, is chosen for all models. The values of the inner band are 0.15 and -0.15, respectively.
- Moving average models: All combinations of a short-term moving average (MAS) between 1 and 15 days and a long-term moving average (MAL) between 30 and 50 days are tested. Hence, 315 moving average models are used for each of the six types of signal generation, for a total of 1890 models (= 6*315).
- Momentum models: All models with a time span I between 20 and 50 days are tested, i. e., a total of 186 models (= 6*31).
- RSIN models: All models with a time span i between 10 and 30 days are tested. Since RSIN models are only of the contrarian type, additional values for the wider band and the inner band are used, namely (-)0.35/(-)0.175 and (-)0.4/(-)0.2. Hence, a total of 189 RSIN models are tested (= (3*3*21).
- In total, the performance of 2265 technical models in trading daily exchange rates is investigated.

When trading based on 30-minutes exchange rates is simulated, the following models are used:

- Bands: The same bands are used as for daily models.
- Moving average models: All combinations of a short-term moving average (MAS) between 10 and 20 time units (i. e., 30-minutes intervals) and a long-term moving average (MAL) between 40 and 70 time units are investigated. Hence, a total of 2046 moving average models is tested (= 6*11*21).

[8]) Similar sets of models were used when testing the profitability and price effects of technical trading based on daily data in the foreign exchange market (*Schulmeister*, 2006; 2008A; 2008B) and - based on daily as well as on 30-minutes data - in the stock market (*Schulmeister*, 2009C).

- Momentum models: All models with a time span I between 30 and 50 days are selected. In addition to the standard bands (-)0.3/(-)0.15 also the band (-)0.4/(-)0.2 are tested, i. e., a total of 231 models (= 21 + 2*5*21).
- RSIN models: The same models are tested as in the case of daily data (189 models).
- In total, the performance of 2466 technical models in trading 30-minutes exchange rates is simulated.

The samples comprise a wide range of different technical models. The "fastest" daily models like a RSIN model with a time span of 10 (days) produce roughly 45 trading signals per year. Hence, open positions generated by these models last only 8 days on average.[9]) The "slowest" models like the MA model 15/50 (MAS=15, MAL=50) produce only 6 trading signals per year, their open positions last roughly 60 days on average. When trading based on 30-minutes data is simulated, open positions of the "slowest" models last even 11 times longer than open positions generated by the "fastest" 30-minutes models (roughly 2 days and 4 hours, respectively).

The approach of model selection adopted in this study differs from the usual procedure of testing the profitability of trading rules. In most studies, this is done in the following way. The researcher selects out of a sample of some hundreds or even thousands different rules the best performing one and then tests for the statistical significance of their profitability. This is done using the "bootstrap" methodology (see, e. g., *Brock-Lakonishok-LeBaron*, 1992; *Levich-Thomas*, 1993) and in addition the "reality check for data snooping" (see, e. g., *Sullivan – Timmermann - White*, 1999; *Park-Irwin*, 2005; *Neely – Weller – Ulrich*, 2007; *Marshall – Cahan – Cahan*, 2008). In most cases it then turns out that the ex-post best performing models do not survive these tests. The reason is simple: Their ex-post-profitability is mainly due to "data snooping" or "model mining" and, hence, is achieved just by chance.

To put it differently: Since the researcher restricts the analysis of the performance of trading systems to only a few ex-post best performing models he himself practices a "biased selection" which he then "detects" by testing for a "data snooping bias". From this result it is then concluded that technical trading in general is not consistently profitable. Such a conclusion is not warranted because in practice (experienced) technical traders do not use such a (necessarily biased) optimization procedure. By contrast, the literature for practitioners warns against (over)optimization precisely because this causes one to select a model out of the extreme right tail of a probability distribution of a great number of models. In particular, it is warned against the use of a very great number of "test models" since the probability of committing a "selection error" increases with the number of "test models". For these reasons practitioners restrict their selection to a range of models which have performed relatively

[9]) For models which are always in the market (no neutral positions) like SG1 or SG3, the relationship between trading signals, transactions and open positions is as follows. The number of overall transactions is twice the number of trading signals minus 2 since every signal induces two transactions, namely, closing the former position and opening the new one (except for the first and last signal). The number of open positions is therefore half the number of transactions.

stable over the long run (the literature often concretizes the parameter ranges for a specific market) instead of choosing a model which performed best over a recent (and arbitrarily specified) "test period".

The present study documents therefore the performance of the total sample of more than 2000 technical models, which are selected according to a certain range of the model parameters. Due to the generally defined selection criteria used for the dollar/euro market as well as for the dollar/DM market, many of the models under investigation produce substantial losses (as shall later be documented). In addition, the procedure of analyzing technical trading systems applied in the present study was already used in studies on the performance trading systems in the foreign exchange market as well as in the stock market and in the commodity futures market (*Schulmeister*, 2006, 2008A, 2009B, 2009C, 2009A). For these reasons, the results of these studies as well as of the present study can hardly be attributed to "data snooping".

4.5 Assumptions underlying the simulation of technical currency trading

The data base for testing technical currency trading covers the actual spot rate at 17 hours Greenwich mean time or the first rate realized thereafter. At this time, the foreign exchange market is particularly liquid (trading is done in London as well as in the US). The 30-minute data run each week from Sunday, 22,30 hours Greenwich mean time (when trading starts on Monday in East Asia) to Friday, 22,00 hours.

Transaction costs are estimated at 0.01%. This estimate implies a bid-ask spread of 3 basis points as is typical for the most liquid foreign exchange market, i. e., the dollar/euro market.

The profitability of the trading systems is calculated in the following way. The single rate of return (SRR_i) from any position i opened at time t and closed at t+n is

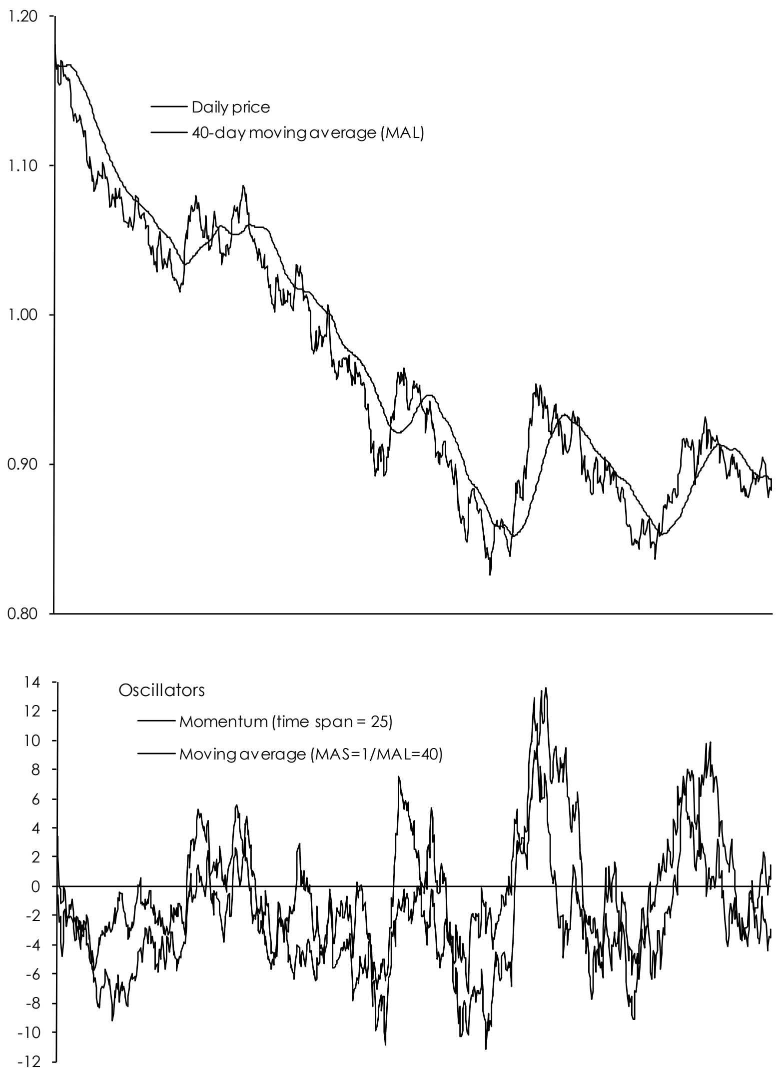
$SRR_i = \{(P_{t+n} - P_t)/P_t\} * 100$ for long positions (P_{t+n} is the sell price)

$SRR_i = \{(P_t - P_{t+n})/ P_t\} * 100$ for short positions (P_t is the sell price)

The single rates of return can be considered as absolute returns in cents if one assumes that there is always 1$ in the game (value of any open position). The sum of all positive (negative) returns gives the gross profits (losses). The gross rate of return (per year) is then the difference between gross profits (per year) and gross losses (per year). If one subtracts transaction costs one gets the net rate of return (the number of transactions is always twice the number of open positions and, hence, of the single returns).

For any open position, interest is earned from the long position and paid for the short position. If one calculates the overall interest effect using the information on the duration of the long and the short dollar positions and on the interest differential it turns out that this effect was close to zero during the sample period (similar results were already reported in by *LeBaron*, 1999, and *Schulmeister*, 2000).

Figure 12: Technical trading signals for DM/euro trading
1999/01/04 - 2001/12/31



The gross rate of return (GRR) of any technical trading model can be split into six components, the number of profitable/unprofitable positions (NPP/NPL), the average return per day during profitable/unprofitable positions (DRP/DRL), and the average duration of profitable/unprofitable positions (DPP/DPL). The following relationship holds:

GRR = NPP*DRP*DPP – NPL*DRL*DPL

The probability of making an overall loss when blindly following a technical trading model is estimated by testing the mean of the single rates of return against zero (only if it is negative does the trading rule produce an overall loss).[10])

[10]) The t-statistic of the means of the single returns measures their statistical significance and, hence, estimates the probability of making an overall loss when following a specific trading rule. The t-statistic is therefore conceptually

4.6 Performance of technical trading based on daily dollar/euro rates 1999-2006

Figure 12 and table 11 show how a simple moving average model (MAS=1, MAL=40) and a momentum model (time span i = 25) perform when trading the dollar/euro exchange rate based on daily data between January 2, 1999 and December 31, 2001. After five single losses, the MA model successfully exploits a downward trend between January 15, and May 6, 1999: The current exchange rate, which serves as MAS, is lower than the MAL (the MA oscillator is negative), hence, the model keeps holding a short position. The single profit from this position amounts to 7.40% or cents if one assumes that there is always 1$ in the "game". Figure 12 and table 11 demonstrate that the MA model produces many more single losses than single profits, however, the losses are much smaller than the profits since the former are due to minor price fluctuations whereas the latter stem from "riding" persistent trends (this pattern of profitability is typical for technical trading in general).

Over the entire trading period of 3 years, the MA model 1/40 would have achieved a gross rate of return per year (GRR) of 8.8% % per year (the GRR of the momentum model was 25 11.9). The components of the profitability of the sample model are as follows (table 11):

- The number of profitable trades per year is lower than the number of unprofitable trades (5 relative to 9).
- The average return per day during profitable positions is smaller (in absolute terms) than during unprofitable positions (0.06 relative to -0.13).
- Profitable positions last on average almost 10 times longer than unprofitable positions (60.5 days relative to 6.9).

The overall profitability of the model is therefore due to the exploitation of persistent exchange rate trends. This pattern is typical for the performance of technical trading systems in general: Smaller fluctuations often cause technical models to produce losses, which, however, are small, precisely because the fluctuations are small.

The distribution of the single rates of return reflects these properties of technical trading systems (for the MA model 1/40 see table 11):

- The median is negative.
- The standard deviation is several times higher than the mean.
- The distribution is skewed to the right and leptokurtotic.

The probability of making an overall loss by blindly following a technical trading system is estimated by testing the mean of the single rates of return against zero (only if it is negative does the trading rule produce an overall loss). For our sample model the t-statistic amounts to

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different from the Sharpe ratio which measures the univariate risk-return relation. As the number of observations goes to infinity, an estimated t-statistic will go to zero or to positive or negative infinity. By contrast, an estimated Sharpe ratio will converge to the true Sharpe ratio. However, in the context of the present study (with finite samples) the informational content of the t-statistic and the Sharpe ratio is equivalent. This is so because the t-statistic differs from the Sharpe ratio only by the factor $\sqrt{n-1}$ (where n is the sample size) and by the risk-free rate.

1.72. Hence, the probability of making an overall loss by following this model over the entire sample period of 3 years was roughly 5%.

Table 11: Performance of a moving average model 1999 - 2001

Price series: Daily dollar/euro exchange rate
Begin of trading: 04/01/1999
End of trading: 31/12/2001

Short-term moving average (MAS):	1
Long-term moving average (MAL):	40

The sequence of long, short and neutral positions

Date	Signal	Duration	Price	Single rate of return	Rate of return per year
:	:	:	:	:	:
:	:	:	:	:	:
1999/05/06	l	111	1.08	7.40	7.27
1999/05/11	s	5	1.07	-0.79	4.71
1999/07/20	l	70	1.04	2.73	8.10
1999/08/25	s	36	1.04	0.07	6.96
1999/08/31	l	6	1.06	-1.50	4.50
1999/09/09	s	9	1.05	-0.42	3.72
1999/09/29	l	20	1.06	-0.85	2.29
1999/10/26	s	27	1.06	-0.52	1.44
2000/01/04	l	70	1.03	2.63	3.79
2000/01/14	s	10	1.01	-1.74	2.00
2000/02/22	l	39	1.01	0.73	2.45
2000/02/24	s	2	0.99	-1.29	1.30
2000/05/26	l	92	0.93	6.65	5.84
2000/07/12	s	47	0.94	1.03	6.03
2000/11/03	l	114	0.86	9.20	10.02
:	:	:	:	:	:
:	:	:	:	:	:
2000/12/31	n	0	0.89	0.00	8.77

The Profitability of the trading system

Gross rate of return	8.77
Net rate of return	8.49
Average duration of positions	26.00
Long	15.76
Short	36.24
Neutral	0.00
Sum of profits per year	16.79
Profitable positions	
Number per year (NPP)	5.01
Average return	
Per position (RPP)	3.35
Per day (DRP)	0.055
Average duration (DPP)	60.47
Sum of losses per year	-8.02
Unprofitable positions	
Number per year (NPL)	2.68
Average return	
Per position (RPL)	-0.89
Per day (DRL)	-0.130
Average duration (DPL)	6.85
Distribution of the single rates of return	
Mean	0.63
t-statistic	1.49
Median	-0.51
Standard deviation	2.68
Skewness	1.72
Excess kurtosis	2.03
Sample size	42

Table 12: Components of the profitability of 2265 trading systems 1999 - 2006
Price series: Daily dollar/euro exchange rate

	Number of models		Mean over each class of model									
	Abolute	Share in %	Gross rate of return	t-statistic	Net rate of return	Profitable positions			Unprofitable positions			
						Number per year	Return per day	Duration in days	Number per year	Return per day	Duration in days	
t-statistic of the mean of the single returns												
< 0	59	2.6	-1.1	-0.350	-1.5	7.87	0.078	25.93	14.00	-0.116	11.69	
0 - < 1.0	456	20.1	2.1	0.623	1.7	6.10	0.062	44.62	11.04	-0.109	11.85	
1.0 - <=2.0	1679	74.1	4.8	1.487	4.6	3.85	0.049	71.44	6.28	-0.081	18.52	
> 2.0	71	3.1	6.9	2.118	6.6	5.61	0.054	54.05	8.05	-0.089	13.37	
All models	2265	100.0	4.2	1.285	3.9	4.47	0.052	64.31	7.49	-0.088	16.84	
Moving average models	1890	83.4	4.5	1.374	4.3	3.76	0.049	70.88	6.35	-0.082	18.46	
Momentum models	186	8.2	4.3	1.259	3.9	6.90	0.053	40.78	12.08	-0.104	8.25	
RSIN models	189	8.3	1.1	0.416	0.6	9.11	0.084	21.81	14.40	-0.127	9.05	
1999 - 2000	2265	-	8.7	1.038	8.5	4.35	0.068	72.21	6.11	-0.102	17.11	
2001 - 2002	2265	-	2.9	0.427	2.6	4.98	0.056	55.68	9.05	-0.099	14.92	
2003 - 2004	2265	-	5.1	0.709	4.8	4.74	0.058	61.07	7.33	-0.117	15.06	
2005 - 2006	2265	-	0.6	0.109	0.3	4.28	0.043	58.18	8.30	-0.061	21.20	

Table 12 classifies all models according to their performance as measured by the t-statistic into four groups and quantifies the components of profitability for each of them. A t-statistic greater than 2.0 is achieved by only 3.1% of all models, the average rate of return per year (GRR) over these models amounts to 6.9%. The t-statistic of most models (74.1%) lies between 1.0 and 2.0 (GRR: 4.6%), 20.1% generate a t-statistic between 0.0 and 3.5 (GRR: 2.1%). The share of unprofitable models is 2.6%, their average rate of return is -1.1%. All 2265 technical models produce an average GRR of 4.2% per year. Since the models produce only 13.7 open positions per year on average, the net rate of return (NRR) is only slightly smaller (3.9%) than the gross rate.

Moving average models perform slightly better than momentum models (GRR: 4.5% and 4.3% per year, respectively), RSIN models perform comparatively poorly (GRR: 1.1%).

The pattern of profitability is the same for each class of models (table 12). The number of single losses exceeds the number of single profits, the average return per day (in absolute terms) is higher during unprofitable positions than during profitable positions, hence, the overall profitability is only due to profitable positions lasting roughly four times longer than unprofitable positions. The same pattern of profitability was found when testing the performance of technical trading systems in the dollar/deutschmark market (*Schulmeister*, 2008A), in the yen/dollar market (*Schulmeister*, 2009B), in the US stock market (*Schulmeister*, 2009C) and in four commodity futures markets (*Schulmeister*, 2009A).

In order to investigate the performance of technical trading in the dollar/euro market, the overall sample period 1999/2006 is divided into 4 sub-periods each lasting 2 years. As table 12 shows, the models would have been profitable over each sub-period on average. However, their performance varies across sub-periods: Over the first sub-period (1999/2000), the models would have produced an average GRR of 8.7% per year, whereas their GRR would have amounted to only 0.6% over the last sub-period (2005/2006).

Table 18 shows that the same 2265 models would have been similarly profitable when trading the dollar/DM exchange rate between 1987 and 1998. Also over this period did the profitability decline over time. This result is in line with other studies on technical trading in the foreign exchange market (*Ohlson*, 2004; *Neely – Weller – Ulrich*, 2007; *Schulmeister*, 2008B) as well as in the stock market (*Schulmeister*, 2009C).

The decline in the profitability of technical trading can be explained in four different ways:

- In the first case, the profitability of trading rules as reported in several studies was merely the result of "data mining" and, hence, cannot be reproduced out of sample. In a recent study *Neely – Weller – Ulrich* (2007) reject this hypothesis for most studies they evaluated.
- In the second case, markets become gradually more efficient in an evolutionary process as expected by the Adaptive Market Hypothesis (AMH). This theoretical concept was developed by *Lo* (2004) as an alternative to the too rigid Efficient Market Hypothesis (EMH). By learning to exploit profit opportunities, market participants will gradually erode these opportunities. According to *Neely – Weller – Ulrich* (2007) the results of their out-of-sample-tests support the AMH.
- In the third case, the continuous rise in the "speed" of transactions causes technical traders to use increasingly intraday data instead of daily data.[11]) This development could have caused intraday exchange rate movements to become more persistent and, hence, exploitable by technical models. As a consequence, exchange rate changes based on daily data have become bigger and more erratic which in turn causes technical trading on the basis of daily data to become less profitable.[12])
- In the fourth case, technical traders use increasingly more complex trading models instead of traditional rules like moving average or momentum rules. Such a shift will in turn change the trending pattern of exchange rates and, hence, cause traditional models to become unprofitable (for the feed-back of the aggregate trading behaviour of technical models on exchange rate movements see *Schulmeister*, 2006 and 2009B). Such a shift to more complex trading rules will be strengthened by the shift to intraday data

[11]) Such a shift to using data of higher frequencies than daily data when applying (automated) trading systems has most probably contributed to the tremendous increase in transaction volume in financial markets in general and in foreign exchange markets in particular (as documented in *Schulmeister – Schratzenstaller – Picek*, 2008). E.g., between 1986 and 2007 currency transactions in spot and derivatives markets rose by 15.0% per year.

[12]) Studies on the profitability of technical currency trading based on intraday data arrive at mixed results. *Osler* (2000), *Dempster-Jones* (2002) and *Gencay et al.* (2003) find this type of trading to be profitable, *Curcio et al*. (1997) and Neely-Weller (2003) arrive at the opposite conclusion. As regards stock trading, *Schulmeister* (2008B) reports that the profitability of technical models in the stock index futures market has been declining over the 1990s when based on daily data but has remained roughly the same when based on 30-minute-data. However, since 2000 the profitability of technical stock trading based on 30-minute-data has been declining (it might have shifted to even higher data frequencies and/or the use of more complex rules).

since the latter call for more sophisticated techniques to filter out short-term trends (exchange rate volatility rises with data frequency as is documented in chapter 3 of this study).

Also the AMH expects that new and more sophisticated trading strategies will emerge once the "old" and simpler rules have become unprofitable. The main difference between the AMH and the hypotheses 3 and 4 sketched above is as follows. The AMH assumes that any originally profitable trading rules will become gradually less profitable because more and more people use them (i.e., through the classical arbitrage mechanism). As a consequence, smart traders seek for and finally discover new profitable rules.

By contrast, the hypotheses 3 and 4 assume that the causality runs from the use of new and more complex rules based on an ever increasing data frequency to the erosion of the profitability of the older and simpler rules. This effect is mainly due to the change in the trending pattern of asset prices caused by the gradually increasing use of the new trading strategies. To shed more light on this issue, sections 4.7 and 4.9 of this study explores the performance of technical currency trading based on 30-minutes data.

Table 13: Cluster of 2265 trading systems according to profit components 1999 - 2006
Price series: Daily dollar/euro exchange rate

	Number of models		Mean over each class of model									
	Abolute	Share in %	Gross rate of return	t-statistic	Net rate of return	Profitable positions			Unprofitable positions		
						Number per year	Return per day	Duration in days	Number per year	Return per day	Duration in days
All models											
Cluster 1	444	19.6	2.9	0.901	2.5	8.06	0.068	30.97	14.40	-0.122	7.34
Cluster 2	1039	45.9	4.3	1.288	4.1	4.10	0.052	61.12	6.96	-0.088	15.52
Cluster 3	782	34.5	4.7	1.499	4.6	2.91	0.045	87.47	4.28	-0.068	23.99
Total	2265	100.0	4.2	1.285	3.9	4.47	0.052	64.31	7.49	-0.088	16.84

In order to detect similarities in the trading behaviour of certain groups of technical models, statistical clustering techniques are used. These methods classify all models into similar groups in the following way. All models characterized by a certain number of variables (profitability components in our case) are assigned to different clusters under the condition that the differences between the models are minimized within each cluster and maximized across clusters. For this (descriptive) exercise the simple approach called K-Means Cluster Analysis was adopted (provided by the SPSS software package). In this case the number of clusters has to be predetermined (here three clusters are sufficient to illustrate characteristic differences in the trading behaviour of technical models).

Table 13 displays the results of the cluster analysis. When trading the daily dollar/euro exchange rate the 444 models of cluster 1 produce the highest number of open positions (22.4 per year on average), mainly for that reason the duration of profitable positions is relatively short (31.0 days on average). Cluster 1 comprises therefore those ("fast") models which are most sensitive to price changes. The 1039 models of cluster 2 signal 14.1 open positions per year, the profitable positions last 61.1 days on average. Cluster 3 comprises 782 models holding only 7.2 open positions per year, their profitable positions last 87.5 days on average ("slow" models).

The results of the cluster analysis con be interpreted in the following way (table 13). First, the models of cluster 1 "specialize" on the exploitation of short-term exchange rate trends, those of cluster 2 "specialize" on medium-term trends, whereas the models of cluster 3 exploit mainly long-term trends. Second, since exchange rate trends tend to be the steeper the shorter they last, the daily returns during profitable positions are highest for the models of cluster 1 and lowest for the models of cluster 3. Third, the daily losses during the – comparatively shorter – unprofitable positions are also highest in the case of cluster 1, and lowest in the case of cluster 3 (the slope of the ups and downs during whipsaws are steeper than during trends, even if the trends last only short). Fourth, the ratio between the number of profitable and unprofitable positions is smaller for the models of cluster 1 and highest for the models of cluster 3.

As result of the differences in the profitability pattern, the models of cluster 1 produce on average a smaller GRR (2.9%) than the models of cluster 2 and cluster 3 (4.3% and 4.7%, respectively).

Chapter 3 of this study has shown that persistent exchange rate trends occur "abnormally" frequently. In this chapter, the ex-post-analysis of the profitability pattern of technical currency trading reveals that it is precisely this trending behaviour of exchange rates which causes technical models to be profitable. However, the relationship between exchange rate trending and ex-post-profits from technical trading does not ensure the profitability of technical trading ex ante. If, e. g., a trader selects a model that would have performed best over the most recent past for trading over a subsequent period, then he might become a victim of his own "model mining" for the following reason.

Table 14: Performance of the 25 most profitable trading systems by subperiods in sample and out of sample 1999 - 2006

Price series: Daily dollar/euro exchange rate

	In sample				Out of sample			
	Gross rate of return	t-statistic	Net rate of return	Duration of profitable positions	Gross rate of return	t-statistic	Net rate of return	Duration of profitable positions
1999 - 2000	18.5	2.2	18.2	42.5				
2001 - 2002	10.1	1.4	9.9	59.2	-0.3	-0.1	-0.9	29.8
2003 - 2004	11.8	1.6	11.5	52.1	5.7	0.8	5.4	57.6
2005 - 2006	9.7	1.7	9.4	33.8	-0.1	0.0	-0.4	52.3
1999 - 2006	12.5	1.7	12.3	46.9	1.8	0.3	1.4	46.6

The ex-post profitability of the best models consists of two components. The first stems from the "normal" non-randomness of exchange rate dynamics, namely, the occurrence of persistent price trends. The second component stems from the selection or overfitting bias since a part of the ex-post profits of the best models would have been produced only by chance (*Sullivan-Timmerman-White*, 1999). Now, if the "optimal" profitability of a selected model is mainly the result of this "model mining" then this model will perform much worse over the subsequent period. However, if the in-sample profitability stems mainly from the exploitation of "usual" exchange rate trends then it might be reproduced out of sample.

In order to investigate this matter, I shall simulate a hypothetical “model optimization” in the following way. In a first step, the 25 best models are identified on the basis of their ex-post-performance (measured by the net rate of return) over the most recent sub period (in sample). Then the performance of the selected models is simulated over the subsequent sub-period (out of sample).

Table 14 shows that the gross and net rates of return of the 25 best models would have been roughly three times higher than the average returns of all 2265 models (table 12). However, the out-of-sample-performance of the 25 best models is rather poor, only over the sub-period 2003/04 would these models have been markedly profitable. This result is in line with previous studies on technical trading in the dollar/DM market and in the dollar/yen market. In both cases, technical currency trading based on daily data was highly profitable in sample as well as out of sample until the mid 1990s. Since then, however, this trading strategy would have been no longer profitable.

In the following section, I shall address the question whether this result could be due to a shift in technical trading from daily data to intraday data. More specifically, section 4.7 deals with the performance of 2466 technical models when trading the dollar/euro exchange rate based on 30-minutes data.

4.7 Performance of technical trading based on dollar/euro rates at 30-minutes intervals 1999-2006

As a comparison of table 15 with table 12 shows, that technical currency trading performed worse when based on 30-minute data than when based on daily data. This difference is particularly great in the case of net returns. Whereas the daily models produce a net rate of return (NRR) of 3.9% per year on average, the 30-minutes models would have incurred an annual net loss of 6.1%. The reason for that is simple. The models based on 30-minutes data produce on average 363 open positions per year (daily models: 11.4). The related transaction costs cause the NRR to be by 7.2 percentage points smaller than the still slightly positive GRR (1.1% on average).

Table 15: Components of the profitability of 2466 trading systems 1999 – 2006
Prices series: Daily dollar/euro exchange rate

	Number of models		Mean over each class of model								
	Abolute	Share in %	Gross rate of return	t-statistic	Net rate of return	Profitable positions: Number per year	Profitable positions: Return per day	Profitable positions: Duration in days	Unprofitable positions: Number per year	Unprofitable positions: Return per day	Unprofitable positions: Duration in days
t-statistic of the mean of the single returns											
< 0	811	32.9	-2.4	-0.886	-11.0	158.7	0.309	1.89	271.7	-0.454	0.83
0 - < 1.0	930	37.7	1.5	0.524	-4.9	122.8	0.306	1.51	196.5	-0.449	0.72
1.0 - <=2.0	649	26.3	4.3	1.373	-2.3	134.0	0.314	1.65	195.2	-0.442	0.96
> 2.0	76	3.1	7.7	2.272	-1.7	186.9	0.328	1.71	281.8	-0.470	1.09
All models	2466	100.0	1.1	0.338	-6.1	139.5	0.310	1.68	223.5	-0.449	0.83
Moving average models	2046	83.0	1.3	0.386	-2.7	80.0	0.274	1.90	117.9	-0.371	0.96
Momentum models	231	9.4	3.4	1.085	-12.9	294.5	0.393	0.79	517.6	-0.733	0.25
RSIN models	189	7.7	-3.5	-1.096	-35.6	595.0	0.592	0.32	1007.0	-0.953	0.12
1999 - 2000	2466	-	-5.2	-0.816	-12.8	141.9	0.344	1.69	238.9	-0.542	0.78
2001 - 2002	2466	-	2.5	0.409	-4.9	144.1	0.318	1.62	225.6	-0.465	0.80
2003 - 2004	2466	-	3.8	0.578	-3.5	141.5	0.324	1.64	223.5	-0.436	0.85
2005 - 2006	2466	-	3.4	0.773	-3.4	131.5	0.255	1.78	207.2	-0.353	0.91

As in the case of daily models, the worst performing type of technical model are the RSIN models, mainly because these models trade extremely frequently (they produce 1007.0 unprofitable positions per year on average). By contrast, the MA models produce much less trading signals, their performance is the best of all three types of models, in particular in term of net returns (even though NRR is slightly negative also for MA models – table 15).

Table 16: Cluster of 2466 trading systems according to profit components 1999 - 2006
Price series: Dollar/euro exchange rate at 30-minutes intervals

	Number of models		Mean over each class of model								
	Abolute	Share in %	Gross rate of return	t-statistic	Net rate of return	Profitable positions: Number per year	Profitable positions: Return per day	Profitable positions: Duration in days	Unprofitable positions: Number per year	Unprofitable positions: Return per day	Unprofitable positions: Duration in days
All models											
Cluster 1	102	4.1	-7.0	-2.159	-45.1	708.8	0.642	0.26	1195.4	-0.992	0.11
Cluster 2	252	10.2	2.8	0.858	-18.8	393.8	0.460	0.52	682.3	-0.835	0.16
Cluster 3	2112	85.6	1.3	0.396	-2.7	81.7	0.276	1.89	121.8	-0.377	0.94
Total	2466	100.0	1.1	0.338	-6.1	139.5	0.310	1.68	223.5	-0.449	0.83

The structure of profitability of the 30-minutes models is qualitatively the same as in the case of daily models, however, the pattern is less pronounced with respect to the sole profit source of technical trading, i. e., the difference in duration of profitable and unprofitable positions. When trading is based on daily data, profitable positions last roughly four times longer than unprofitable positions (table 12) but only twice as long when 30-minutes data are used (table 15). This difference reflects the fact that the trending behaviour of exchange rates is the less pronounced the higher is the data frequency (as shown in chapter 3).

Table 16 displays the results of the cluster analysis (again the K-Means Cluster Analysis as provided by the SPSS software package was applied). The "fastest" models of cluster 1 signal a very great number of open positions (1076.1 per year) since these models react quickly even to only minor price movements (such ups and downs occur more frequently on the basis of 30-minutes data than on the basis of daily data). The high transaction frequency of the cluster 1 models causes their average NRR to be almost 40 percentage points smaller than their average GRR.

Table 17: Performance of the 25 most profitable trading systems by subperiods in sample and out of sample 1999 - 2006

Price series: Dollar/euro exchange rate at 30-minutes intervals

	Gross rate of return	t-statistic	Net rate of return	Duration of profitable positions	Gross rate of return	t-statistic	Net rate of return	Duration of profitable positions
	In sample				Out of sample			
- 2000	4.4	0.6	0.0	2.4				
- 2002	12.9	2.0	9.3	2.3	4.2	0.6	-0.3	2.5
- 2004	19.3	2.5	16.0	2.5	12.3	1.7	8.6	2.2
- 2006	13.3	2.3	10.0	2.6	8.0	1.4	5.5	3.5
- 2006	12.5	1.8	8.8	2.4	8.2	1.2	4.6	2.7

The 25 ex-post best performing models produce a GRR of 12.5%, and an NRR of 8.8% per year on average over the entire sample period (table 17). Their profitability was significantly smaller over the first sub-period 1999/2000 (GRR: 4.4%, NRR: 0.0%), it was much greater over the third sub-period 2003/2004 (GRR: 19.3%, NRR: 16.0%). The 25 best models produced positive gross and net returns also out of sample (with the exception of the NRR over the first out-of-sample sub-period). Over the entire out-of-sample period 2001/2006, the 25 best models would have produced an ex-ante GRR of 8.2% per year and a NRR of 4.6% per year. The comparatively high profitability of these models is due to the fact that they focused on the exploitation of relatively long 30-minutes trends: The profitable positions of the 25 best performing models (in sample as well as out of sample) last on average almost twice as long as the profitable positions of all 2466 models (tables 17 and 15).

Table 18: Components of the profitability of 2265 trading systems by classes of the -statistic, by types of models and by subperiods 1987 - 1999
Price series: Daily dollar/DM exchange rate

	Number of models		Mean over each class of model									
	Abolute	Share in %	Gross rate of return	t-statistic	Net rate of return	Profitable positions			Unprofitable positions		
						Number per year	Return per day	Duration in days	Number per year	Return per day	Duration in days
t-statistic of the mean of the single returns											
< 0	23	1.0	-0.8	-0.252	-1.3	10.31	0.092	21.51	17.75	-0.132	8.69
0 - < 1.0	347	15.3	2.2	0.764	1.9	5.56	0.061	53.12	9.39	-0.097	16.33
1.0 - <=2.0	1717	75.8	4.1	1.440	3.9	4.26	0.053	62.57	6.87	-0.084	18.86
> 2.0	178	7.9	6.2	2.228	6.0	4.59	0.053	68.46	6.79	-0.074	22.65
All models	2265	100.0	3.9	1.381	3.7	4.55	0.055	61.17	7.36	-0.085	18.67
Moving average models	1890	83.4	4.1	1.436	3.9	3.76	0.050	67.64	6.08	-0.078	20.76
Momentum models	186	8.2	4.1	1.354	3.7	7.10	0.057	38.02	12.19	-0.105	8.56
RSIN models	189	8.3	2.3	0.855	1.8	9.91	0.098	19.20	15.43	-0.136	7.66
1987 - 1989	2265	-	7.7	1.176	7.5	4.42	0.066	62.14	6.90	-0.070	20.66
1990 - 1992	2265	-	4.9	0.689	4.7	4.69	0.068	61.93	7.43	-0.114	17.42
1993 - 1995	2265	-	1.0	0.228	0.8	4.98	0.044	54.93	7.36	-0.090	20.45
1996 - 1998	2265	-	2.1	0.438	1.8	4.66	0.046	57.10	8.13	-0.077	17.71

4.8 Performance of technical trading based on daily dollar/deutschmark rates 1987-1998

This section reports the performance of the 2265 technical models in the dollar/deutschmark market between 1987 and 1998 based on daily data. Over the entire period, the models produce an average GRR of 3.9% per year, and an average NRR of 3.7% per year (table 18). The performance of the daily models in the dollar/DM market 1987/1998 is very similar to their performance in the dollar/euro market 1999/2006 (GRR: 4.2%; NRR: 3.9%). In both markets do the RSIN models produce the smallest returns. Also the pattern of profitability is similar. When trading the dollar/DM rate, profitable positions last on average 62.1 days, when trading the dollar/euro rate 64.3 days (tables 12 and 18). The results of the cluster analysis reflect these similarities (tables 13 and 19).

The 25 best performing daily models yield a GRR of 11.7% per year in the dollar/DM market in sample (1987/1998) and an GRR of (only) 2.2% per year out of sample (1990/1998). These results are (also) very similar to the performance of the 25 best models in the dollar/euro market (tables 14 and 20).

Table 19: Cluster of 2265 trading systems according to profit components 1987 - 1999
Price series: Daily dollar/DM exchange rate

	Number of models		Mean over each class of model									
	Abolute	Share in %	Gross rate of return	t-statistic	Net rate of return	Profitable positions			Unprofitable positions		
						Number per year	Return per day	Duration in days	Number per year	Return per day	Duration in days
All models											
Cluster 1	440	19.4	3.8	1.283	3.3	8.32	0.076	29.68	14.47	-0.123	7.35
Cluster 2	1197	52.8	4.0	1.368	3.8	4.02	0.052	61.32	6.49	-0.085	17.70
Cluster 3	628	27.7	4.0	1.475	3.8	2.90	0.045	82.94	4.04	-0.060	28.44
Total	2265	100.0	3.9	1.381	3.7	4.55	0.055	61.17	7.36	-0.085	18.67

Table 20: Performance of the 25 most profitable trading systems by subperiods in sample and out of sample 1987 - 1989
Price series: Daily dollar/DM exchange rate

	Gross rate of return	t-statistic	Net rate of return	Duration of profitable positions	Gross rate of return	t-statistic	Net rate of return	Duration of profitable positions
	In sample				Out of sample			
1987 - 1989	17.6	2.4	17.4	58.3				
1990 - 1992	13.3	1.8	13.1	80.0	4.8	0.6	4.5	49.9
1993 - 1995	9.6	1.8	9.2	27.9	1.5	0.3	1.3	80.7
1996 - 1998	6.4	1.4	6.1	63.9	0.4	0.0	0.0	27.9
1987 - 1998	11.7	1.8	11.4	57.5	2.2	0.3	1.9	52.8

4.9 Performance of technical trading based on dollar/deutschmark rates at 30-minutes intervals 1987-1998

The 2466 30-minutes models would have performed slightly better when trading the dollar/DM rate between 1987 and 1998 than when trading the dollar/euro rate between 1999 and 2006 (GRR: 3.4% and 1.1%, respectively). The differences in the performance of the three types of models as well as the pattern of the profitability of technical trading are very similar in the dollar/DM market and in the dollar/euro market (tables 15 and 21). As a consequence, the cluster analysis yields similar results for technical trading based on 30-minutes data in both markets (tables 16 and 22).

Table 21: Components of the profitability of 2466 trading systems 1987 - 1989
Price series: Dollar/DM exchange rate at 30-minutes intervals

	Number of models		Mean over each class of model									
	Abolute	Share in %	Gross rate of return	t-statistic	Net rate of return	Profitable positions			Unprofitable positions		
						Number per year	Return per day	Duration in days	Number per year	Return per day	Duration in days
t-statistic of the mean of the single returns											
< 0	312	12.7	-1.3	-0.490	-12.2	206.21	0.353	2.02	340.74	-0.533	0.92
0 - < 1.0	587	23.8	1.5	0.565	-6.3	148.66	0.332	1.87	242.48	-0.491	0.86
1.0 - <=2.0	1035	42.0	3.9	1.537	-1.2	100.84	0.317	1.74	156.20	-0.436	0.82
> 2.0	532	21.6	7.3	2.654	-0.3	147.91	0.338	1.54	234.31	-0.496	0.72
All models	2466	100.0	3.4	1.290	-3.6	135.71	0.330	1.76	216.93	-0.474	0.82
Moving average models	2046	83.0	3.2	1.234	-0.6	76.57	0.296	2.00	115.42	-0.394	0.95
Momentum models	231	9.4	7.7	2.705	-8.1	290.20	0.413	0.81	501.67	-0.761	0.24
RSIN models	189	7.7	0.4	0.173	-30.7	587.06	0.595	0.33	967.91	-0.996	0.12
1987 - 1989	2466	-	5.0	0.958	-1.7	132.78	0.324	1.80	203.09	-0.466	0.82
1990 - 1992	2466	-	6.4	1.010	-1.0	144.63	0.386	1.74	226.09	-0.573	0.76
1993 - 1995	2466	-	2.3	0.415	-4.9	138.26	0.321	1.76	223.58	-0.478	0.81
1996 - 1998	2466	-	-0.1	-0.027	-6.9	127.78	0.278	1.76	215.51	-0.384	0.91

The returns of the 25 best models out of sample are slightly lower in the dollar/DM market between 1987 and 1998 (GRR: 7.1, NRR: 1.4%) than in the dollar/euro market between 1999 and 2006 (GRR: 8.2%, NRR: 4.6%). In both cases, the 25 best models focus on the exploitation of relatively persistent trends of exchange rates at 30-minutes intervals, when trading in the dollar/euro market even more so than when trading in the dollar/DM market. As a consequence, the difference between GRR and NRR (i. e., transaction costs) are lower when the dollar/euro rate is traded than when the dollar/DM rate is traded (tables 17 and 23).

Table 22: Cluster of 2466 trading systems according to profit components 1987 - 1989
Price series: Dollar/DM exchange rate at 30-minutes intervals

	Number of models		Mean over each class of model									
	Abolute	Share in %	Gross rate of return	t-statistic	Net rate of return	Profitable positions			Unprofitable positions		
						Number per year	Return per day	Duration in days	Number per year	Return per day	Duration in days
All models											
Cluster 1	102	4.1	0.1	0.039	-36.7	700.13	0.635	0.28	1140.29	-1.059	0.10
Cluster 2	252	10.2	5.7	1.956	-15.3	387.50	0.475	0.52	662.70	-0.852	0.16
Cluster 3	2112	85.6	3.3	1.271	-0.6	78.41	0.298	1.98	119.15	-0.401	0.93
Total	2466	100.0	3.4	1.290	-3.6	135.71	0.330	1.76	216.93	-0.474	0.82

This section has shown that the profitability of the best performing technical models is sufficiently high in the dollar/euro market to “seduce” an increasing number of market participants to use them as one basis for their trading decisions. The next section investigates therefore the dynamics of excess demand or supply stemming from the aggregate trading signals of different technical models in the dollar/euro market.

Table 23: Performance of the 25 most profitable trading systems by subperiods in sample and out of sample 1987 - 1989
Price series: Dollar/DM exchange rate at 30-minutes intervals

	Gross rate of return	t-statistic	Net rate of return	Duration of profitable positions	Gross rate of return	t-statistic	Net rate of return	Duration of profitable positions
	In sample				Out of sample			
1987 - 1989	17.7	3.0	11.7	2.2				
1990 - 1992	22.5	3.2	15.5	1.8	11.7	1.6	5.3	2.2
1993 - 1995	12.3	2.1	8.4	2.4	6.8	1.2	-0.4	1.7
1996 - 1998	6.8	1.4	3.1	2.6	2.8	0.6	-0.6	2.7
1987 - 1998	14.8	2.4	9.7	2.2	7.1	1.1	1.4	2.2

5. Interaction between technical trading systems and exchange rate movements in the dollar/euro market

At first, I show how indices of the aggregate transactions and positions of the technical models are calculated. Based on these indices, I document the concentration of transactions in terms of buys and sells and of position holding in terms of long and short. Finally, I analyze the relationship between the level and the change of the net position index and the subsequent exchange rate movements. In each section I shall first present the results for the daily models and then for the models based on 30-minutes data.[13])

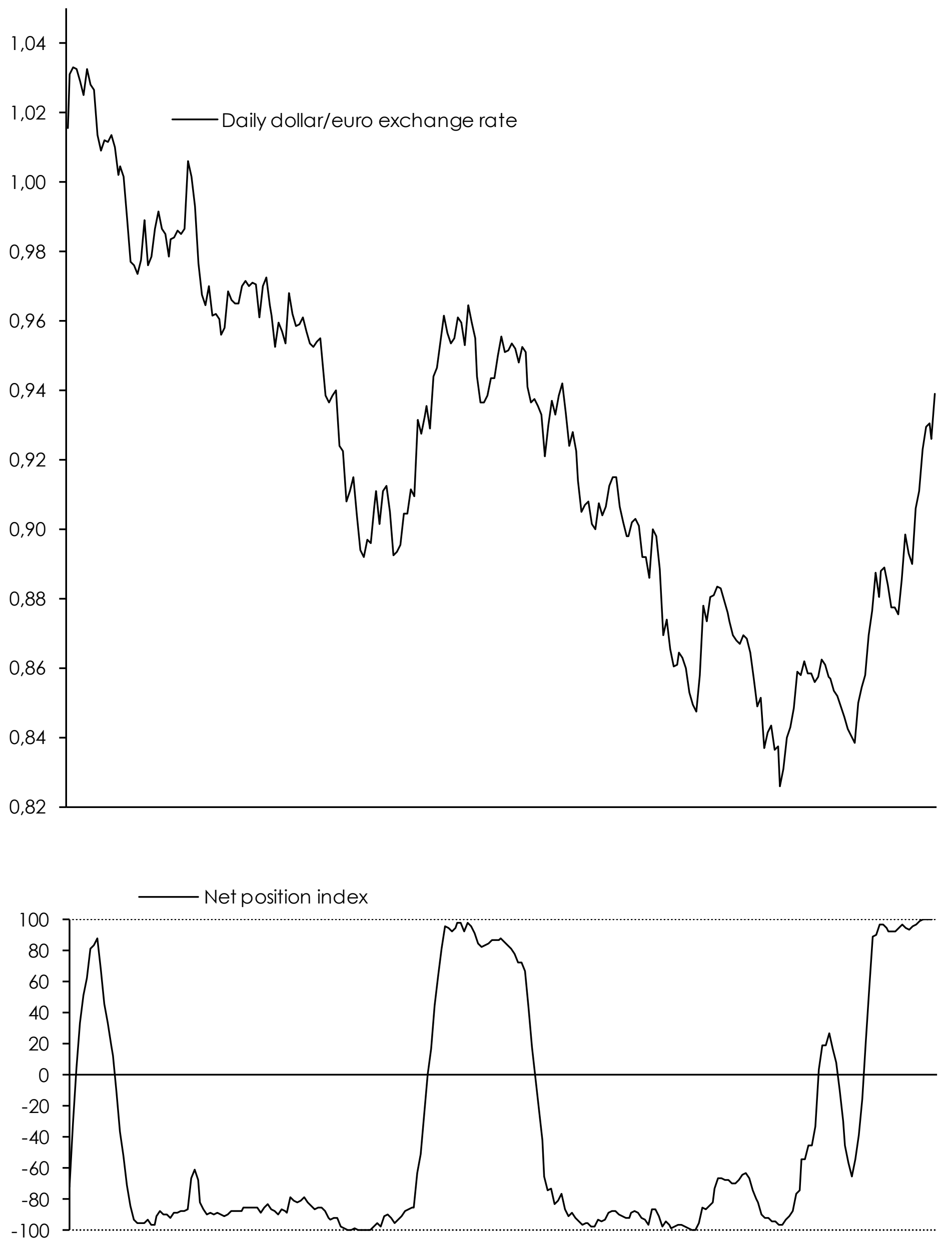
5.1 The aggregation of trading signals

The open positions of technical models are aggregated as follows. For every trading period (day or 30-minutes interval, respectively) the number +1 (-1) is assigned to any long (short) position of each single model (to any neutral position the number 0 is assigned). The net position index (PI) is then calculated as the sum of these numbers over all models divided by the number of models. Therefore, an index value of +100 (-100) means that 100% of the models hold a long (short) position. A value of 90 (-90) indicates that 95% of the models are long (short) and 5% short (long). The percentage share of models holding a long position can

[13]) This analysis is done only for the dollar/euro exchange rates. There are two reasons for this restriction. First, the analogous investigation concerning the daily dollar/deutschmark market has already been carried out (*Schulmeister*, 2006; for a similar study on the interaction between technical trading and the dynamics of the daily dollar/yen exchange rate see *Schulmeister*, 2009B). Second, the respective analysis based on 30-minutes data involves an extremely great amount of calculations.

generally be derived from the value of the net position index (PI) as [PI+100]/2 (if PI equals 0, then half the models signal a long position and half signal a short position.

Figure 13: Aggregate trading signals of 2265 technical models and exchange rate movements 2000
Price series: Daily dollar/euro exchange rate 2000



The net transaction index (TI) is the first difference of the net position index. Its theoretical maximum (minimum) value is twice as high (in absolute terms) as in the case of the net position index since the number of transactions is always twice the number of (changed) open positions. The extreme value of +200 (-200) would be realized if all models change the open position from short to long (from long to short) between two consecutive trading days.

In order to investigate the extent to which the signals from technical models balance each other, the components of the net transaction index are also documented, i.e., the number of buys and sells on each trading day (divided by the number of all models).

5.2 Similarities in position taking of technical models

Figure 13 shows the gradual adjustment of the 2265 daily models to exchange rate movements, using the year 2000 as example. Due to a depreciation trend in December 1999, most models hold a short position on January 2. The short appreciation movement of the dollar/euro rate in early January causes roughly 90% of the models to switch their positions from short to long. These changes are again quickly reversed due the subsequent downward trend which lasts for roughly three months. Almost all models profit from keeping short positions during this depreciation trend.

An investigation into the trading behaviour of the 2265 daily models over the entire sample reveals the following. First, most of the time the great majority of the models is on the same side of the market. Second, the process of changing open positions usually takes off 1 to 3 days after the local exchange rate minimum (maximum) has been reached. Third, it takes between 10 and 20 trading days to gradually reverse the positions of (almost) all models if a persistent exchange rate trend develops. Fourth, after all technical models have adjusted their open positions to the current trend, the trend often continues for some time.

Table 24 quantifies some of these observations. On 21.3% (19.6%) of all days more than 95% of the models hold a long (short) position. Hence, on 40.9% of all days more than 95% of the models hold the same – long or short – position. By contrast, periods during which short positions and long positions are roughly in balance seldom occur (the position index lies between 10 and –10 on only 2.7% of all days).

On 77.4% of all days less than 5% of the models execute buy or sell signals (TI lies between 10 and –10). There are two reasons for that. First, the majority of the models hold the same position for most of the time. Second, the process of changing open positions evolves only gradually.

Table 24: Distribution of time by positions and transactions of 2265 technical trading systems
Price series: Daily dollar/euro exchange rate 1999 - 2006

Aggregate positions

Net position index	Share in total Sample period in %	Mean of the net position index	Mean of the gross position index Long	Short	Neutral
> 90	21.32	96.56	97.64	-1.08	1.28
70 - 90	13.67	82.95	89.58	-6.63	3.79
50 - 70	5.00	60.96	75.60	-14.65	9.75
30 - 50	3.61	40.95	63.75	-22.80	13.45
30 - 10	2.79	20.09	53.02	-32.94	14.04
-10 - 10	2.65	0.82	43.65	-42.83	13.53
-30 - -10	2.74	-19.93	33.43	-53.36	13.21
-50 - -30	4.23	-40.39	23.55	-63.93	12.52
-70 - -50	6.79	-61.15	15.17	-76.32	8.51
-90 - -70	17.56	-83.50	6.47	-89.97	3.56
< -90	19.63	-95.01	1.71	-96.72	1.57
Total	100.00	-2.69	46.19	-48.89	4.92

Aggregate Transactions

	Share in total Sample period in %	Mean of the net transaction index	Mean of the gross transaction index Long	Short
> 70	0.00	0.00	0.00	0.00
50 - 70	0.00	0.00	0.00	0.00
30 - 50	1.73	37.58	38.04	-0.46
30 - 10	9.67	17.47	19.32	-1.84
-10 - 10	77.43	-0.11	2.48	-2.59
-30 - -10	10.11	-17.96	1.67	-19.64
-50 - -30	0.91	-37.28	0.70	-37.98
-70 - -50	0.14	-55.69	0.16	-55.85
< -70	0.00	0.00	0.00	0.00
Total	100.00	0.02	4.62	-4.60

Table 24 also shows that the signals produced by technical models would cause their users to trade very little with each other. If the models move relatively fast from short to long positions (10<TI<30) or vice versa (-10>TI>-30) then roughly10 times more buy (sell) signals are produced than sell (buy) signals. On days when less than 5% of the models trade (10>TI>-10) roughly the same number of buys and sells are executed, however, their size is rather small.

Table 25: Similarity of different types of daily trading systems in holding open positions
Price series: Daily dollar/euro exchange rate 1999 - 2006

	Relative share of models holding the same - long or short - position		
	97.50% (|PI| > 95)	95% (|PI| > 90)	90% (|PI| > 80)
	Share in total sample period in %		
Types of models			
By the t-statistic of the mean rate of return			
< 0.0	11.69	17.47	28.15
0.0 - <=1.0	14.97	21.94	35.08
1.0 - <=2.0	59.19	66.07	74.35
> 2.0	36.43	58.47	70.60
By stability			
Stable models	56.79	66.27	74.88
Unstable models	18.19	28.97	51.83
By duration of profitable positions			
Short-term	14.97	22.47	38.55
Medium-term	66.99	72.23	78.73
Long-term	81.81	84.74	88.50
All models	23.29	40.95	64.63

Table 25 shows the similarity in the trading behaviour of different classes of technical models. The trading behaviour of those models, which perform comparatively well, is more similar than the trading behaviour of the comparatively worse performing models (the t-statistic is taken as performance criterion. E. g., more than 95% of the models hold the same open position on roughly 60% of all days in the case of the best performing models (t-statistic > 1.0) as compared to roughly 20% of all days in the case of the worst performing models (t-statistic < 1.0). In line with this tendency, the position holding of stable models (those models, which are profitable over each sub-period) is more similar as compared to unstable models. Since the comparatively better performing and more stable models are those which "specialize" on the exploitation of medium-term and long-term exchange rate trends, the medium-term and long-term models display a more similar trading behaviour than the short-term models.

Table 26: Distribution of time by positions and transactions of 2466 technical trading systems
Price series: Dollar/euro exchange rate at 30-minutes intervals 1999 - 2006

		Aggregate positions			
	Share in total		Mean of the gross position index		
Net position index	Sample period in %	Mean of the net position index	Long	Short	Neutral
> 90	5.77	95.88	97.15	-1.27	1.58
70 - 90	5.95	79.96	83.68	-3.72	12.60
50 - 70	11.17	59.09	65.56	-6.47	27.97
30 - 50	10.64	40.21	55.01	-14.80	30.19
30 - 10	11.30	20.21	44.04	-23.83	32.12
-10 - 10	10.53	-0.04	32.29	-32.33	35.38
-30 - -10	11.15	-20.01	23.77	-43.78	32.45
-50 - -30	11.22	-40.18	14.83	-55.01	30.16
-70 - -50	11.29	-59.04	6.44	-65.48	28.08
-90 - -70	5.60	-79.74	3.61	-83.36	13.03
< -90	5.38	-95.78	1.28	-97.06	1.66
Total	100.00	0.42	37.45	-37.03	25.52

		Aggregate Transactions		
	Share in total		Mean of the gross transaction index	
	Sample period in %	Mean of the net transaction index	Long	Short
> 70	0.00	0.00	0.00	0.00
50 - 70	0.00	0.00	0.00	0.00
30 - 50	0.03	34.72	34.84	-0.12
30 - 10	3.61	13.44	13.73	-0.30
-10 - 10	92.58	0.02	2.60	-2.59
-30 - -10	3.76	-13.37	0.31	-13.68
-50 - -30	0.02	-33.75	0.08	-33.84
-70 - -50	0.00	0.00	0.00	0.00
< -70	0.00	0.00	0.00	0.00
Total	100.00	0.00	2.93	-2.93

Table 26 shows the concentration of 2466 technical models based on 30-minutes data on either long or short positions when trading the dollar/euro exchange rate between 1999 and 2006. This concentration is much less pronounced in the case of 30-minutes models than in the case of daily models (table 24). This difference is due to persistent trends occurring more seldom on the basis of 30-minutes exchange rates than on the basis of daily rates (as has been shown in chapter 3). However, also the 30-minutes models are much more often on the same side of the market than is to be expected if the exchange rate followed a random walk (in this case, the net position index should lie between 10 and -10 most of the time). E. g., on 22.9% of all 30-minutes-intervals of the entire sample period more than 75% of the models hold a long position (PI>50), and on 22.3% of all intervals more than 75% of the models hold a short position (PI<-50). Hence, on 45.2% of all trading intervals more than 75% of the models hold the same – long or short – position.

Table 27: Similarity of different types of 30-minutes trading systems in holding open positions

Price series: Dollar/euro exchange rate at 30-minutes intervals 1999 - 2006

	Relative share of models holding the same - long or short - position		
	97.50% (|PI| > 95)	95% (|PI| > 90)	90% (|PI| > 80)
	Share in total sample period in %		
Types of models			
By the t-statistic of the mean rate of return			
< 0.0	2.14	5.62	13.15
0.0 - <=1.0	10.25	13.63	19.61
1.0 - <=2.0	11.36	17.74	38.13
> 2.0	25.35	31.62	41.70
By stability			
Stable models	17.62	20.05	26.36
Unstable models	6.47	11.04	16.72
By duration of profitable positions			
Short-term	3.17	4.89	9.43
Medium-term	13.24	16.08	21.84
Long-term	11.14	13.72	19.19
All models	6.62	11.15	16.86

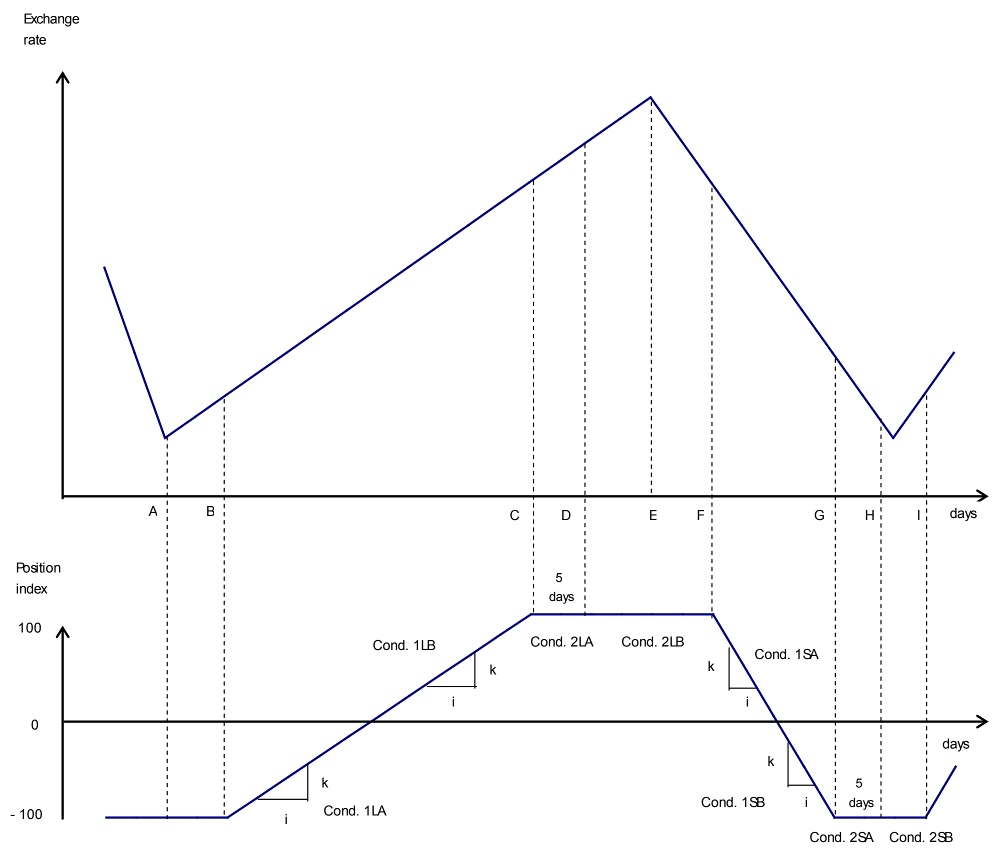
By contrast, on only 10.5% of all 30-minutes-intervals are short and long positions roughly in balance (|PI|<10). These situations occur primarily during the change of the models from short to long positions and vice versa. In these phases the share of neutral positions reaches a maximum (35.4% of the models hold neutral positions when |PI|<10).

Table 27 shows that the position holding of different classes of 30-minutes models is similar to the position holding of daily models (table 25): The trading behaviour of the best performing models (t-statistic > 2) is more similar than the trading behaviour of the comparatively worse performing models (t-statistic <= 1). The same is true for stable models relative to unstable models, and for long-term models relative to short-term models.

5.3 Exchange rate "trending" and aggregate technical trading – a stylized representation

In this section, the possible interactions between the aggregate trading behaviour of technical models and the development of an exchange rate trend shall be discussed in a stylized manner, taking an appreciation trend as example.

Figure 14: Exchange rate trends and aggregate positions of technical models



The first phase of a trend (marked by A and B in figure 14) is brought about by the excess demand of non-technical traders, usually triggered off by some news (causing news-based traders to expect a dollar appreciation and, hence, to open long dollar positions).

During the second phase of an upward trend (between B and C in figure 2) technical models produce a sequence of buy signals, the fastest models at first, the slowest models al last. The execution of the respective order flows then contributes to the prolongation of the trend.

Over the third phase of the trend all technical models hold long positions while the trend continues for some time (marked by C and E in figure 2). Since technical models already hold a long position the prolongation of the trend is caused by an additional demand of non-technical traders, possibly amateur "bandwagonists" who jump later on trends than professional traders (the latter consider bandwagon effects as one of the four most important factors driving exchange rates – see *Cheung-Chinn-Marsh*, 2004; *Cheung-Wong*, 2000; *Cheung-Chinn*, 2001).

As the exchange rate trend continues the probability that it ends becomes progressively greater. This is so for at least three reasons. First, the number of traders who get on the bandwagon declines. Second, the incentive to cash in profits rises. Third, more and more contrarian traders consider the dollar overbought (oversold) and, hence, open a short (long) position in order to profit from the expected reversal of the trend.

When the appreciation trend finally comes to an end, mostly triggered by some news, a countermovement usually takes off. With some lag technical models start to close the former positions and open new counter-positions (on day F in figure 14).

For technical currency trading to be overall profitable, it is necessary that appreciation (depreciation) trends continue for some time after the models have taken long (short) positions. This is so for three reasons. First, all models have to be compensated for the losses they incur during "whipsaws". Second, fast models often make losses during an "underlying" exchange rate trend as they react to short-lasting counter-movements. Third, slow models open a long (short) position only at a comparatively late stage of an upward (downward) trend so that they can exploit the trend successfully only if it continues for some time.

5.4 Aggregate technical trading and exchange rate exchange rate movements

In order to explore the interaction between exchange rate movements and the trading behaviour of technical models the following exercise is carried out. At first, some conditions concerning the change and the level of the net position index are specified. These conditions grasp typical configurations in the aggregate trading behaviour of technical models. Then the difference between the means of the exchange rate changes observed under these conditions from their unconditional means is evaluated.

The first type of conditions concerns the speed at which technical models switch their open positions from short to long (condition 1L) or from long to short (condition 1S). Condition 1L comprises all cases where 10% (20%, 40%) of all models have been moving continuously from short to long positions over the past 3 (5, 10) business days (PI increases monotonically). In addition, the condition 1L excludes all cases where more than 90% of the models hold long positions (these cases are comprised by condition 2L). Hence, condition 1L is defined as follows.

More formally condition 1L is defined as follows.

Condition 1L: $[PI_t\text{-}PI_{t\text{-}i}]>k \cap [PI_{t\text{-}n}\text{-}PI_{t\text{-}n\text{-}1}]\geq 0 \cap [PI_t\leq 80]$

k = 20, 40, 80

i = 3, 5, 10

n = 0, 1, ... (i-1)

Condition 1S comprises the analogous cases of changes positions from long to short.

Condition 1S: $[PI_t\text{-}PI_{t\text{-}i}]<\text{-}k \cap [PI_{t\text{-}n}\text{-}PI_{t\text{-}n\text{-}1}] \leq 0 \cap [PI_t \geq \text{-}80]$

k = 20, 40, 80

I = 3, 5, 10

n = 0, 1, ... (i-1)

Condition 2L(S) comprises all cases where more than 90% of all models hold long (short) positions:

Condition 2L(S): PI > 80 (PI < 80)

Figure 14 gives a graphical representation of the meaning of these four conditions (the subdivision of the conditions 1 and 2, marked by "A" and "B", will be discussed later).

For each trading interval t (day and 30-minutes interval) on which these conditions are fulfilled the rate of change (CER_t) between the current exchange rate (ER_t) and the exchange rate j days (ER_{t+j}) ahead is calculated (j...5, 10, 20, 40). Then the means over the conditional exchange rate changes are compared to the unconditional means over the entire sample and the significance of the differences is estimated using the t-statistic. This comparison shall examine if and to what extent the exchange rate continues to rise (fall) after 10% (20%, 40%) of technical models have changed their position from short (long) to long (short), and if and to what extent this is the case when 90% of all models hold long (short) positions.

For each day on which condition 1 is fulfilled also the exchange rate changes over the past 3 (5, 10) days are calculated and compared to the unconditional exchange rate changes. The purpose of this exercise is to estimate the strength of the interaction between exchange rate movements and the simultaneous execution of technical trading signals induced by these movements.

Table 28 shows that the conditions 1 are rather frequently fulfilled. E. g., in 212 (212) cases more than 10% of all models change their open positions from short to long (from long to short) within 3 business days (conditions 1L(S) with k=20 and i=3, abbreviated as condition 1L(S)[20/3)]). In 146 (158) cases more than 20% of the models change their open position in the same direction within 10 business days. Conditions 1L(S)[80/10] are realized in only 96 (103) cases. The number of cases fulfilling conditions 1 is decreasing as the parameter k rises. E. g., if k=80 then the possible realizations of condition 1L are restricted to a range of the position index between 0 and 90, however, if k=20 then condition 1L could be fulfilled within a range of the position index between -60 and 90.

Table 28: Aggregate trading signals of 2265 daily models and subsequent exchange rate movements

Price series: Daily dollar/euro exchange rate

Parameters of the conditions for	Time span j of CER	More than 10% (20%, 40%) of all models change open positions in the same direction within 3 (5,. 10) business days					
k	j	From short to long positions (condition 1L)			From long to short position (condition 1S)		
		Number of cases	Mean of CER_{t+j}	t-statistic	Number of cases	Mean of CER_{t+j}	t-statistic
20	-3	212	0.9105	14.7520	212	-0.8971	-14.0803
	5	212	0.0206	-0.1595	212	0.0117	-0.2588
	10	212	0.0981	0.1937	212	0.0155	-0.4097
	20	212	0.5002	1.6777	212	0.0786	-0.3524
	40	212	1.4159	3.4090	212	0.1868	-0.4550
40	-5	146	1.3433	15.7789	158	-1.3976	-17.2058
	5	146	0.0496	0.1175	158	0.0286	-0.0683
	10	146	0.1927	0.7553	158	0.1263	0.3449
	20	146	0.6572	2.0494	158	0.1387	-0.0320
	40	146	1.4488	2.9851	158	0.3047	-0.0848
80	-10	96	2.0878	16.3233	103	-2.0531	-18.5029
	5	96	-0.0759	-0.7795	103	-0.1692	-1.5743
	10	96	0.2339	0.8645	103	-0.1982	-1.5875
	20	96	0.6291	1.8262	103	-0.2361	-1.6451
	40	96	1.2891	2.1973	103	-0.1998	-1.2313
		More than 90% of all models hold the same type of open positions					
		Long positions (condition 2L)			Short positions (condition 2S)		
	5	657	0.1550	1.9369	686	-0.0095	-0.7723
	10	657	0.3180	2.7337	686	-0.0381	-1.3593
	20	657	0.5629	3.3276	686	-0.2469	-3.4639
	40	657	0.5392	1.1534	686	-0.2504	-3.5452

The table presents the means of exchange rates changes over i business days (CER_{t+j}) under four different conditions.

Condition 1L (S) comprises all situations where more than 10% (20%, 40%) of all trading systems have been moving monotonically from short to long (long to short) positions over the past 3 (5, 10) business days. The moves are restricted to a range of the position index PI_t between 80 and –80.

Condition 2L (S) comprises all situations beyond this range. i.e. where more than 90% of all trading systems hold long (short) positions.

More formally these conditions are defined as follows:

Condition 1L (S): $[PI_t - PI_{t-i}] > k\ (<- k) \cap [PI_{t-n} - PI_{t-n-1}] \geq 0\ (\leq = 0) \cap [-80 \leq PI_t \leq 80]$

k......20, 40, 80

i........3, 5, 10

n.......0, 1, ... t_{i-1}

Condition 2L (S): PI > 80 (< -80)

$CER_{t+j} = 100 * [ER_{t+j} - ER_t] / ER_t$ for j........5, 10, 20, 40

$CER_{t+j} = 100 * [ER_t - ER_{t+j}] / ER_t$ for j.......-3, -5, -10

The t-statistic tests for the significance of the difference between the mean of the conditional exchange rate changes and the unconditional mean over the entire sample, the latter being as follows:

For j=	3	0.0220
	5	0.0362
	10	0.0717
	20	0.1456
	40	0.3371

Conditions 2 occur more frequently than conditions 1. In 657 cases more than 90% of all models hold a long position (condition 2L). Since the dollar was depreciating over the entire sample period, condition 2S was slightly more frequently realized (686 cases).

Despite the different restrictions imposed on conditions 1L(S) and 2L(S) either of them is fulfilled on 1767 days out of the entire sample of 2080 days.[14]) This behaviour of technical models can hardly be reconciled with the hypothesis that daily exchange rates follow a (near) random walk.

The means of the exchange rate changes (CER_t) on all days satisfying condition 1 over the past 3 (5, 10) days are very much higher than the unconditional means over the entire sample period. E. g., the average (relative) exchange rate change over 5 consecutive days amounts to 0.0362% between 1999 and 2006, however, when 20% of the technical models turn their open position from short to long within 5 days the exchange rate increases on average by 1.343%. This highly significant difference (t-statistic: 15.8) can be explained as the result of the simultaneous interaction between exchange rate movements and the changes of open positions by technical models.

The means of the conditional exchange rate changes over the 5 (10, 20, 40) days following the realization of condition 1L have the same (positive) sign as the preceding change in the position index (except for 2 out of 12 cases) and are significantly different from the unconditional means in 6 cases. These cases concern the exchange rate changes over the 20 and 40 days subsequent to the realization of condition 1L (table 28). This result suggests that the switching of technical models from short to long positions reinforces the appreciation movement.

Such a price effect of technical trading seems to be weaker when models change their position from long to short. Only when more than 40% of the models switch from long positions to short positions within 10 business days (condition 1S[80/10]) are the subsequent exchange rate changes markedly smaller than on average over the entire sample. However, the statistical significance of this relationship is comparatively weak.

Subsequent to the realizations of condition 2, i. e., when 90% of all models hold a long (short) position, the exchange rate rises (falls) much stronger than on average over the entire sample (table 28). The means of the conditional (ex-ante) exchange rate changes have the same sign as the preceding change in the position index, and are more significantly different from the unconditional means than in the case of conditions 1. This implies that the probability of a prolongation of an exchange rate trend is higher after (almost) all models have opened the same – long or short – position as compared to those phases where the models are still changing their positions. The frequent continuation of exchange rate trends after conditions 2 are satisfied must be attributed to the transactions of non-technical traders ("bandwagonists") since technical traders are just keeping their positions.

[14]) In order to avoid double-counting only the cases of conditions 1L(S)[20/3] are considered as regards condition 1 – most cases satisfying condition 1 with k=40 or k=80 are a subset of the cases satisfying condition 1 with k=20.

Table 29: Eight phases of technical trading of 2265 daily models and subsequent exchange rate movements
Price series: Daily dollar/euro exchange rate

Conditions for CER_{t+j} (= Phases of Technical trading)	Time span j of CER_{t+j}	(Increasing) Long positions (Conditions .L.)			(Increasing) Short position (Conditions .S.)		
		Number of cases	Mean of CER_{t+j}	t-statistic	Number of cases	Mean of CER_{t+j}	t-statistic
1A	5	43	0.0972	0.3166	119	0.0185	-0.1351
1B	5	103	0.0297	-0.0471	39	0.0593	0.1166
2A	5	267	0.0536	0.1986	286	0.0425	0.0768
2B	5	390	0.2243	2.4572	400	-0.0466	-1.1052
1A	10	43	-0.1301	-0.6451	119	0.1162	0.4099
1B	10	103	0.3275	1.4126	39	0.1573	0.2659
2A	10	267	0.2285	1.1356	286	0.0254	-0.4063
2B	10	390	0.3793	2.8474	400	-0.0835	-1.5507
1A	20	43	0.4721	0.6760	119	0.2120	0.2669
1B	20	103	0.7344	2.0532	39	-0.0848	-0.5602
2A	20	267	0.8929	3.7616	286	-0.3456	-3.1883
2B	20	390	0.3369	1.3220	400	-0.1763	-2.2485
1A	40	43	1.1849	1.1885	119	0.2213	-0.2645
1B	40	103	1.5590	2.8415	39	0.5589	0.2915
2A	40	267	0.9090	2.0766	286	0.0760	-1.0420
2B	40	390	0.2860	-0.2541	400	-0.4838	-4.2617

Each of the four phases of technical trading defined by the conditions 1L (S) and the conditions 2L (S) for k = 40 and i = 5 (see table 4) is divided into two subphases by the conditions A and B:

Condition 1L (S): More than 20% of all trading systems have been moving from short to long (long to short) positions over the past five 30-minutes-intervals within the range $\{-80 \le PI_t \le 80\}$ and ....
Condition 1L (S) A: Less than 50% of the models hold long (short) positions, i.e., $PI_t \le 0$ ($PI_t \ge 0$).
Condition 1L (S) B: More than 50% of the models hold long (short) positions, i.e., $PI_t \ge 0$ ($PI_t \le 0$).

Condition 2L (S): More than 90% of all trading systems hold long (short) positions, i.e., $PI_t > 80$ ($PI_t < -80$).
Condition 2L (S) A: Comprises the first five 30-minutes-intervals for which condition 2L (S) holds true.
Condition 2L (S) B: Comprises the other 30-minutes-intervals for which condition 2L (S) holds true.

The t-statistics tests for the significance of the difference between the mean of the conditional stock price changes and the unconditional mean over the entire sample, the latter being 0.0362 (for j = 5).

Finally, the following exercise is carried out. Each of the four phases of technical trading as defined by the conditions 1L(S) and 2L(S) is divided into two sub-phases by the (additional) conditions A and B (the parameters of condition 1 are set at k=40 and i=5). The meaning of the (sub)conditions A and B is explained as follows, taking an upward trend as example (figure 14):

- Condition 1LA comprises all cases where 20% of all models have changed their positions from long to short and where at the same time still less than 50% of the models hold long positions. Hence, condition 1LA covers the first phase of reversing technical positions after stock prices have started to rise (all cases under condition 1LA lie below the zero level of the position index – see figure 14).
- Condition 1LB comprises the second phase of position changes, e. g., when a stock price trends has gained momentum so that already more that 50% of the models are holding long positions.
- Condition 2LA covers the third phase in the trading behaviour of technical models during an upward trend, namely, the first 5 trading intervals (days or 30-minutes-intervals, respectively) after more than 90% of all models have opened and are still holding long positions.
- Condition 2LB comprises the other trading intervals over which 90% of all models keep holding long positions, i.e., the fourth and last phase which endures until the models start to again reverse their position in reaction to a downward movement.

The size of the conditional ex-ante exchange rate changes differs strongly across the four phases of an appreciation trend (table 29). When 25% of the models have switched from short to long positions and more than 50% of the models are still short (condition 1LA) the appreciation movements often do not persist. Hence, the means of the conditional exchange rate changes following the realization of conditions 1LA differ only insignificantly from the unconditional means.

The ex-ante dollar/euro exchange rate changes get significantly positive after the exchange rate trend has gained momentum (condition 1LB) and during the first 5 days after 90% of all models have taken long positions (condition 2LA). Exchange rate changes subsequent to the realizations of condition 2LB are significantly positive over the subsequent 5 and 10 days, but much smaller or even negative over the subsequent 20 and 40 days. The main reason for this result is the fact that the longer a trend lasts, the higher becomes the probability of a reversal.

Exchange rate changes subsequent to the four conditions of technical trading during depreciation trends differ from the average change over the entire sample period in only three cases, namely, following the conditions 2SA and 2SB over 20 days, and following the condition 2SB over 40 days.

Table 30: Aggregate trading signals of 2466 30-minutes models and subsequent exchange rate movements

Price series: Dollar/DM exchange rate at 30-minutes intervals

Parameters of the conditions for	Time span j of CER	More than 10% (20%, 40%) of all models change open positions in the same direction within 3 (5,. 10) 30-minutes-intervalls					
k	j	From short to long positions (condition 1L)			From long to short position (condition 1S)		
		Number of cases	Mean of CER_{t+j}	t-statistic	Number of cases	Mean of CER_{t+j}	t-statistic
20	-3	5236	0.1913	61.5604	5317	-0.1839	-63.5623
	5	5236	0.0079	2.1862	5317	0.0007	-0.0000
	10	5236	0.0160	3.1641	5317	-0.0033	-1.0447
	20	5236	0.0206	3.0167	5317	-0.0175	-3.4895
	40	5236	0.0232	2.1020	5317	-0.0187	-3.1977
40	-5	2353	0.2683	45.2376	2501	-0.2639	-47.1256
	5	2353	0.0153	3.1569	2501	-0.0005	-0.2463
	10	2353	0.0199	2.9164	2501	-0.0014	-0.4327
	20	2353	0.0238	2.6336	2501	-0.0131	-1.9374
	40	2353	0.0069	0.0679	2501	-0.0078	-1.2436
80	-10	1152	0.5120	48.9642	1362	-0.4543	-51.4489
	5	1152	0.0121	1.6441	1362	-0.0008	-0.2127
	10	1152	0.0216	2.1641	1362	-0.0014	-0.3219
	20	1152	0.0302	2.5754	1362	-0.0057	-0.7727
	40	1152	0.0092	0.1804	1362	0.0216	1.0069
		More than 90% of all models hold the same type of open positions					
		Long positions (condition 2L)			Short positions (condition 2S)		
	5	8714	0.0003	-0.1920	8096	-0.0025	-1.4235
	10	8714	0.0038	0.7997	8096	-0.0079	-3.1052
	20	8714	0.0104	1.7138	8096	-0.0085	-2.7134
	40	8714	-0.0204	-3.9697	8096	0.0230	2.6022

The table presents the means of exchange rates changes over i business days (CER_{t+j}) under four different conditions.

Condition 1L (S) comprises all situations where more than 10% (20%, 40%) of all trading systems have been moving monotonically from short to long (long to short) positions over the past 3 (5, 10) business days. The moves are restricted to a range of the position index PI_t between 80 and –80.

Condition 2L (S) comprises all situations beyond this range. i.e. where more than 90% of all trading systems hold long (short) positions.

More formally these conditions are defined as follows:

Condition 1L (S): $[PI_t - PI_{t-i}] > k\ (<- k) \cap [PI_{t-n} - PI_{t-n-1}] \geq 0\ (\leq = 0) \cap [-80 \leq PI_t \leq 80]$

k......20, 40, 80

i........3, 5, 10

n.......0, 1, ... t_{i-1}

Condition 2L (S): PI > 80 (< -80)

$CER_{t+j} = 100 * [ER_{t+j} - ER_t] / ER_t$ for j........5, 10, 20, 40

$CER_{t+j} = 100 * [ER_t - ER_{t+j}] / ER_t$ for j.......-3, -5, -10

The t-statistic tests for the significance of the difference between the mean of the conditional exchange rate changes and the unconditional mean over the entire sample, the latter being as follows:

For j=	3	0.0004
	5	0.0007
	10	0.0015
	20	0.0030
	40	0.0061

Table 31: Eight phases of technical trading of 2466 30-minutes models and subsequent exchange rate movements

Price series: Dollar/euro exchange rate at 30-minutes intervalls

Conditions for CER_{t+j} (= Phases of Technical trading)	Time span j of CER_{t+j}	(Increasing) Long positions (Conditions .L.)			(Increasing) Short position (Conditions .S.)		
		Number of cases	Mean of CER_{t+j}	t-statistic	Number of cases	Mean of CER_{t+j}	t-statistic
1A	5	660	-0.0059	-0.7681	1773	0.0007	0.0000
1B	5	1693	0.0236	4.2063	728	-0.0032	-0.4606
2A	5	4351	-0.0081	-2.9577	4043	-0.0011	-0.5625
2B	5	4363	0.0086	2.8602	4053	-0.0040	-1.5550
1A	10	660	0.0009	-0.0489	1773	0.0000	-0.1935
1B	10	1693	0.0272	3.5204	728	-0.0047	-0.4757
2A	10	4351	-0.0104	-3.0064	4043	-0.0099	-2.6783
2B	10	4363	0.0179	4.1440	4053	-0.0060	-1.8260
1A	20	660	0.0259	1.3220	1773	-0.0115	-1.5577
1B	20	1693	0.0230	2.3307	728	-0.0169	-1.1614
2A	20	4351	-0.0008	-0.6842	4043	-0.0083	-2.0299
2B	20	4363	0.0216	2.9282	4053	-0.0088	-1.9254
1A	40	660	0.0461	1.6618	1773	0.0069	0.0619
1B	40	1693	-0.0083	-1.0819	728	-0.0436	-2.3057
2A	40	4351	-0.0185	-2.6345	4043	0.0097	0.3959
2B	40	4363	-0.0223	-3.0902	4053	0.0364	3.4022

Each of the four phases of technical trading defined by the conditions 1L (S) and the conditions 2L (S) for k = 40 and i = 5 (see table 4) is divided into two subphases by the conditions A and B:

Condition 1L (S): More than 20% of all trading systems have been moving from short to long (long to short) positions over the past five 30-minutes-intervals within the range $\{-80 \leq PI_t \leq 80\}$ and ....
Condition 1L (S) A: Less than 50% of the models hold long (short) positions, i.e., $PI_t \leq 0$ ($PI_t \geq 0$).
Condition 1L (S) B: More than 50% of the models holg long (short) positions, i.e., $PI_t \geq 0$ ($PI_t \leq 0$).

Condition 2L (S): More than 90% of all trading systems hold long (short) positions, i.e., $PI_t > 80$ ($PI_t < -80$).
Condition 2L (S) A: Comprises the first five 30-minutes-intervals for which condition 2L (S) holds true.
Condition 2L (S) B: Comprises the other 30-minutes-intervals for which condition 2L (S) holds true.

The t-statistics tests for the significance of the difference between the mean of the conditional stock price changes and the unconditional mean over the entire sample, the latter being 0.0007 (for j = 5).

Tables 30 and 31 document the relationship between the trading behaviour of 2466 models based on 30-minutes data and the simultaneous as well as the subsequent movements of the dollar/euro exchange rate at 30-minutes intervals (the tables are analogous to the tables 28 and 29 for daily models and exchange rates). The main results can be summarized as follows:

- When the technical models change open positions at a certain speed (as defined by the conditions 1L and 1S) then the simultaneous exchange rate changes are much stronger than on average over the entire sample. The respective t-statistic exceeds 40 in any of the 6 cases.

- The means of exchange rate changes over the 5 (10, 20, 40) 30-minutes-intervals following the realization of condition 1 have in 22 out of 24 cases the same sign as the preceding change in the position index and are in most cases significantly different from the unconditional means (table 30). However, this relationship holds true to a greater extent for appreciation movements than for depreciation movements.
- After those 30-minutes-intervals during which 90% of all models hold already a long position (condition 2L) exchange rates do often not continue to rise stronger than on average over the entire sample. Hence, the mean exchange rate change over the first 5 intervals following condition 2L is slightly smaller than the unconditional mean (for the same reason, the means of the exchange rate changes following the conditions 2LA in table 31 are negative). However, over the 10 and 20 intervals of 30 minutes after the realization of condition 2L (when a trend has gained some persistence), the exchange rate continues to rise stronger than on average over the entire period.
- Over a time span of 40 intervals (roughly one trading day), the average exchange rate change becomes significantly negative. This result reflects the fact that exchange rate trends based on 30-minutes intervals are less persistent than daily trends, often reverting into a counter-movement.
- This pattern is less pronounced after those 30-minutes-intervals during which 90% of all models hold already a short position (condition 2S). However, also in this case are is the mean of exchange rate changes over 40 intervals of 30 minutes following the realization of condition 2S significantly positive, indicating the trend reverting behaviour of exchange rate movements.

The above analysis of the aggregate trading behaviour of technical models implies that the transactions of technical traders and of other "bandwagonists" interact with exchange rate dynamics in such a way as to bring about clusters of transactions. In turn, these clusters of either buy or sell transactions strengthen the trending behaviour of exchange rates.

6. Concluding remarks

The most important results of the present study are as follows:

First, the dollar/euro as well as the dollar/deutschmark exchange rate fluctuate most of the time around "underlying" short-term trends which occur on the basis of daily data as well as on the basis of intraday data. Over a extended period of time, these trends (e. g., monotonic movements when the original data are smoothed by moving averages) last longer in one direction than in the other. The accumulation of upward (downward) runs lasting longer than counter-movements brings about a "bull market" ("bear market") in a stepwise process.

Second, the phenomenon of trending of exchange rates (as well as of asset prices in general) represents the sole source of profitability of technical trading systems. Since exchange rate trends are more persistent on the basis of daily data as compared to intraday data, the simple models tested in this study perfom better when daily data are user instead of 30-minutes data. The fact that "whipsaws" (i. e., short "sideways" fluctuations) are more pronounced on the basis of intraday data as compared to daily data, also contributes to the worse performance of 30-minutes models relative to daily models (the result might be different if more sophisticated models had been tested which also account for volatility – in practice, those types of models are actually applied).

Third, there operates a strong feed-back mechanism between the transactions of technical models and exchange rate movements. Rising (falling) exchange rates cause increasingly more technical models to produce buy (sell) signals. The execultion of these trading signals in turn strengthens and lengthens the upward (downward) trend.

An evaluation of these results with respect to the "fundamentalist hypothesis" on the one hand, and the "bull-bear-hypothesis" on the other hand as sketched in chapter 2 suggests the following. The empirical evidence as elaborated in this study seems to be more in line with the "bull-bear-hypothesis" as compared to the "fundamentalist hypothesis". However, much more research has still to be done on this controversal issue.

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Annex

Table A1: Classification of exchange rate runs by duration

Daily dollar/euro rates

	Run length	Upward runs: Number		Upward runs: Average Duration (Days)	Upward runs: Average slope 1)		Downward runs: Number		Downward runs: Average Duration (Days)	Downward runs: Average slope 1)		*Contribution to overall change in price*: Upward runs, In cents	Upward runs, In %	Downward runs, In cents	Downward runs, In %
							Based on original data								
1999/01/01 - 2000/10/25	1	57.0		1.00	0.560		42.0		1.00	- 0.536		31.9	33.3	- 22.5	17.3
		(59.1)	-	(1.00)	(0.502)	-	(59.3)	***	(1.00)	-(0.504)	-	(29.7)	(25.1)	-(29.9)	(25.3)
	2	36.0		2.00	0.436		27.0		2.00	- 0.499		31.4	32.8	- 26.9	20.7
		(29.6)	*	(2.00)	(0.499)	-	(29.5)	-	(2.00)	-(0.498)	-	(29.5)	(25.0)	-(29.4)	(24.8)
	3	12.0		3.00	0.329		24.0		3.00	- 0.527		11.8	12.3	- 37.9	29.1
		(14.8)	-	(3.00)	(0.497)	***	(14.8)	***	(3.00)	-(0.504)	-	(22.1)	(18.7)	-(22.4)	(18.9)
	4	5.0		4.00	0.681		8.0		4.00	- 0.456		13.6	14.2	- 14.6	11.2
		(7.4)	-	(4.00)	(0.505)	***	(7.3)	-	(4.00)	-(0.502)	-	(15.0)	(12.7)	-(14.6)	(12.4)
	5	1.0		5.00	0.380		6.0		5.00	- 0.500		1.9	2.0	- 15.0	11.5
		(3.6)	*	(5.00)	(0.506)	-	(3.7)	-	(5.00)	-(0.506)	-	(9.2)	(7.8)	-(9.3)	(7.8)
	6	2.0		6.00	0.429		4.0		6.00	- 0.336		5.2	5.4	- 8.1	6.2
		(1.8)	-	(6.00)	(0.497)	-	(1.8)	**	(6.00)	-(0.496)	*	(5.3)	(4.5)	-(5.3)	(4.5)
	≥ 7	0.0		-	-		2.0		7.50	- 0.343		0.0	0.0	- 5.1	3.9
		(1.8)	*	(7.97)	(0.508)		(1.8)	-	(8.01)	-(0.505)	*	(7.2)	(6.1)	-(7.4)	(6.2)
	All	113.0		1.79	0.474		113.0		2.38	- 0.484		95.8	100.0	- 130.2	100.0
		(118.2)	-	(1.99)	(0.501)	-	(118.2)	-	(1.99)	-(0.502)	-	(118.1)	(100.0)	-(118.2)	(100.0)
							5-days moving average								
1999/01/01 - 2000/10/25	1	17.0		1.00	0.060		11.0		1.00	- 0.066		1.0	2.6	- 0.7	1.0
		(13.5)	-	(1.00)	(0.071)	-	(13.7)	-	(1.00)	-(0.072)	-	(1.0)	(1.8)	-(1.0)	(1.9)
	2	6.0		2.00	0.125		6.0		2.00	- 0.091		1.5	3.9	- 1.1	1.5
		(6.6)	-	(2.00)	(0.105)	-	(6.4)	-	(2.00)	-(0.105)	-	(1.4)	(2.6)	-(1.4)	(2.6)
	3	3.0		3.00	0.164		4.0		3.00	- 0.210		1.5	3.9	- 2.5	3.5
		(4.1)	-	(3.00)	(0.135)	-	(4.1)	-	(3.00)	-(0.133)	**	(1.7)	(3.2)	-(1.6)	(3.1)
	4	2.0		4.00	0.246		2.0		4.00	- 0.192		2.0	5.1	- 1.5	2.1
		(3.0)	-	(4.00)	(0.160)	**	(3.0)	-	(4.00)	-(0.157)	-	(1.9)	(3.7)	-(1.9)	(3.6)
	5	7.0		5.00	0.225		1.0		5.00	- 0.039		7.9	20.6	- 0.2	0.3
		(5.1)	-	(5.00)	(0.198)	-	(5.3)	**	(5.00)	-(0.199)	***	(5.1)	(9.8)	-(5.2)	(10.0)
	6	2.0		6.00	0.231		3.0		6.00	- 0.204		2.8	7.2	- 3.7	5.1
		(3.5)	-	(6.00)	(0.231)	-	(3.6)	-	(6.00)	-(0.231)	-	(4.9)	(9.3)	-(4.9)	(9.4)
	≥ 7	7.0		10.57	0.292		18.0		12.94	- 0.266		21.6	56.6	- 62.0	86.4
		(12.5)	**	(10.88)	(0.268)	-	(12.4)	**	(10.88)	-(0.269)	-	(36.3)	(69.5)	-(36.4)	(69.5)
	All	44.0		3.80	0.229		45.0		6.64	- 0.240		38.3	100.0	- 71.7	100.0
		(48.4)	-	(4.83)	(0.224)	-	(48.4)	-	(4.82)	-(0.224)	-	(52.2)	(100.0)	-(52.4)	(100.0)

1) Average change in exchange rate level per day in cents.

Notes: Values in parentheses are expected means under the random-walk-hypothesis. These means are derived from a Monte-Carlo-simulation based on 1000 random walk series. The random walks were constructed with an expected zero mean of the first differences and with an expected standard deviation of the first differences as observed in the original exchange rate series over the respective-period. * (**, ***) indicate the significance of the difference between the observed means and the expected means under the random-walk-hypothesis at the 10% (5%, 1%) level.

Table A1 (cont.): Classification of exchange rate runs by duration

Daily dollar/euro rates

	Run length	Upward runs: Number		Upward runs: Average Duration	Upward runs: Average slope 1)		Downward runs: Number		Downward runs: Average Duration	Downward runs: Average slope 1)		*Contribution to overall change in price*: Upward runs		*Contribution to overall change in price*: Downward runs	
				Days					Days			In cents	In %	In cents	In %
							Based on original data								
2000/10/25 - 2002/01/31	1	40.0		1.00	0.422		40.0		1.00	- 0.464		16.9	21.2	- 18.6	14.3
		(40.8)	-	(1.00)	(0.496)	-	(40.8)	-	(1.00)	-(0.500)	-	(20.3)	(25.2)	-(20.4)	(17.3)
	2	21.0		2.00	0.438		16.0		2.00	- 0.557		18.4	23.1	- 17.8	13.7
		(20.2)	-	(2.00)	(0.500)	-	(20.2)	-	(2.00)	-(0.498)	-	(20.2)	(25.2)	-(20.1)	(17.0)
	3	7.0		3.00	0.329		24.0		3.00	- 0.527		11.8	12.3	- 37.9	29.1
		(10.2)	-	(3.00)	(0.494)	***	(10.2)	-	(3.00)	-(0.502)	-	(15.2)	(18.9)	-(15.4)	(13.0)
	4	6.0		4.00	0.557		5.0		4.00	- 0.438		13.4	16.8	- 8.8	6.7
		(5.0)	-	(4.00)	(0.495)	-	(5.1)	-	(4.00)	-(0.499)	-	(9.9)	(12.3)	-(10.1)	(8.6)
	5	3.0		5.00	0.560		4.0		5.00	- 0.404		8.4	10.5	- 8.1	6.2
		(2.5)	-	(5.00)	(0.493)	-	(2.5)	-	(5.00)	-(0.496)	-	(6.2)	(7.7)	-(6.3)	(5.3)
	6	1.0		6.00	0.820		1.0		6.00	- 0.449		4.9	6.2	- 2.7	2.1
		(1.2)	-	(6.00)	(0.493)	***	(1.2)	-	(6.00)	-(0.501)	-	(3.6)	(4.5)	-(3.7)	(3.1)
	≥ 7	1.0		8.00	0.489		2.0		8.50	- 0.297		3.9	4.9	- 5.1	3.9
		(1.3)	-	(8.03)	(0.495)	-	(1.2)	-	(8.00)	-(0.499)	**	(5.0)	(6.2)	-(4.9)	(4.2)
	All	79.0		1.97	0.510		79.0		2.13	- 0.457		79.6	100.0	- 76.8	59.0
		(81.3)	-	(1.99)	(0.505)	***	(81.3)	-	(1.99)	-(0.499)	*	(80.3)	(100.0)	-(80.9)	(68.5)
							5-days moving average								
2000/10/25 - 2002/01/31	1	15.0		1.00	0.043		4.0		1.00	- 0.056		0.6	1.8	- 0.2	0.7
		(9.5)	**	(1.00)	(0.070)	-	(9.4)	*	(1.00)	-(0.070)	-	(0.7)	(1.9)	-(0.7)	(1.8)
	2	5.0		2.00	0.091		8.0		2.00	- 0.083		0.9	2.5	- 1.3	3.9
		(4.4)	-	(2.00)	(0.103)	-	(4.4)	*	(2.00)	-(0.107)	-	(0.9)	(2.6)	-(0.9)	(2.7)
	3	0.0		3.00	0.000		5.0		3.00	- 0.113		0.0	0.0	- 1.7	5.0
		(2.9)	**	(3.00)	(0.136)	***	(2.9)	-	(3.00)	-(0.130)	-	(1.2)	(3.4)	-(1.1)	(3.1)
	4	3.0		4.00	0.171		1.0		4.00	- 0.071		2.1	5.7	- 0.3	0.8
		(2.1)	-	(4.00)	(0.161)	-	(2.1)	-	(4.00)	-(0.162)	**	(1.3)	(3.8)	-(1.4)	(3.8)
	5	5.0		5.00	0.242		4.0		5.00	- 0.239		6.1	16.7	- 4.8	14.0
		(3.7)	-	(5.00)	(0.193)	-	(3.6)	-	(5.00)	-(0.198)	-	(3.5)	(10.1)	-(3.5)	(9.9)
	6	2.0		6.00	0.279		4.0		6.00	- 0.234		3.4	9.3	- 5.6	16.5
		(2.4)	-	(6.00)	(0.230)	-	(2.5)	-	(6.00)	-(0.228)	-	(3.3)	(9.4)	-(3.4)	(9.5)
	≥ 7	7.0		10.43	0.317		10.0		8.80	- 0.228		23.1	64.0	- 20.1	59.1
		(8.4)	-	(10.91)	(0.265)	**	(8.5)	-	(10.88)	-(0.266)	-	(24.2)	(68.8)	-(24.6)	(69.1)
	All	37.0		3.97	0.246		36.0		4.75	- 0.199		36.2	100.0	- 34.0	100.0
		(33.3)	-	(4.78)	(0.220)	-	(33.3)	-	(4.82)	-(0.222)	-	(35.1)	(100.0)	-(35.7)	(100.0)

1) Average change in exchange rate level per day in cents.

Notes: Values in parentheses are expected means under the random-walk-hypothesis. These means are derived from a Monte-Carlo-simulation based on 1000 random walk series. The random walks were constructed with an expected zero mean of the first differences and with an expected standard deviation of the first differences as observed in the original exchange rate series over the respective-period. * (**, ***) indicate the significance of the difference between the observed means and the expected means under the random-walk-hypothesis at the 10% (5%, 1%) level.

Table A1 (cont.): Classification of exchange rate runs by duration

Daily dollar/euro rates

		Upward runs					Downward runs					*Contribution to overall change in price*			
	Run length	Number		Average Duration	Average slope 1)		Number		Average Duration	Average slope 1)		Upward runs		Downward runs	
				Days					Days			In cents	In %	In cents	In %
							Based on original data								
2002/01/3103 - 2004/12/30	1	104.0		1.00	0.579		134.0		1.00	- 0.478		60.2	26.4	- 64.0	36.1
		(94.3)	-	(1.00)	(0.558)	-	(94.4)	***	(1.00)	-(0.557)	**	(52.6)	(24.9)	-(52.6)	(25.0)
	2	59.0		2.00	0.590		43.0		2.00	- 0.560		69.7	30.6	- 48.2	27.1
		(47.6)	**	(2.00)	(0.559)	-	(47.4)	-	(2.00)	-(0.557)	-	(53.2)	(25.2)	-(52.8)	(25.1)
	3	21.0		3.00	0.329		24.0		3.00	- 0.527		11.8	12.3	- 37.9	29.1
		(23.6)	-	(3.00)	(0.555)	-	(23.9)	**	(3.00)	-(0.559)	*	(39.3)	(18.6)	-(40.1)	(19.1)
	4	17.0		4.00	0.542		8.0		4.00	- 0.513		36.8	16.2	- 16.4	9.2
		(11.9)	*	(4.00)	(0.564)	-	(11.8)	-	(4.00)	-(0.559)	-	(26.8)	(12.7)	-(26.3)	(12.5)
	5	4.0		5.00	0.420		2.0		5.00	- 0.624		8.4	3.7	- 6.2	3.5
		(5.9)	-	(5.00)	(0.562)	-	(5.7)	*	(5.00)	-(0.561)	-	(16.6)	(7.9)	-(16.1)	(7.6)
	6	1.0		6.00	0.598		6.0		6.00	- 0.542		3.6	1.6	- 19.5	11.0
		(2.9)	-	(6.00)	(0.554)	-	(2.9)	**	(6.00)	-(0.554)	-	(9.6)	(4.5)	-(9.5)	(4.5)
	≥ 7	4.0		7.50	0.475		0.0		-	-		14.3	6.3	0.0	0.0
		(2.9)	-	(7.93)	(0.563)	-	(2.9)	**	(8.01)	-(0.558)		(12.9)	(6.1)	-(13.1)	(6.2)
	All	210.0		1.95	0.557		209.0		1.66	- 0.513		227.7	100.0	- 177.6	100.0
		(189.0)	***	(2.00)	(0.559)	-	(189.1)	***	(2.00)	(0.000)	-	(211.0)	(100.0)	-(210.5)	(100.0)
							5-days moving average								
2002/01/3103 - 2004/12/30	1	15.0		1.00	0.076		20.0		1.00	- 0.085		1.1	1.0	- 1.7	2.6
		(21.7)	*	(1.00)	(0.079)	-	(21.5)	-	(1.00)	-(0.079)	-	(1.7)	(1.8)	-(1.7)	(1.8)
	2	5.0		2.00	0.137		11.0		2.00	- 0.090		1.4	1.2	- 2.0	3.0
		(10.3)	*	(2.00)	(0.115)	-	(10.4)	-	(2.00)	-(0.116)	-	(2.4)	(2.5)	-(2.4)	(2.6)
	3	9.0		3.00	0.143		7.0		3.00	- 0.133		3.9	3.3	- 2.8	4.2
		(6.4)	-	(3.00)	(0.149)	-	(6.4)	-	(3.00)	-(0.148)	-	(2.9)	(3.0)	-(2.9)	(3.1)
	4	2.0		4.00	0.300		4.0		4.00	- 0.227		2.4	2.1	- 3.6	5.4
		(4.9)	*	(4.00)	(0.176)	***	(4.8)	-	(4.00)	-(0.178)	-	(3.4)	(3.7)	-(3.4)	(3.6)
	5	9.0		5.00	0.179		6.0		5.00	- 0.260		8.1	6.9	- 7.8	11.7
		(8.3)	-	(5.00)	(0.220)	-	(8.3)	-	(5.00)	-(0.218)	-	(9.1)	(9.7)	-(9.0)	(9.7)
	6	4.0		6.00	0.244		5.0		6.00	- 0.238		5.8	5.0	- 7.1	10.7
		(5.7)	-	(6.00)	(0.258)	-	(5.8)	-	(6.00)	-(0.256)	-	(8.8)	(9.3)	-(8.9)	(9.5)
	≥ 7	26.0		13.27	0.271		15.0		9.13	- 0.305		93.4	80.4	- 41.8	62.5
		(20.0)	**	(10.97)	(0.300)	-	(20.0)	*	(10.93)	-(0.298)	-	(65.7)	(69.9)	-(65.2)	(69.7)
	All	70.0		6.77	0.245		68.0		4.06	- 0.242		116.1	100.0	- 66.9	100.0
		(77.1)	-	(4.87)	(0.250)	-	(77.1)	*	(4.87)	-(0.249)	-	(93.9)	(100.0)	-(93.5)	(100.0)

1) Average change in exchange rate level per day in cents.

Notes: Values in parentheses are expected means under the random-walk-hypothesis. These means are derived from a Monte-Carlo-simulation based on 1000 random walk series. The random walks were constructed with an expected zero mean of the first differences and with an expected standard deviation of the first differences as observed in the original exchange rate series over the respective-period. * (**, ***) indicate the significance of the difference between the observed means and the expected means under the random-walk-hypothesis at the 10% (5%, 1%) level.

Table A1 (cont.): Classification of exchange rate runs by duration

Daily dollar/euro rates

	Run length	Upward runs: Number		Upward runs: Average Duration (Days)	Upward runs: Average slope 1)		Downward runs: Number		Downward runs: Average Duration (Days)	Downward runs: Average slope 1)		*Contribution to overall change in price*: Upward runs, In cents	Upward runs, In %	Downward runs, In cents	Downward runs, In %
Based on original data															
2004/12/30 -	1	72.0		1.00	0.499		73.0		1.00	- 0.433		35.9	28.5	- 31.6	24.4
2006/12/30		(65.1)	-	(1.00)	(0.510)	-	(65.1)	-	(1.00)	-(0.511)	*	(33.2)	(25.2)	-(33.3)	(25.2)
	2	41.0		2.00	0.491		32.0		2.00	- 0.439		40.3	31.9	- 28.1	21.7
		(32.6)	*	(2.00)	(0.507)	-	(32.5)	-	(2.00)	-(0.507)	*	(33.0)	(25.1)	-(33.0)	(25.0)
	3	15.0		3.00	0.329		24.0		3.00	- 0.527		11.8	12.3	- 37.9	29.1
		(16.1)	-	(3.00)	(0.504)	-	(16.2)	-	(3.00)	-(0.509)	-	(24.3)	(18.5)	-(24.8)	(18.8)
	4	6.0		4.00	0.619		12.0		4.00	- 0.537		14.9	11.8	- 25.8	19.9
		(8.2)	-	(4.00)	(0.516)	*	(8.1)	*	(4.00)	-(0.508)	-	(16.9)	(12.8)	-(16.5)	(12.5)
	5	3.0		5.00	0.470		3.0		5.00	- 0.392		7.1	5.6	- 5.9	4.5
		(4.1)	-	(5.00)	(0.510)	-	(4.0)	-	(5.00)	-(0.512)	-	(10.4)	(7.9)	-(10.3)	(7.8)
	6	2.0		6.00	0.553		2.0		6.00	- 0.598		6.6	5.3	- 7.2	5.5
		(2.0)	-	(6.00)	(0.509)	-	(2.0)	-	(6.00)	-(0.508)	-	(6.1)	(4.6)	-(6.0)	(4.6)
	≥ 7	0.0		-	-		1.0		8.00	- 0.498		0.0	0.0	- 4.0	3.1
		(1.9)	*	(7.99)	(0.500)	-	(1.9)	-	(8.02)	-(0.512)	-	(7.8)	(5.9)	-(7.9)	(6.0)
	All	139.0		1.80	0.505		139.0		1.93	- 0.484		126.3	100.0	- 129.7	100.0
		(129.9)	*	(1.99)	(0.508)	-	(129.9)	*	(1.99)	-(0.509)	-	(131.7)	(100.0)	-(131.8)	(100.0)
5-days moving average															
2004/12/30 -	1	15.0		1.00	0.063		11.0		1.00	- 0.049		0.9	1.7	- 0.5	0.9
2006/12/30		(14.9)	-	(1.00)	(0.073)	-	(15.1)	-	(1.00)	-(0.073)	*	(1.1)	(1.9)	-(1.1)	(1.9)
	2	11.0		2.00	0.089		10.0		2.00	- 0.125		2.0	3.5	- 2.5	4.3
		(7.2)	*	(2.00)	(0.107)	-	(7.2)	-	(2.00)	-(0.107)	-	(1.5)	(2.7)	-(1.5)	(2.6)
	3	3.0		3.00	0.120		10.0		3.00	- 0.153		1.1	1.9	- 4.6	7.9
		(4.5)	-	(3.00)	(0.136)	-	(4.4)	***	(3.00)	-(0.136)	-	(1.8)	(3.2)	-(1.8)	(3.1)
	4	4.0		4.00	0.125		1.0		4.00	- 0.117		2.0	3.5	- 0.5	0.8
		(3.4)	-	(4.00)	(0.164)	-	(3.2)	-	(4.00)	-(0.160)	-	(2.2)	(3.8)	-(2.1)	(3.6)
	5	8.0		5.00	0.231		6.0		5.00	- 0.183		9.2	16.3	- 5.5	9.5
		(5.7)	-	(5.00)	(0.201)	-	(5.8)	-	(5.00)	-(0.200)	-	(5.7)	(9.8)	-(5.8)	(9.9)
	6	5.0		6.00	0.293		3.0		6.00	- 0.224		8.8	15.5	- 4.0	6.9
		(4.0)	-	(6.00)	(0.234)	-	(3.9)	-	(6.00)	-(0.236)	-	(5.5)	(9.5)	-(5.5)	(9.4)
	≥ 7	10.0		11.20	0.291		15.0		10.47	- 0.259		32.6	57.6	- 40.6	69.7
		(13.6)	*	(10.91)	(0.271)	-	(13.6)	-	(10.92)	-(0.273)	-	(40.3)	(69.2)	-(40.6)	(69.5)
	All	56.0		4.36	0.232		56.0		4.82	- 0.216		56.6	100.0	- 58.2	100.0
		(53.3)	-	(4.83)	(0.226)	-	(53.2)	-	(4.83)	-(0.227)	-	(58.2)	(100.0)	-(58.5)	(100.0)

1) Average change in exchange rate level per day in cents.

Notes: Values in parentheses are expected means under the random-walk-hypothesis. These means are derived from a Monte-Carlo-simulation based on 1000 random walk series. The random walks were constructed with an expected zero mean of the first differences and with an expected standard deviation of the first differences as observed in the original exchange rate series over the respective-period. * (**, ***) indicate the significance of the difference between the observed means and the expected means under the random-walk-hypothesis at the 10% (5%, 1%) level.

Table A2: Non-random components in duration and slope of exchange rate runs

Daily dollar/euro rates

	Run length	Upward runs: Number, observed	Number, RW-Simulation: Without drift	z-stat	With drift	z-stat	Slope 1), observed	Slope 1), RW-Simulation: Without drift	z-stat	With drift	z-stat	Downward runs: Number, observed	Number, RW-Simulation: Without drift	z-stat	With drift	z-stat	Slope 1), observed	Slope 1), RW-Simulation: Without drift	z-stat	With drift	z-stat
										1999/01/01 - 2000/10/25											
Original data	1-2	93	88.7	-	93.0	-	0.491	0.501	-	0.476	-	69	88.8	***	82.0	**	-0.515	-0.501	-	-0.530	-
	3-6	20	27.7	**	22.9	-	0.445	0.501	*	0.477	-	42	27.5	***	31.9	***	-0.478	-0.502	-	-0.529	*
	≥ 7	0	1.8	*	1.0	-	-	0.508		0.471		2	1.8	-	3.0	-	-0.343	-0.505	*	-0.530	**
	All	113	118.2	-	116.9	-	0.474	0.501	-	0.476	-	113	118.2	-	116.9	-	-0.484	-0.502	-	-0.530	**
5-days moving averages 2)	1-6	37	35.9	-	38.3	-	0.179	0.162	-	0.154	*	27	36.0	*	30.7	-	-0.148	-0.162	-	-0.168	-
	7-14	5	10.4	**	7.6	-	0.250	0.261	-	0.250	-	11	10.4	-	12.1	-	-0.267	-0.262	-	-0.280	-
	≥ 15	2	2.0	-	0.8	-	0.342	0.286	-	0.263	-	7	2.0	***	4.0	**	-0.265	-0.286	-	-0.306	-
	All	44	48.4	-	46.7	-	0.229	0.224	-	0.199	*	45	48.4	-	46.9	-	-0.240	-0.224	-	-0.253	-
10-days moving averages 2)	1-9	26	23.9	-	24.6	-	0.064	0.084	*	0.082	*	18	24.0	-	19.3	-	-0.074	-0.083	-	-0.084	-
	10-24	6	8.4	-	6.0	-	0.216	0.182	*	0.172	**	14	8.3	***	9.0	**	-0.195	-0.184	-	-0.196	-
	≥ 25	0	1.3	-	0.4	-	-	0.214		0.196		2	1.3	-	3.0	-	-0.212	-0.212	-	-0.233	-
	All	32	33.6	-	31.1	-	0.152	0.158	-	0.134	-	34	33.6	-	31.3	-	-0.181	-0.158	-	-0.189	-
20-days moving averages 2)	1-14	16	18.0	-	16.9	-	0.032	0.051	**	0.050	*	11	18.0	*	13.6	-	-0.058	-0.052	-	-0.051	-
	15-34	3	4.1	-	2.8	-	0.165	0.124	**	0.113	**	5	4.1	-	3.9	-	-0.101	-0.123	-	-0.133	-
	≥ 35	0	1.4	*	0.3	-	-	0.150		0.136		4	1.4	***	3.0	-	-0.147	-0.151	-	-0.173	-
	All	19	23.5	-	20.1	-	0.117	0.110	-	0.087	*	20	23.5	-	20.5	-	-0.122	-0.110	-	-0.143	-
40-days moving averages 2)	1-14	5	11.8	*	10.0	-	0.039	0.025	**	0.024	**	4	11.8	*	8.2	-	-0.030	-0.026	-	-0.025	-
	15-39	2	2.0	-	1.5	-	0.069	0.063	-	0.061	-	0	2.0	*	1.4	-	-	-0.063		-0.070	
	≥ 40	0	2.0	**	0.6	-	-	0.101		0.090		4	1.9	**	3.0	-	-0.105	-0.101	-	-0.126	-
	All	7	15.8	**	12.1	-	0.063	0.077	-	0.054	-	8	15.8	*	12.6	-	-0.099	-0.076	-	-0.112	-
										2000/10/25 - 2002/01/31											
Original data	1-2	61	61.1	-	61.0	-	0.430	0.498	*	0.503	**	56	61.0	-	62.1	-	-0.506	-0.499	-	-0.492	-
	3-6	17	19.0	-	19.3	-	0.613	0.495	***	0.500	***	21	19.0	-	18.4	-	-0.447	-0.499	-	-0.494	-
	≥ 7	1	1.3	-	1.3	-	0.489	0.495	-	0.501	-	2	1.2	-	1.1	-	-0.297	-0.499	**	-0.494	**
	All	79	81.3	-	81.6	-	0.510	0.496	-	0.502	-	79	81.3	-	81.6	-	-0.457	-0.499	*	-0.493	-
5-days moving averages 2)	1-6	30	25.0	-	24.5	-	0.176	0.161	-	0.161	-	26	24.8	-	25.3	-	-0.168	-0.161	-	-0.159	-
	7-14	5	7.0	-	7.5	-	0.317	0.259	*	0.261	*	9	7.1	-	6.9	-	-0.213	-0.260	-	-0.257	-
	≥ 15	2	1.3	-	1.4	-	0.317	0.281	-	0.283	-	1	1.4	-	1.2	-	-0.304	-0.282	-	-0.280	-
	All	37	33.3	-	33.5	-	0.246	0.220	-	0.224	-	36	33.3	-	33.4	-	-0.199	-0.222	-	-0.217	-
10-days moving averages 2)	1-9	18	16.6	-	16.2	-	0.089	0.083	-	0.083	-	15	16.4	-	16.7	-	-0.084	-0.084	-	-0.083	-
	10-24	5	5.6	-	5.8	-	0.158	0.181	-	0.182	-	8	5.7	-	5.5	*	-0.163	-0.182	-	-0.179	-
	≥ 25	1	0.9	-	1.0	-	0.317	0.212	**	0.216	**	1	0.9	-	0.8	-	-0.158	-0.211	-	-0.210	-
	All	24	23.1	-	23.0	-	0.168	0.156	-	0.159	-	24	23.0	-	23.0	-	-0.142	-0.157	-	-0.153	-
20-days moving averages 2)	1-14	14	12.2	-	12.1	-	0.047	0.051	-	0.051	-	12	12.2	-	12.4	-	-0.044	-0.051	-	-0.050	-
	15-34	0	2.8	**	2.9	**	-	0.123		0.123		2	2.7	-	2.7	-	-0.089	-0.122	-	-0.121	-
	≥ 35	2	0.9	*	1.0	-	0.187	0.149	-	0.151	-	2	0.9	*	0.8	*	-0.094	-0.150	*	-0.148	*
	All	16	15.9	-	16.0	-	0.127	0.109	-	0.112	-	16	15.9	-	15.9	-	-0.082	-0.110	-	-0.105	-
40-days moving averages 2)	1-14	5	7.8	-	7.6	-	0.019	0.025	-	0.025	-	5	7.8	-	7.8	-	-0.036	-0.025	-	-0.024	-
	15-39	0	1.4	-	1.4	-	-	0.065		0.066		1	1.4	-	1.4	-	-0.064	-0.065	-	-0.063	-
	≥ 40	2	1.3	-	1.3	-	0.127	0.100	-	0.103	-	1	1.3	-	1.2	-	-0.076	-0.100	-	-0.100	-
	All	7	10.5	-	10.4	-	0.108	0.076	*	0.078	-	7	10.5	-	10.3	-	-0.067	-0.075	-	-0.073	-

1) Average change in exchange rate level per day in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective moving average.

Notes: See tables A6.

Table A2 (cont.): Non-random components in duration and slope of exchange rate runs

Daily dollar/euro

	Run length	Upward runs										Downward runs									
		Number					Slope 1)					Number					Slope 1)				
		ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation			
			Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat
		2002/01/31 - 2004/12/30																			
Original data	1-2	*163*	*141.9*	**	*133.6*	***	0.585	0.558	-	0.585	-	*177*	*141.8*	***	*147.9*	***	-0.510	-0.557	*	-0.534	-
	3-6	*43*	*44.3*	-	*49.7*	-	0.532	0.558	-	0.583	*	*32*	*44.3*	***	*38.1*	-	-0.519	-0.559	-	-0.535	-
	≥ 7	*4*	*2.9*	-	*4.6*	-	0.475	0.563	-	0.584	*	*0*	*2.9*	**	*1.8*	*	-	-0.562		-0.535	
	All	*210*	*189.0*	***	*187.9*	***	0.557	0.559	-	0.584	-	*209*	*189.1*	***	*187.8*	***	-0.513	-0.558	**	-0.535	-
5-days moving averages 2)	1-6	*44*	*57.2*	**	*50.7*	-	0.176	0.181	-	0.186	-	*53*	*57.1*	-	*60.9*	-	-0.180	-0.180	-	-0.174	-
	7-14	*18*	*16.6*	-	*19.3*	-	0.279	0.292	-	0.306	-	*15*	*16.8*	-	*13.0*	-	-0.305	-0.291	-	-0.279	-
	≥ 15	*8*	*3.3*	***	*5.7*	-	0.262	0.319	-	0.339	**	*0*	*3.2*	**	*1.6*	*	-	-0.320		-0.302	
	All	*70*	*77.1*	-	*75.7*	-	0.245	0.250	-	0.276	**	*68*	*77.1*	*	*75.6*	-	-0.242	-0.249	-	-0.226	-
10-days moving averages 2)	1-9	*42*	*38.4*	-	*32.9*	*	0.113	0.093	*	0.093	*	*40*	*38.3*	-	*40.4*	-	-0.079	-0.093	-	-0.092	-
	10-24	*6*	*13.3*	***	*14.6*	***	0.188	0.204	-	0.215	*	*13*	*13.5*	-	*10.2*	-	-0.211	-0.204	-	-0.192	-
	≥ 25	*6*	*2.2*	***	*4.3*	-	0.234	0.239	-	0.255	-	*0*	*2.0*	*	*0.9*	-	-	-0.235		-0.221	
	All	*54*	*53.9*	-	*51.7*	-	0.190	0.177	-	0.203	-	*53*	*53.9*	-	*51.5*	-	-0.159	-0.176	-	-0.153	-
20-days moving averages 2)	1-14	*29*	*28.7*	-	*23.4*	-	0.058	0.057	-	0.058	-	*31*	*28.7*	-	*28.3*	-	-0.050	-0.058	-	-0.056	-
	15-34	*4*	*6.5*	-	*6.3*	-	0.129	0.138	-	0.145	-	*6*	*6.6*	-	*4.8*	-	-0.141	-0.138	-	-0.129	-
	≥ 35	*5*	*2.4*	**	*4.5*	-	0.181	0.168	-	0.187	-	*0*	*2.3*	**	*0.8*	-	-	-0.169		-0.158	
	All	*38*	*37.5*	-	*34.2*	-	0.144	0.125	-	0.152	-	*37*	*37.5*	-	*33.9*	-	-0.096	-0.124	**	-0.102	-
40-days moving averages 2)	1-14	*11*	*19.5*	*	*14.7*	-	0.026	0.028	-	0.028	-	*14*	*19.4*	-	*17.4*	-	-0.024	-0.028	-	-0.027	-
	15-39	*3*	*3.3*	-	*2.4*	-	0.055	0.068	-	0.073	-	*2*	*3.3*	-	*2.7*	-	-0.045	-0.070	*	-0.067	-
	≥ 40	*5*	*3.2*	*	*4.8*	-	0.133	0.113	-	0.135	-	*2*	*3.3*	-	*1.3*	-	-0.100	-0.114	-	-0.102	-
	All	*19*	*26.0*	-	*21.8*	-	0.115	0.086	**	0.118	-	*18*	*26.1*	*	*21.4*	-	-0.070	-0.088	-	-0.066	-
		2004/12/30 - 2006/12/30																			
Original data	1-2	*113*	*97.6*	**	*98.0*	**	0.495	0.509	-	0.505	-	105	*97.6*	-	*97.1*	-	-0.436	-0.509	**	-0.512	**
	3-6	*26*	*30.3*	-	*30.1*	-	0.522	0.509	-	0.506	-	33	*30.4*	-	*30.8*	-	-0.537	-0.509	-	-0.511	-
	≥ 7	*0*	*1.9*	*	*1.8*	*	-	0.500		0.512		1	*1.9*	-	*2.1*	-	-0.498	-0.512	-	-0.518	-
	All	*139*	*129.9*	*	*129.9*	**	0.505	0.508	-	0.506	-	139	*129.9*	*	*129.9*	**	-0.484	-0.509	-	-0.512	-
5-days moving averages 2)	1-6	*46*	*39.6*	-	*40.0*	-	0.182	0.165	***	0.163	-	41	*39.6*	-	*39.2*	-	-0.156	-0.165	-	-0.165	-
	7-14	*9*	*11.4*	-	*11.2*	-	0.285	0.264	***	0.264	-	12	*11.4*	-	*11.7*	-	-0.267	-0.267	-	-0.269	-
	≥ 15	*1*	*2.2*	-	*2.0*	-	0.315	0.290	***	0.285	-	3	*2.2*	-	*2.4*	-	-0.240	-0.289	-	-0.292	-
	All	*56*	*53.3*	-	*53.3*	-	0.232	0.226	***	0.223	-	56	*53.2*	-	*53.3*	-	-0.216	-0.227	-	-0.230	-
10-days moving averages 2)	1-9	*34*	*26.3*	*	*26.8*	-	0.080	0.085	-	0.086	-	33	*26.3*	-	*26.1*	-	-0.094	-0.085	-	-0.085	-
	10-24	*8*	*9.3*	-	*8.8*	-	0.184	0.184	-	0.185	-	10	*9.2*	-	*9.3*	-	-0.182	-0.186	-	-0.187	-
	≥ 25	*2*	*1.4*	-	*1.3*	-	0.216	0.218	-	0.214	-	1	*1.4*	-	*1.6*	-	-0.235	-0.214	-	-0.217	-
	All	*44*	*36.9*	*	*37.0*	*	0.156	0.160	-	0.159	-	44	*37.0*	*	*37.0*	*	-0.160	-0.161	-	-0.163	-
20-days moving averages 2)	1-14	*17*	*19.7*	-	*19.8*	-	0.034	0.052	*	0.052	**	18	*19.7*	-	*19.4*	-	-0.055	-0.052	-	-0.052	-
	15-34	*4*	*4.5*	-	*4.5*	-	0.100	0.125	-	0.123	-	6	*4.5*	-	*4.6*	-	-0.114	-0.126	-	-0.126	-
	≥ 35	*3*	*1.5*	*	*1.4*	*	0.144	0.152	-	0.152	-	1	*1.5*	-	*1.7*	-	-0.195	-0.153	-	-0.157	-
	All	*24*	*25.7*	-	*25.6*	-	0.109	0.112	-	0.110	-	25	*25.7*	-	*25.7*	-	-0.114	-0.112	-	-0.115	-
40-days moving averages 2)	1-14	*11*	*13.2*	-	*13.0*	-	0.027	0.026	-	0.025	-	12	*13.3*	-	*12.8*	-	-0.029	-0.026	-	-0.026	-
	15-39	*3*	*2.3*	-	*2.3*	-	0.066	0.064	-	0.063	-	2	*2.3*	-	*2.2*	-	-0.038	-0.064	*	-0.065	-
	≥ 40	*2*	*2.2*	-	*2.0*	***	0.112	0.103	-	0.104	-	2	*2.1*	-	*2.3*	-	-0.108	-0.102	-	-0.106	-
	All	*16*	*17.7*	-	*17.3*	-	0.077	0.078	-	0.077	**	16	*17.7*	-	*17.3*	-	-0.076	-0.077	-	-0.082	-

1) Average change in exchange rate level per day in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective moving average.

Notes: See tables A6.

Table A3: Classification of exchange rate runs by duration: Daily dollar/deutschmark rates

Daily dollar/deutschmark rates 1987 – 1998

		Upward runs					Downward runs					Contribution to overall change in price			
	Run length	Number		Average Duration	Average slope 1)		Number		Average Duration	Average slope 1)		Upward runs		Downward runs	
				Days					Days			In cents	In %	In cents	In %
							Based on original data								
1987/01/01 -	1	256.0		1.00	0.567		250.0		1.00	- 0.637		145.2	21.6	- 159.2	25.3
1995/04/19		(265.6)	-	(1.00)	(0.665)	***	(265.0)	-	(1.00)	-(0.665)	-	(176.6)	(25.0)	-(176.2)	(24.9)
	2	122.0		2.00	0.658		146.0		2.00	- 0.540		160.6	23.9	- 157.7	25.0
		(132.3)	-	(2.00)	(0.664)	-	(133.0)	*	(2.00)	-(0.664)	***	(175.7)	(24.9)	-(176.6)	(25.0)
	3	70.0		3.00	0.638		68.0		3.00	- 0.634		134.0	19.9	- 129.4	20.5
		(66.1)	-	(3.00)	(0.666)	-	(66.3)	-	(3.00)	-(0.667)	-	(132.1)	(18.7)	-(132.6)	(18.8)
	4	38.0		4.00	0.599		29.0		4.00	- 0.567		91.0	13.5	- 65.8	10.4
		(33.2)	-	(4.00)	(0.665)	*	(33.0)	-	(4.00)	-(0.664)	**	(88.4)	(12.5)	-(87.6)	(12.4)
	5	18.0		5.00	0.692		22.0		5.00	- 0.670		62.3	9.3	- 73.7	11.7
		(16.6)	-	(5.00)	(0.665)	-	(16.6)	*	(5.00)	-(0.669)	-	(55.3)	(7.8)	-(55.4)	(7.8)
	6	9.0		6.00	0.610		4.0		6.00	- 0.818		32.9	4.9	- 19.6	3.1
		(8.3)	-	(6.00)	(0.666)	-	(8.3)	*	(6.00)	-(0.664)	**	(33.3)	(4.7)	-(33.0)	(4.7)
	≥ 7	11.0		7.55	0.565		5.0		8.00	- 0.628		46.9	7.0	- 25.1	4.0
		(8.5)	-	(7.98)	(0.662)	*	(8.6)	-	(7.98)	-(0.664)	-	(44.8)	(6.3)	-(45.5)	(6.4)
	All	524.0		2.08	0.618		524.0		1.98	- 0.609		672.8	100.0	- 630.6	100.0
		(530.7)	-	(2.00)	(0.665)	***	(530.7)	-	(2.00)	-(0.665)	***	(706.1)	(100.0)	-(707.0)	(100.0)
							5-days moving average								
1987/01/01 -	1	51.0		1.00	0.084		70.0		1.00	- 0.068		4.3	1.3	- 4.7	1.7
1995/04/19		(60.6)	-	(1.00)	(0.094)	-	(60.2)	-	(1.00)	-(0.094)	***	(5.7)	(1.8)	-(5.7)	(1.8)
	2	22.0		2.00	0.138		21.0		2.00	- 0.133		6.1	1.9	- 5.6	1.9
		(28.4)	-	(2.00)	(0.137)	-	(28.9)	*	(2.00)	-(0.137)	-	(7.8)	(2.5)	-(7.9)	(2.5)
	3	20.0		3.00	0.150		15.0		3.00	- 0.130		9.0	2.8	- 5.9	2.0
		(18.4)	-	(3.00)	(0.176)	-	(18.1)	-	(3.00)	-(0.175)	**	(9.7)	(3.1)	-(9.5)	(3.0)
	4	13.0		4.00	0.186		10.0		4.00	- 0.185		9.7	3.0	- 7.4	2.6
		(13.3)	-	(4.00)	(0.209)	-	(13.4)	-	(4.00)	-(0.209)	-	(11.2)	(3.5)	-(11.2)	(3.6)
	5	19.0		5.00	0.273		24.0		5.00	- 0.288		26.0	7.9	- 34.5	12.1
		(23.4)	-	(5.00)	(0.262)	-	(23.6)	-	(5.00)	-(0.261)	-	(30.6)	(9.7)	-(30.8)	(9.7)
	6	21.0		6.00	0.274		15.0		6.00	- 0.385		34.6	10.6	- 34.7	12.1
		(16.0)	-	(6.00)	(0.305)	-	(15.7)	-	(6.00)	-(0.308)	***	(29.3)	(9.3)	-(29.1)	(9.2)
	≥ 7	62.0		11.21	0.342		53.0		11.04	- 0.331		237.4	72.6	- 193.3	67.6
		(56.6)	-	(10.95)	(0.357)	-	(56.7)	-	(11.00)	-(0.356)	**	(221.4)	(70.1)	-(221.9)	(70.2)
	All	208.0		5.40	0.291		208.0		4.77	- 0.288		326.9	100.0	- 286.1	100.0
		(216.7)	-	(4.89)	(0.298)	-	(216.7)	-	(4.90)	-(0.298)	-	(315.7)	(100.0)	-(316.1)	(100.0)

1) Average change in exchange rate level per day in cents.

Notes: See tables A1.

Table A3 (cont.): Classification of exchange rate runs by duration

Daily dollar/deutschmark rates 1987 – 1998

		Upward runs					Downward runs					*Contribution to overall change in price*			
	Run length	Number		Average Duration	Average slope 1)		Number		Average Duration	Average slope 1)		Upward runs		Downward runs	
				Days					Days			In cents	In %	In cents	In %
							Based on original data								
1995/04/20 - 98/31/12	1	156.0		1.00	0.503		132.0		1.00	- 0.503		78.4	33.1	- 66.4	25.5
		(119.6)	***	(1.00)	(0.569)	**	(119.5)	-	(1.00)	-(0.571)	**	(68.1)	(25.0)	-(68.2)	(25.1)
	2	64.0		2.00	0.522		64.0		2.00	- 0.439		66.9	28.2	- 56.2	21.6
		(59.8)	-	(2.00)	(0.568)	-	(60.0)	-	(2.00)	-(0.567)	***	(67.9)	(25.0)	-(68.0)	(25.0)
	3	24.0		3.00	0.638		68.0		3.00	- 0.634		134.0	19.9	- 129.4	20.5
		(29.7)	-	(3.00)	(0.570)	***	(29.8)	**	(3.00)	-(0.566)	-	(50.8)	(18.7)	-(50.6)	(18.6)
	4	12.0		4.00	0.517		13.0		4.00	- 0.547		24.8	10.5	- 28.4	10.9
		(15.0)	-	(4.00)	(0.568)	-	(15.0)	-	(4.00)	-(0.568)	-	(34.2)	(12.6)	-(34.0)	(12.5)
	5	5.0		5.00	0.363		9.0		5.00	- 0.599		9.1	3.8	- 27.0	10.3
		(7.6)	-	(5.00)	(0.570)	***	(7.4)	-	(5.00)	-(0.569)	-	(21.6)	(7.9)	-(21.0)	(7.7)
	6	0.0		6.00	0.000		3.0		6.00	- 0.417		0.0	0.0	- 7.5	2.9
		(3.6)	**	(6.00)	(0.574)	***	(3.7)	-	(6.00)	-(0.567)	*	(12.5)	(4.6)	-(12.7)	(4.7)
	≥ 7	2.0		7.00	0.528		3.0		8.00	- 0.549		7.4	3.1	- 13.2	5.1
		(3.7)	-	(7.98)	(0.568)	-	(3.7)	-	(7.99)	-(0.569)	-	(17.0)	(6.2)	-(17.0)	(6.3)
	All	263.0		1.68	0.534		262.0		1.96	- 0.508		236.7	100.0	- 260.6	100.0
		(0.0)	***	(2.00)	(0.569)	**	(239.1)	***	(2.00)	-(0.568)	***	(272.0)	(100.0)	-(271.6)	(100.0)
							5-days moving average								
1995/04/20 - 98/31/12	1	34.0		1.00	0.078		31.0		1.00	- 0.062		2.7	2.7	- 1.9	1.5
		(27.8)	-	(1.00)	(0.080)	-	(27.4)	-	(1.00)	-(0.081)	*	(2.2)	(1.8)	-(2.2)	(1.8)
	2	12.0		2.00	0.110		14.0		2.00	- 0.118		2.6	2.7	- 3.3	2.7
		(12.9)	-	(2.00)	(0.117)	-	(13.4)	-	(2.00)	-(0.119)	-	(3.0)	(2.5)	-(3.2)	(2.6)
	3	6.0		3.00	0.150		15.0		3.00	- 0.130		9.0	2.8	- 5.9	2.0
		(8.3)	-	(3.00)	(0.152)	-	(8.2)	-	(3.00)	-(0.150)	-	(3.8)	(3.1)	-(3.7)	(3.1)
	4	6.0		4.00	0.166		10.0		4.00	- 0.199		4.0	4.0	- 8.0	6.4
		(5.9)	-	(4.00)	(0.180)	-	(6.2)	*	(4.00)	-(0.177)	-	(4.2)	(3.5)	-(4.4)	(3.6)
	5	11.0		5.00	0.200		7.0		5.00	- 0.161		11.0	11.2	- 5.6	4.5
		(10.5)	-	(5.00)	(0.225)	-	(10.5)	-	(5.00)	-(0.223)	**	(11.9)	(9.8)	-(11.7)	(9.7)
	6	13.0		6.00	0.221		4.0		6.00	- 0.265		17.3	17.5	- 6.4	5.1
		(7.3)	**	(6.00)	(0.259)	-	(7.0)	-	(6.00)	-(0.263)	-	(11.4)	(9.4)	-(11.1)	(9.2)
	≥ 7	21.0		9.52	0.290		29.0		11.69	- 0.281		58.1	58.9	- 95.1	76.7
		(25.2)	-	(10.97)	(0.305)	-	(25.4)	-	(10.96)	-(0.304)	-	(84.4)	(69.8)	-(84.6)	(70.0)
	All	103.0		4.20	0.228		102.0		5.08	- 0.239		98.7	100.0	- 124.0	100.0
		(98.0)	-	(4.85)	(0.254)	**	(98.0)	-	(4.86)	-(0.253)	-	(121.0)	(100.0)	-(120.9)	(100.0)

1) Average change in exchange rate level per day in cents.

Notes: See tables A1.

Table A4: Non-random components in duration and slope of exchange rate runs

Daily dollar/deutschmark rates 1987 – 1998

	Run lengt	Upward runs										Downward runs									
		Number					Slope 1)					Number					Slope 1)				
		ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation			
			Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat
										1987/01/01 - 1995/04/19											
Original data	1-2	*378*	*397.9*	-	*394.9*	-	0.612	0.665	***	0.674	***	*396*	*398.0*	-	*404.5*	-	-0.585	-0.665	***	-0.585	***
	3-6	*135*	*124.3*	-	*128.4*	-	0.633	0.665	*	0.670	*	*123*	*124.1*	-	*120.9*	-	-0.636	-0.666	*	-0.636	-
	≥ 7	*11*	*8.5*	-	*9.0*	-	0.565	0.662	*	0.673	**	*5*	*8.6*	-	*7.1*	-	-0.628	-0.664	-	-0.628	-
	All	*524*	*530.7*	-	*532.4*	-	0.618	0.665	***	0.672	***	*524*	*530.7*	-	*532.4*	-	-0.609	-0.665	***	-0.609	***
5-days moving averages 2)	1-6	*146*	*160.0*	-	*159.2*	-	0.209	0.215	-	0.215	-	*155*	*160.0*	-	*166.4*	-	-0.228	-0.215	-	-0.228	*
	7-14	*52*	*47.3*	-	*49.3*	-	0.336	0.348	-	0.350	-	*45*	*47.1*	-	*45.0*	-	-0.315	-0.347	**	-0.315	*
	≥ 15	*10*	*9.3*	-	*10.7*	-	0.355	0.379	-	0.383	-	*8*	*9.6*	-	*7.7*	-	-0.366	-0.378	-	-0.366	-
	All	*208*	*216.7*	-	*219.1*	-	0.291	0.298	-	0.303	-	*208*	*216.7*	-	*219.1*	-	-0.288	-0.298	-	-0.288	-
10-days moving averages 2)	1-9	*83*	*108.9*	**	*105.0*	**	0.127	0.110	**	0.110	**	*89*	*108.4*	**	*110.6*	**	-0.100	-0.110	-	-0.100	-
	10-24	*39*	*38.1*	-	*39.1*	-	0.228	0.240	-	0.244	-	*35*	*38.6*	-	*36.3*	-	-0.223	-0.240	-	-0.223	-
	≥ 25	*9*	*6.0*	-	*7.6*	-	0.266	0.280	-	0.286	-	*6*	*6.0*	-	*4.9*	-	-0.288	-0.282	-	-0.288	-
	All	*131*	*153.0*	**	*151.8*	**	0.216	0.209	-	0.218	-	*130*	*153.0*	**	*151.8*	**	-0.201	-0.209	-	-0.201	-
20-days moving averages 2)	1-14	*68*	*81.1*	-	*79.5*	-	0.086	0.067	***	0.067	***	*67*	*81.0*	-	*83.5*	*	-0.062	-0.067	-	-0.062	-
	15-34	*12*	*18.6*	**	*19.0*	**	0.172	0.163	-	0.164	-	*18*	*18.6*	-	*17.8*	-	-0.144	-0.163	*	-0.144	-
	≥ 35	*12*	*6.7*	***	*8.2*	**	0.183	0.202	-	0.206	-	*6*	*6.8*	-	*5.3*	-	-0.220	-0.204	-	-0.220	-
	All	*92*	*106.4*	*	*106.7*	*	0.158	0.149	-	0.155	-	*91*	*106.4*	*	*106.6*	*	-0.147	-0.150	-	-0.147	-
40-days moving averages 2)	1-14	*44*	*56.7*	-	*54.2*	-	0.037	0.033	-	0.033	-	*44*	*56.4*	-	*57.1*	-	-0.026	-0.033	**	-0.026	**
	15-39	*6*	*9.2*	-	*8.9*	-	0.072	0.081	-	0.081	-	*5*	*9.1*	*	*9.0*	*	-0.081	-0.080	-	-0.081	-
	≥ 40	*10*	*9.4*	-	*11.0*	-	0.136	0.136	-	0.141	-	*10*	*9.8*	-	*7.9*	-	-0.139	-0.135	-	-0.139	-
	All	*60*	*75.2*	*	*74.1*	*	0.116	0.104	-	0.112	-	*59*	*75.2*	*	*74.0*	*	-0.113	-0.104	-	-0.113	*
										1995/04/19 - 98/12/31											
Original data	1-2	*220*	*179.4*	***	*183.4*	***	0.512	0.568	**	0.561	**	196	*179.4*	*	*176.4*	**	-0.472	-0.569	***	-0.576	***
	3-6	*41*	*56.0*	***	*53.0*	**	0.579	0.569	-	0.557	-	63	*55.9*	-	*58.8*	-	-0.545	-0.567	-	-0.578	-
	≥ 7	*2*	*3.7*	-	*3.0*	-	0.527	0.568	-	0.563	-	3	*3.7*	-	*4.3*	-	-0.549	-0.569	-	-0.574	-
	All	*263*	*239.1*	***	*239.5*	***	0.534	0.569	**	0.560	*	262	*239.1*	***	*239.5*	***	-0.508	-0.568	***	-0.577	***
5-days moving averages 2)	1-6	*82*	*72.8*	-	*75.4*	-	0.174	0.184	-	0.180	-	73	*72.6*	-	*70.7*	-	-0.162	-0.183	*	-0.185	*
	7-14	*19*	*21.1*	-	*19.5*	-	0.296	0.297	-	0.290	-	22	*21.1*	-	*22.6*	-	-0.271	-0.295	-	-0.302	*
	≥ 15	*2*	*4.2*	-	*3.3*	-	0.261	0.324	*	0.316	-	7	*4.3*	*	*5.0*	-	-0.294	-0.324	-	-0.331	-
	All	*103*	*98.0*	-	*98.2*	-	0.228	0.254	**	0.243	-	102	*98.0*	-	*98.3*	-	-0.239	-0.253	-	-0.263	*
10-days moving averages 2)	1-9	*48*	*48.6*	-	*50.3*	-	0.069	0.094	**	0.093	***	47	*48.5*	-	*46.7*	-	-0.090	-0.094	-	-0.094	-
	10-24	*18*	*17.0*	-	*15.8*	-	0.173	0.206	**	0.203	*	15	*17.1*	-	*17.9*	-	-0.224	-0.206	-	-0.210	-
	≥ 25	*2*	*2.7*	-	*2.0*	-	0.242	0.241	-	0.234	-	4	*2.7*	-	*3.6*	-	-0.193	-0.237	-	-0.248	*
	All	*68*	*68.3*	-	*68.1*	-	0.155	0.179	*	0.171	-	66	*68.3*	-	*68.2*	-	-0.176	-0.178	-	-0.189	-
20-days moving averages 2)	1-14	*34*	*36.2*	-	*37.3*	-	0.066	0.058	-	0.058	-	31	*36.2*	-	*34.8*	-	-0.061	-0.058	-	-0.058	-
	15-34	*9*	*8.3*	-	*7.8*	-	0.112	0.139	*	0.136	-	10	*8.3*	-	*8.5*	-	-0.136	-0.139	-	-0.142	-
	≥ 35	*2*	*3.0*	-	*2.1*	-	0.184	0.174	-	0.168	-	4	*3.0*	-	*4.0*	-	-0.159	-0.172	-	-0.178	-
	All	*45*	*47.5*	-	*47.1*	-	0.113	0.127	-	0.118	-	45	*47.5*	-	*47.3*	-	-0.131	-0.127	-	-0.136	-
40-days moving averages 2)	1-14	*30*	*25.1*	-	*24.8*	-	0.032	0.028	-	0.028	-	26	*24.9*	-	*23.3*	-	-0.029	-0.028	-	-0.029	-
	15-39	*2*	*4.0*	-	*4.1*	-	0.095	0.070	*	0.070	**	2	*4.1*	-	*3.9*	-	-0.049	-0.069	-	-0.070	-
	≥ 40	*3*	*4.2*	-	*3.1*	-	0.114	0.116	-	0.111	-	7	*4.2*	**	*5.2*	-	-0.109	-0.116	-	-0.123	-
	All	*35*	*33.2*	-	*32.1*	-	0.086	0.089	-	0.080	-	35	*33.2*	-	*32.3*	-	-0.089	-0.089	-	-0.099	-

1) Average change in exchange rate level per day in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed the respective moving average.

Notes: See tables A6.

Table A5: Classification of exchange rate runs by duration

Dollar/euro rates at 30-minutes intervals

		Upward runs					Downward runs					*Contribution to overall change in price*			
	Run length	Number		Average Duration	Average slope 1)		Number		Average Duration	Average slope 1)		Upward runs		Downward runs	
				Intervals					Intervals			In cents	In %	In cents	In %
							Based on original data								
1999/01/01 -	1	3066.0		1.00	0.073		3088.0		1.00	- 0.073		222.6	29.3	- 225.4	28.4
2000/10/25		(2685.7)	***	(1.00)	(0.085)	***	(2685.8)	***	(1.00)	-(0.084)	***	(227.0)	(25.1)	-(226.0)	(25.0)
	2	1505.0		2.00	0.069		1523.0		2.00	- 0.075		207.3	27.3	- 229.1	28.8
		(1342.0)	***	(2.00)	(0.085)	***	(1346.7)	***	(2.00)	-(0.085)	***	(227.0)	(25.0)	-(228.1)	(25.2)
	3	693.0		3.00	0.069		641.0		3.00	- 0.071		142.7	18.8	- 136.7	17.2
		(670.3)	-	(3.00)	(0.084)	***	(666.7)	-	(3.00)	-(0.084)	***	(169.8)	(18.7)	-(168.7)	(18.6)
	4	315.0		4.00	0.068		321.0		4.00	- 0.074		85.4	11.2	- 95.3	12.0
		(332.8)	-	(4.00)	(0.085)	***	(331.3)	-	(4.00)	-(0.085)	***	(112.8)	(12.5)	-(112.0)	(12.4)
	5	134.0		5.00	0.067		139.0		5.00	- 0.081		45.2	5.9	- 56.0	7.0
		(167.7)	***	(5.00)	(0.085)	***	(168.6)	***	(5.00)	-(0.085)	**	(70.9)	(7.8)	-(71.5)	(7.9)
	6	54.0		6.00	0.085		51.0		6.00	- 0.075		27.7	3.6	- 23.0	2.9
		(83.7)	***	(6.00)	(0.085)	-	(82.8)	***	(6.00)	-(0.085)	***	(42.5)	(4.7)	-(42.2)	(4.7)
	≥ 7	41.0		8.00	0.088		46.0		7.59	- 0.082		28.8	3.8	- 28.7	3.6
		(83.2)	***	(7.98)	(0.085)	*	(83.5)	***	(7.99)	-(0.085)	-	(56.2)	(6.2)	-(56.4)	(6.2)
	All	5808.0		1.85	0.071		5809.0		1.84	- 0.074		759.6	100.0	- 794.1	100.0
		(5365.4)	***	(2.00)	(0.085)	***	(5365.4)	***	(2.00)	-(0.085)	***	(906.1)	(100.0)	-(905.1)	(100.0)
							5-period moving average								
1999/01/01 -	1	735.0		1.00	0.011		735.0		1.00	- 0.010		7.8	2.1	- 7.4	1.8
2000/10/25		(610.9)	***	(1.00)	(0.012)	***	(609.6)	***	(1.00)	-(0.012)	***	(7.3)	(1.6)	-(7.3)	(1.6)
	2	346.0		2.00	0.015		322.0		2.00	- 0.015		10.4	2.8	- 9.4	2.3
		(290.8)	***	(2.00)	(0.017)	***	(290.7)	**	(2.00)	-(0.017)	***	(10.1)	(2.2)	-(10.1)	(2.3)
	3	243.0		3.00	0.018		208.0		3.00	- 0.017		13.3	3.6	- 10.8	2.7
		(183.3)	***	(3.00)	(0.022)	***	(184.5)	**	(3.00)	-(0.022)	***	(12.3)	(2.7)	-(12.3)	(2.8)
	4	156.0		4.00	0.019		140.0		4.00	- 0.019		12.1	3.3	- 10.6	2.6
		(133.8)	**	(4.00)	(0.027)	***	(136.0)	-	(4.00)	-(0.027)	***	(14.3)	(3.2)	-(14.5)	(3.2)
	5	246.0		5.00	0.030		282.0		5.00	- 0.028		37.1	10.1	- 39.8	9.9
		(240.0)	-	(5.00)	(0.033)	***	(237.1)	***	(5.00)	-(0.033)	***	(39.7)	(8.9)	-(39.3)	(8.8)
	6	181.0		6.00	0.032		176.0		6.00	- 0.035		34.6	9.4	- 36.7	9.1
		(160.0)	**	(6.00)	(0.039)	***	(161.4)	-	(6.00)	-(0.039)	***	(37.3)	(8.3)	-(37.7)	(8.4)
	≥ 7	520.0		12.22	0.040		564.0		12.16	- 0.042		253.4	68.7	- 289.5	71.6
		(574.4)	***	(12.59)	(0.045)	***	(573.9)	-	(12.61)	-(0.045)	***	(327.7)	(73.0)	-(326.9)	(73.0)
	All	2427.0		4.27	0.031		2427.0		4.46	- 0.033		368.6	100.0	- 404.2	100.0
		(2193.2)	***	(4.88)	(0.038)	***	(2193.2)	***	(4.88)	-(0.038)	***	(448.8)	(100.0)	-(448.1)	(100.0)
							50-period moving average								
1999/01/01 -	1	222.0		1.00	0.001		192.0		1.00	- 0.001		0.1	0.1	- 0.1	0.1
2000/10/25		(200.4)	*	(1.00)	(0.001)	**	(202.2)	-	(1.00)	-(0.001)	**	(0.2)	(0.2)	-(0.2)	(0.2)
	2	65.0		2.00	0.001		85.0		2.00	- 0.001		0.1	0.1	- 0.2	0.1
		(89.8)	***	(2.00)	(0.002)	-	(89.9)	-	(2.00)	-(0.002)	-	(0.3)	(0.2)	-(0.3)	(0.2)
	3	43.0		3.00	0.002		47.0		3.00	- 0.002		0.2	0.2	- 0.2	0.2
		(53.3)	-	(3.00)	(0.002)	-	(54.0)	-	(3.00)	-(0.002)	**	(0.3)	(0.3)	-(0.4)	(0.3)
	4	37.0		4.00	0.002		40.0		4.00	- 0.002		0.3	0.3	- 0.4	0.3
		(37.3)	-	(4.00)	(0.003)	**	(35.8)	-	(4.00)	-(0.003)	-	(0.4)	(0.3)	-(0.4)	(0.3)
	5	18.0		5.00	0.003		27.0		5.00	- 0.002		0.2	0.2	- 0.3	0.2
		(26.6)	*	(5.00)	(0.003)	*	(27.4)	-	(5.00)	-(0.003)	-	(0.4)	(0.3)	-(0.4)	(0.3)
	6	23.0		6.00	0.003		25.0		6.00	- 0.002		0.4	0.5	- 0.4	0.3
		(21.3)	-	(6.00)	(0.003)	*	(21.6)	-	(6.00)	-(0.003)	***	(0.4)	(0.3)	-(0.4)	(0.3)
	≥ 7	260.0	-	6.00	0.003	-	25.0	-	6.00	- 0.002	-	0.4	0.5	- 0.4	0.3
		(258.2)	-	(37.84)	(0.013)	***	(256.1)	-	(37.89)	-(0.013)	**	(125.5)	(98.3)	-(124.5)	(98.3)
	All	668.0		14.09	0.010		668.0		17.84	- 0.011		95.1	100.0	- 129.2	100.0
		(687.0)	-	(15.61)	(0.012)	***	(687.0)	-	(15.51)	-(0.012)	**	(127.6)	(100.0)	-(126.6)	(100.0)

1) Average change in exchange rate level per 30-minutes-interval in cents.

Notes: See tables A1.

Table A5 (cont.): Classification of exchange rate runs by duration

Dollar/euro rates at 30-minutes intervals

		Upward runs					Downward runs					*Contribution to overall change in price*			
	Run length	Number		Average Duration	Average slope 1)		Number		Average Duration	Average slope 1)		Upward runs		Downward runs	
				Intervals					Intervals			In cents	In %	In cents	In %
							Based on original data								
2002/01/31 - 2004/12/30	1	4739.0		1.00	0.070		4814.0		1.00	- 0.066		333.6	26.8	- 318.1	26.6
		(4386.1)	***	(1.00)	(0.082)	***	(4386.3)	***	(1.00)	-(0.082)	***	(361.3)	(25.0)	-(359.8)	(25.0)
	2	2366.0		2.00	0.068		2389.0		2.00	- 0.069		322.1	25.8	- 327.8	27.5
		(2191.7)	***	(2.00)	(0.082)	***	(2199.5)	***	(2.00)	-(0.083)	***	(361.3)	(25.0)	-(363.2)	(25.2)
	3	1128.0		3.00	0.069		641.0		3.00	- 0.071		142.7	18.8	- 136.7	17.2
		(1094.8)	-	(3.00)	(0.082)	***	(1088.8)	-	(3.00)	-(0.082)	***	(270.3)	(18.7)	-(268.7)	(18.6)
	4	531.0		4.00	0.072		534.0		4.00	- 0.071		153.9	12.3	- 151.5	12.7
		(543.6)	-	(4.00)	(0.083)	***	(541.1)	-	(4.00)	-(0.082)	***	(179.6)	(12.4)	-(178.4)	(12.4)
	5	4739.0		1.00	0.072		4814.0		1.00	- 0.069		88.0	7.1	- 89.2	7.5
		(273.8)	**	(5.00)	(0.082)	***	(275.2)	-	(5.00)	-(0.083)	***	(112.9)	(7.8)	-(113.8)	(7.9)
	6	117.0		6.00	0.074		91.0		6.00	- 0.077		51.9	4.2	- 41.9	3.5
		(136.8)	**	(6.00)	(0.083)	***	(135.3)	***	(6.00)	-(0.083)	***	(67.7)	(4.7)	-(67.3)	(4.7)
	≥ 7	105.0		7.86	0.075		65.0		7.86	- 0.077		62.1	5.0	- 39.2	3.3
		(136.5)	***	(7.99)	(0.082)	***	(136.5)	***	(7.99)	-(0.082)	***	(89.9)	(6.2)	-(89.8)	(6.2)
	All	9229.0		1.88	0.070		9228.0		1.88	- 0.069		1246.6	100.0	- 1193.7	100.0
		(8762.8)	***	(2.00)	(0.082)	***	(8762.8)	***	(2.00)	-(0.082)	***	(1443.1)	(100.0)	-(1441.0)	(100.0)
							5-periods moving average								
2002/01/31 - 2004/12/30	1	1161.0		1.00	0.010		1168.0		1.00	- 0.009		12.0	2.1	- 11.1	2.1
		(997.6)	***	(1.00)	(0.012)	***	(995.7)	***	(1.00)	-(0.012)	***	(11.7)	(1.8)	-(11.6)	(1.8)
	2	523.0		2.00	0.014		543.0		2.00	- 0.014		14.7	2.6	- 14.7	2.8
		(474.9)	**	(2.00)	(0.017)	***	(474.7)	***	(2.00)	-(0.017)	***	(16.1)	(2.5)	-(16.1)	(2.5)
	3	354.0		1.00	0.011		735.0		1.00	- 0.010		13.3	3.6	- 10.8	2.7
		(299.4)	***	(3.00)	(0.022)	***	(301.2)	**	(3.00)	-(0.022)	***	(19.6)	(3.0)	-(19.6)	(3.0)
	4	254.0		4.00	0.019		285.0		4.00	- 0.021		19.8	3.5	- 23.9	4.6
		(218.4)	***	(4.00)	(0.026)	***	(222.0)	***	(4.00)	-(0.026)	***	(22.7)	(3.5)	-(23.0)	(3.6)
	5	427.0		5.00	0.028		421.0		5.00	- 0.028		60.2	10.5	- 59.5	11.4
		(392.0)	*	(5.00)	(0.032)	***	(387.2)	**	(5.00)	-(0.032)	***	(63.3)	(9.8)	-(62.6)	(9.7)
	6	321.0		6.00	0.033		301.0		6.00	- 0.031		63.4	11.1	- 55.9	10.7
		(261.3)	***	(6.00)	(0.038)	***	(263.6)	***	(6.00)	-(0.038)	***	(59.4)	(9.2)	-(60.0)	(9.3)
	≥ 7	890.0		10.38	0.042		876.0		9.98	- 0.039		386.0	67.2	- 341.8	65.3
		(938.2)	***	(10.92)	(0.044)	***	(937.5)	***	(10.93)	-(0.044)	***	(452.6)	(70.1)	-(450.9)	(70.0)
	All	3930.0		4.47	0.033		3930.0		4.34	- 0.031		573.9	100.0	- 523.5	100.0
		(3581.8)	***	(4.88)	(0.037)	***	(3581.8)	***	(4.89)	-(0.037)	***	(645.3)	(100.0)	-(643.8)	(100.0)
							50-periods moving average								
2002/01/31 - 2004/12/30	1	307.0		1.00	0.001		317.0		1.00	- 0.001		0.2	0.1	- 0.2	0.1
		(327.6)	-	(1.00)	(0.001)	**	(330.3)	-	(1.00)	-(0.001)	-	(0.4)	(0.2)	-(0.4)	(0.2)
	2	143.0		2.00	0.001		145.0		2.00	- 0.001		0.3	0.1	- 0.3	0.2
		(146.7)	-	(2.00)	(0.002)	***	(146.9)	-	(2.00)	-(0.002)	***	(0.5)	(0.2)	-(0.5)	(0.2)
	3	79.0		3.00	0.002		47.0		3.00	- 0.002		0.2	0.2	- 0.2	0.2
		(87.2)	-	(3.00)	(0.002)	-	(88.3)	-	(3.00)	-(0.002)	**	(0.6)	(0.3)	-(0.6)	(0.3)
	4	38.0		4.00	0.002		53.0		4.00	- 0.002		0.3	0.1	- 0.4	0.2
		(61.0)	***	(4.00)	(0.003)	-	(58.4)	-	(4.00)	-(0.003)	***	(0.6)	(0.3)	-(0.6)	(0.3)
	5	42.0		5.00	0.002		46.0		5.00	- 0.002		0.4	0.2	- 0.4	0.3
		(43.5)	-	(5.00)	(0.003)	-	(44.9)	-	(5.00)	-(0.003)	***	(0.6)	(0.3)	-(0.6)	(0.3)
	6	32.0		6.00	0.002		34.0		6.00	- 0.003		0.5	0.2	- 0.5	0.3
		(34.8)	-	(6.00)	(0.003)	**	(35.2)	-	(6.00)	-(0.003)	***	(0.7)	(0.3)	-(0.7)	(0.3)
	≥ 7	423.0		42.11	0.012		388.0		36.55	- 0.012		216.9	99.1	- 166.2	98.7
		(421.8)	-	(37.88)	(0.013)	-	(418.5)	**	(37.91)	-(0.013)	*	(200.0)	(98.4)	-(198.4)	(98.3)
	All	1064.0		18.04	0.012		1063.0		14.75	- 0.011		218.9	100.0	- 168.3	100.0
		(1122.5)	*	(15.61)	(0.012)	-	(1122.5)	*	(15.52)	-(0.012)	*	(203.3)	(100.0)	-(201.8)	(100.0)

1) Average change in exchange rate level per 30-minutes-interval in cents.

Notes: See tables A1.

Table A6: Non-random components in duration and slope of exchange rate runs

Dollar/euro rates at 30-minutes intervals

	Run length	Upward runs: Number, observed	Upward runs: Number, RW-Simulation, Without drift	z-stat	Upward runs: Number, RW-Simulation, With drift	z-stat	Upward runs: Slope 1), observed	Upward runs: Slope 1), RW-Simulation, Without drift	z-stat	Upward runs: Slope 1), RW-Simulation, With drift	z-stat	Downward runs: Number, observed	Downward runs: Number, RW-Simulation, Without drift	z-stat	Downward runs: Number, RW-Simulation, With drift	z-stat	Downward runs: Slope 1), observed	Downward runs: Slope 1), RW-Simulation, Without drift	z-stat	Downward runs: Slope 1), RW-Simulation, With drift	z-stat
Period A: 1999/01/01 - 2000/10/25																					
Original data	*< 3*	*4571*	*4037*	***	*4038*	***	0.071	0.085	***	0.084	***	*4611*	*4037*	***	*3974*	***	-0.074	-0.085	***	-0.085	***
	3 - 9	*1234*	*1325*	***	*1305*	***	0.071	0.085	***	0.084	***	*1196*	*1324*	***	*1367*	***	-0.075	-0.085	***	-0.085	***
	>= 10	*3*	*10*	***	*9*	**	0.068	0.086	***	0.085	***	*2*	*11*	***	*11*	***	-0.073	-0.086	**	-0.085	**
	Total	*5808*	*5372*	***	*5351*	***	0.071	0.085	***	0.084	***	*5809*	*5372*	***	*5351*	***	-0.074	-0.085	***	-0.085	***
5 period moving averages 2)	*< 7*	*1907*	*1631*	***	*1656*	***	0.023	0.027	***	0.027	***	*1863*	*1631*	***	*1613*	***	-0.023	-0.027	***	-0.027	***
	7 - 14	*468*	*477*	-	*463*	-	0.039	0.044	***	0.044	***	*495*	*479*	-	*489*	-	-0.040	-0.044	***	-0.044	***
	>= 15	*52*	*93*	***	*85*	***	0.046	0.048	*	0.048	*	*69*	*92*	***	*103*	***	-0.051	-0.048	**	-0.049	**
	Total	*2427*	*2202*	***	*2204*	***	0.031	0.038	***	0.037	***	*2427*	*2202*	***	*2204*	***	-0.033	-0.038	***	-0.038	***
50 period moving averages 2)	*< 15*	*492*	*516*	-	*520*	-	0.003	0.003	**	0.003	**	*488*	*515*	-	*507*	-	-0.003	-0.003	**	-0.003	**
	15 - 34	*85*	*69*	**	*70*	*	0.006	0.008	***	0.008	***	*63*	*70*	-	*68*	-	-0.007	-0.008	**	-0.008	***
	>= 35	*91*	*103*	**	*93*	-	0.014	0.015	*	0.015	-	*117*	*102*	***	*109*	-	-0.013	-0.015	***	-0.015	***
	Total	*668*	*688*	-	*684*	-	0.011	0.012	***	0.011	**	*668*	*688*	-	*684*	-	-0.011	-0.012	*	-0.013	***
100 period moving averages 2)	*< 15*	*350*	*363*	-	*358*	-	0.002	0.002	*	0.002	*	*330*	*364*	-	*349*	-	-0.001	-0.002	***	-0.002	***
	15 - 34	*41*	*46*	-	*46*	-	0.003	0.004	***	0.004	***	*36*	*47*	*	*45*	-	-0.003	-0.004	***	-0.004	***
	>= 35	*70*	*78*	*	*71*	-	0.009	0.010	**	0.010	-	*95*	*76*	***	*81*	***	-0.009	-0.010	**	-0.011	***
	Total	*461*	*488*	-	*475*	-	0.007	0.008	**	0.008	-	*461*	*488*	-	*475*	-	-0.008	-0.008	-	-0.009	***

1) Average change in exchange rate level per30-minutes interval in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective moving average.

Notes: The table compares the observed numbers and slopes of exchange rate runs by duration to their expected means under the random-walk-hypothesis. These means are derived from a Monte-Carlo-simulation based on 1000 random walk series. The random walks were constructed with an expected zero mean of the first differences (the observed difference in the case of random walks with drift) and with an expected standard deviation of the first differences as observed in the original exchange rate series over the respective-period. * (**, ***) indicate the significance of the difference between the observed means and the expected means under the random-walk-hypothesis at the 10% (5%, 1%) level.

Table A6 (cont.): Non-random components in duration and slope of exchange rate runs

Dollar/euro rates at 30-minutes intervals

	Run length	Upward runs										Downward runs									
		Number					Slope 1)					Number					Slope 1)				
		ob- served	RW-Simulation				ob- served	RW-Simulation				ob- served	RW-Simulation				ob- served	RW-Simulation			
			Without drift	z- stat	With drift	z- stat		Without drift	z- stat	With drift	z- stat		Without drift	z- stat	With drift	z- stat		Without drift	z- stat	With drift	z- stat
		Period C: 2002/01/31 - 2004/12/30																			
Original data	< 3	*7105*	*6594*	***	*6499*	***	0.069	0.082	***	0.083	***	*7203*	*6594*	***	*6594*	***	-0.067	-0.082	***	-0.082	***
	3 - 9	*2118*	*2164*	*	*2226*	***	0.072	0.083	***	0.083	***	*2019*	*2162*	***	*2134*	***	-0.071	-0.083	***	-0.082	***
	>= 10	*6*	*16*	***	*18*	***	0.066	0.084	***	0.084	***	*6*	*18*	***	*14*	**	-0.086	-0.083	-	-0.082	-
	Total	9229	*8773*	***	*8742*	***	0.070	0.083	***	0.083	***	9228	*8773*	***	*8742*	***	-0.069	-0.083	***	-0.082	***
5 period moving averages 2)	< 7	*3040*	*2664*	***	*2625*	***	0.023	0.027	***	0.027	***	*3054*	*2664*	***	*2699*	***	-0.022	-0.027	***	-0.027	***
	7 - 14	*789*	*779*	-	*799*	-	0.039	0.043	***	0.043	***	*788*	*782*	-	*755*	*	-0.038	-0.043	***	-0.043	***
	>= 15	*101*	*152*	***	*168*	***	0.051	0.047	***	0.047	***	*88*	*150*	***	*138*	***	-0.044	-0.047	***	-0.047	***
	Total	*3930*	*3596*	***	*3592*	***	0.033	0.037	***	0.037	***	*3930*	*3596*	***	*3592*	***	-0.031	-0.037	***	-0.036	***
50 period moving averages 2)	< 15	*772*	*843*	**	*829*	*	0.003	0.003	***	0.003	***	*785*	*841*	*	*852*	*	-0.003	-0.003	***	-0.003	***
	15 - 34	*87*	*112*	***	*109*	**	0.005	0.007	***	0.008	***	*114*	*115*	-	*114*	-	-0.006	-0.007	***	-0.007	***
	>= 35	*205*	*169*	***	*180*	***	0.014	0.015	-	0.015	**	*164*	*167*	-	*151*	*	-0.015	-0.015	-	-0.014	-
	Total	*1064*	*1124*	*	*1118*	-	0.012	0.012	-	0.012	*	*1063*	*1124*	*	*1118*	-	-0.011	-0.012	*	-0.011	-
100 period moving averages 2)	< 15	*559*	*595*	-	*569*	-	0.001	0.002	***	0.002	***	*575*	*596*	-	*588*	-	-0.001	-0.002	***	-0.002	***
	15 - 34	*63*	*75*	*	*72*	-	0.003	0.004	***	0.004	***	*77*	*77*	-	*73*	-	-0.003	-0.004	***	-0.004	***
	>= 35	*145*	*128*	***	*134*	**	0.009	0.010	-	0.010	***	*114*	*125*	*	*114*	-	-0.010	-0.010	-	-0.010	-
	Total	*767*	*798*	-	*775*	-	0.008	0.008	-	0.009	**	*766*	*798*	-	*775*	-	-0.008	-0.008	*	-0.008	-

1) Average change in exchange rate level per30-minutes interval in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective moving average.

The table compares the observed numbers and slopes of exchange rate runs by duration to their expected means under the random-walk-hypothesis. These means are derived from a Monte-Carlo-simulation based on 1000 random walk series. The random walks were constructed with an expected zero mean of the first differences (the observed difference in the case of random walks with drift) and with an expected standard deviation of the first differences as observed in the original exchange rate series over the respective-period. * (**, ***) indicate the significance of the difference between the observed means and the expected means under the random-walk-hypothesis at the 10% (5%, 1%) level.

Table A7: Non-random components of exchange rate runs during the "bear market" 1999/2000

Dollar/euro rates at 30-minutes intervals

	Run length	Upward runs											Downward runs										
		Number					Slope 1)					Number					Slope 1)				
		ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation			
			Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat
		Period 1: 1999/01/01 - 1999/07/12																					
Original data	*< 3*	*1314*	*1147*	***	*1164*	***	0.070	0.079	***	0.078	***	*1330*	*1145*	***	*1133*	***	-0.071	-0.079	***	-0.080	***
	3 - 9	*359*	*380*	*	*365*	-	0.066	0.079	***	0.078	***	*343*	*382*	***	*395*	***	-0.075	-0.079	***	-0.080	***
	>= 10	*1*	*3*	-	*3*	-	0.064	0.079	*	0.078	-	*1*	*3*	-	*3*	*	-0.049	-0.079	***	-0.080	***
	Total	*1674*	*1530*	***	*1532*	***	0.068	0.079	***	0.078	***	*1674*	*1530*	***	*1532*	***	-0.073	-0.079	***	-0.080	***
5 period moving averages 2)	*< 7*	*537*	*463*	***	*476*	***	0.022	0.026	***	0.025	***	*530*	*462*	***	*454*	***	-0.022	-0.025	***	-0.026	***
	7 - 14	*141*	*137*	-	*130*	-	0.035	0.041	***	0.041	***	*129*	*138*	-	*143*	*	-0.039	-0.041	**	-0.042	***
	>= 15	*12*	*27*	***	*22*	***	0.049	0.045	*	0.044	**	*31*	*27*	-	*31*	-	-0.047	-0.045	-	-0.046	-
	Total	*690*	*627*	***	*629*	***	0.030	0.035	***	0.034	***	*690*	*627*	***	*629*	***	-0.033	-0.035	***	-0.036	***
50 period moving averages 2)	*< 15*	*162*	*146*	-	*146*	-	0.003	0.003	-	0.003	-	*158*	*145*	-	*139*	-	-0.003	-0.003	-	-0.003	-
	15 - 34	*31*	*20*	***	*20*	***	0.006	0.007	-	0.007	-	*15*	*20*	-	*19*	-	-0.008	-0.007	-	-0.007	-
	>= 35	*19*	*29*	***	*25*	**	0.013	0.014	-	0.013	-	*39*	*29*	***	*33*	**	-0.012	-0.014	**	-0.015	***
	Total	*212*	*195*	-	*191*	-	0.009	0.011	***	0.010	**	*212*	*195*	-	*191*	-	-0.010	-0.011	-	-0.012	**
100 period moving averages 2)	*< 15*	*122*	*102*	-	*100*	*	0.001	0.002	-	0.002	-	*108*	*102*	-	*95*	-	-0.001	-0.002	-	-0.002	-
	15 - 34	*14*	*13*	-	*13*	-	0.003	0.004	-	0.004	-	*14*	*13*	-	*12*	-	-0.003	-0.004	-	-0.004	-
	>= 35	*16*	*22*	**	*19*	-	0.008	0.009	*	0.009	-	*30*	*22*	***	*24*	**	-0.008	-0.009	*	-0.010	**
	Total	*152*	*137*	-	*131*	-	0.006	0.008	**	0.007	-	*152*	*137*	-	*132*	-	-0.007	-0.008	-	-0.009	**

1) Average change in exchange rate level per 30-minutes interval in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective -period moving average.

Notes: See tables A6.

Table A7 (cont.): Non-random components of exchange rate runs during the "bear market" 1999/2000

Dollar/euro rates at 30-minutes intervals

	Run length	Upward runs										Downward runs									
		Number					Slope 1)					Number					Slope 1)				
		ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation			
			Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat
Period 3: 1999/10/15 - 2000/05/04																					
Original data	*< 3*	*1384*	*1227*	***	*1242*	***	0.072	0.088	***	0.087	***	*1380*	*1227*	***	*1207*	***	-0.079	-0.088	***	-0.089	***
	3 - 9	*369*	*406*	***	*389*	*	0.070	0.087	***	0.087	***	*372*	*405*	***	*423*	***	-0.075	-0.088	***	-0.089	***
	>= 10	*1*	*3*	-	*2*	-	0.033	0.087	***	0.085	***	*1*	*3*	-	*4*	*	-0.096	-0.087	-	-0.088	-
	Total	*1754*	*1635*	***	*1634*	***	0.071	0.088	***	0.087	***	*1753*	*1635*	***	*1634*	***	-0.077	-0.088	***	-0.089	***
5 period moving averages 2)	*< 7*	*586*	*495*	***	*505*	***	0.023	0.028	***	0.028	***	*559*	*494*	***	*479*	***	-0.024	-0.028	***	-0.029	***
	7 - 14	*135*	*146*	-	*137*	-	0.039	0.046	***	0.045	***	*153*	*146*	-	*153*	-	-0.040	-0.046	***	-0.046	***
	>= 15	*14*	*29*	***	*24*	**	0.046	0.050	*	0.049	-	*23*	*29*	*	*34*	**	-0.059	-0.050	***	-0.050	***
	Total	*735*	*669*	***	*666*	***	0.031	0.039	***	0.038	***	*735*	*669*	***	*666*	***	-0.035	-0.039	***	-0.040	***
50 period moving averages 2)	*< 15*	*165*	*154*	-	*154*	-	0.003	0.003	***	0.004	***	*162*	*153*	-	*146*	-	-0.003	-0.003	-	-0.003	-
	15 - 34	*26*	*21*	-	*21*	-	0.006	0.008	***	0.008	***	*21*	*21*	-	*20*	-	-0.007	-0.008	**	-0.008	*
	>= 35	*25*	*31*	**	*26*	-	0.014	0.016	**	0.015	-	*34*	*31*	-	*36*	-	-0.015	-0.015	-	-0.016	**
	Total	*216*	*205*	-	*201*	-	0.010	0.012	***	0.011	**	*217*	*205*	-	*201*	-	-0.012	-0.012	-	-0.013	**
100 period moving averages 2)	*< 15*	*109*	*106*	-	*108*	-	0.002	0.002	-	0.002	-	*101*	*106*	-	*102*	-	-0.002	-0.002	*	-0.002	*
	15 - 34	*13*	*14*	-	*13*	-	0.004	0.004	-	0.004	-	*10*	*14*	-	*13*	-	-0.003	-0.004	**	-0.004	*
	>= 35	*18*	*23*	*	*19*	-	0.009	0.010	*	0.010	-	*30*	*24*	**	*26*	-	-0.010	-0.010	-	-0.011	**
	Total	*140*	*143*	-	*141*	-	0.007	0.009	**	0.008	-	*141*	*143*	-	*141*	-	-0.009	-0.009	-	-0.010	*

1) Average change in exchange rate level per 30-minutes interval in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective -period moving average.

Notes: See tables A6.

Table A7 (cont.): Non-random components of exchange rate runs during the "bear market" 1999/2000

Dollar/euro rates at 30-minutes intervals

	Run length	Upward runs										Downward runs									
		Number					Slope 1)					Number					Slope 1)				
		ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation			
			Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat
		Period 5: 2000/06/16 - 2000/10/25																			
Original data	< 3	904	789	***	804	***	0.066	0.083	***	0.082	***	886	788	***	776	***	-0.071	-0.082	***	-0.084	***
	3 - 9	232	262	***	247	*	0.069	0.082	***	0.081	***	250	262	-	274	**	-0.071	-0.082	***	-0.084	***
	>= 10	0	2	*	2	*	0.000	0.083	***	0.082	***	0	2	*	3	*	0.000	-0.081	***	-0.083	***
	Total	1136	1052	***	1053	***	0.067	0.083	***	0.081	***	1136	1052	***	1053	***	-0.071	-0.082	***	-0.084	***
5 period moving averages 2)	< 7	387	318	***	328	***	0.021	0.027	***	0.026	***	369	318	***	310	***	-0.022	-0.027	***	-0.027	***
	7 - 14	87	94	-	88	-	0.037	0.043	***	0.042	***	103	94	*	99	-	-0.042	-0.043	-	-0.044	-
	>= 15	9	19	***	15	*	0.036	0.047	***	0.046	***	10	19	**	23	***	-0.046	-0.047	-	-0.048	-
	Total	483	430	***	431	***	0.029	0.037	***	0.036	***	482	430	***	431	***	-0.033	-0.037	***	-0.038	***
50 period moving averages 2)	< 15	66	100	**	100	***	0.003	0.003	-	0.003	-	63	100	***	95	**	-0.003	-0.003	**	-0.003	**
	15 - 34	13	14	-	14	-	0.006	0.008	**	0.008	***	11	14	-	13	-	-0.007	-0.008	-	-0.008	-
	>= 35	18	20	-	16	-	0.013	0.015	*	0.014	-	24	20	*	23	-	-0.014	-0.015	-	-0.015	*
	Total	97	134	***	130	**	0.010	0.012	*	0.010	-	98	134	**	130	**	-0.012	-0.012	-	-0.013	-
100 period moving averages 2)	< 15	63	70	-	68	-	0.001	0.002	-	0.002	-	59	70	-	64	-	-0.001	-0.002	-	-0.002	-
	15 - 34	7	9	-	9	-	0.003	0.004	-	0.004	-	5	9	-	8	-	-0.002	-0.004	***	-0.004	***
	>= 35	12	15	*	12	-	0.008	0.010	-	0.009	-	19	15	*	17	-	-0.009	-0.010	-	-0.011	-
	Total	82	94	-	89	-	0.007	0.008	-	0.007	-	83	94	-	89	-	-0.009	-0.008	-	-0.010	-

1) Average change in exchange rate level per 30-minutes interval in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective -period moving average.

Notes: See tables A6.

Table A8: Non-random components of exchange rate runs during the "bull market" 2002/2004

Dollar/euro rates at 30-minutes intervals

	Run length	Upward runs										Downward runs									
		Number					Slope 1)					Number					Slope 1)				
		ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation			
			Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat
									Period 7: 2002/01/31 - 2002/07/19												
Original data	*< 3*	*1154*	*1041*	***	*1018*	***	0.054	0.062	***	0.063	***	*1167*	*1041*	***	*1058*	***	-0.052	-0.062	***	-0.061	***
	3 - 9	*328*	*343*	-	*363*	***	0.058	0.062	***	0.063	***	*314*	*343*	**	*324*	-	-0.052	-0.062	***	-0.061	***
	>= 10	*0*	*3*	**	*3*	**	0.000	0.063	***	0.064	***	*0*	*3*	**	*2*	*	0.000	-0.063	***	-0.061	***
	Total	*1482*	*1387*	***	*1384*	***	0.056	0.062	***	0.063	***	*1481*	*1387*	***	*1384*	***	-0.052	-0.062	***	-0.061	***
5 period moving averages 2)	*< 7*	*469*	*418*	***	*404*	***	0.017	0.020	***	0.020	***	*473*	*419*	***	*432*	**	-0.018	-0.020	***	-0.020	***
	7 - 14	*129*	*124*	-	*132*	-	0.033	0.032	-	0.033	-	*127*	*123*	-	*115*	*	-0.026	-0.033	***	-0.032	***
	>= 15	*13*	*24*	***	*30*	***	0.042	0.035	***	0.036	***	*11*	*24*	***	*19*	**	-0.023	-0.036	***	-0.034	***
	Total	*611*	*566*	***	*566*	***	0.026	0.028	***	0.029	***	*611*	*566*	***	*566*	***	-0.022	-0.028	***	-0.027	***
50 period moving averages 2)	*< 15*	*124*	*132*	-	*122*	-	0.002	0.002	-	0.002	-	*126*	*131*	-	*130*	-	-0.003	-0.002	-	-0.002	-
	15 - 34	*16*	*18*	-	*17*	-	0.005	0.006	**	0.006	**	*25*	*18*	*	*17*	**	-0.005	-0.006	-	-0.006	-
	>= 35	*32*	*26*	**	*30*	-	0.012	0.011	-	0.012	-	*20*	*26*	**	*21*	-	-0.008	-0.011	***	-0.010	***
	Total	*172*	*176*	-	*169*	-	0.010	0.009	*	0.010	-	*171*	*176*	-	*169*	-	-0.007	-0.009	***	-0.008	**
100 period moving averages 2)	*< 15*	*104*	*93*	-	*82*	*	0.001	0.001	***	0.001	**	*111*	*92*	-	*87*	*	-0.001	-0.001	**	-0.001	**
	15 - 34	*11*	*12*	-	*10*	-	0.003	0.003	-	0.003	-	*13*	*12*	-	*11*	-	-0.002	-0.003	*	-0.003	-
	>= 35	*26*	*20*	**	*22*	*	0.008	0.007	-	0.008	-	*16*	*20*	*	*16*	-	-0.006	-0.007	**	-0.007	*
	Total	*141*	*124*	-	*114*	*	0.007	0.006	-	0.007	-	*140*	*124*	-	*114*	*	-0.004	-0.006	***	-0.005	**

1) Average change in exchange rate level per day in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective period moving average.

Notes: See tables A6.

Table A8 (cont.) : Non-random components of exchange rate runs during the "bull market" 2002/2004

Dollar/euro rates at 30-minutes intervals

	Run length	Upward runs										Downward runs									
		Number					Slope 1)					Number					Slope 1)				
		ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation			
			Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat
		Period 9: 2002/10/17 - 2003/05/29																			
Original data	< 3	1484	1367	***	1343	***	0.063	0.076	***	0.077	***	1553	1367	***	1387	***	-0.064	-0.076	***	-0.075	***
	3 - 9	452	453	-	472	*	0.069	0.076	***	0.077	***	384	452	***	430	***	-0.065	-0.076	***	-0.075	***
	>= 10	1	3	-	5	**	0.081	0.078	-	0.076	-	0	4	**	3	**	0.000	-0.075	***	-0.074	***
	Total	1937	1823	***	1820	***	0.066	0.076	***	0.077	***	1937	1823	***	1820	***	-0.064	-0.076	***	-0.075	***
5 period moving averages 2)	< 7	613	552	***	532	***	0.022	0.025	***	0.025	***	635	553	***	566	***	-0.019	-0.024	***	-0.024	***
	7 - 14	172	164	-	172	-	0.036	0.040	***	0.040	***	166	162	-	152	*	-0.036	-0.040	***	-0.039	***
	>= 15	25	31	*	40	***	0.047	0.043	**	0.044	*	9	32	***	26	***	-0.043	-0.043	-	-0.042	-
	Total	810	748	***	744	***	0.031	0.034	***	0.035	***	810	748	***	744	***	-0.028	-0.034	***	-0.033	***
50 period moving averages 2)	< 15	157	174	-	162	-	0.003	0.003	*	0.003	*	163	174	-	171	-	-0.003	-0.003	**	-0.003	*
	15 - 34	18	23	-	22	-	0.006	0.007	***	0.007	**	26	23	-	24	-	-0.007	-0.007	-	-0.007	-
	>= 35	45	35	***	40	*	0.013	0.013	-	0.014	**	30	34	-	29	-	-0.013	-0.013	-	-0.013	-
	Total	220	231	-	223	-	0.011	0.011	-	0.012	*	219	231	-	223	-	-0.009	-0.011	**	-0.010	-
100 period moving averages 2)	< 15	98	120	-	113	-	0.001	0.002	-	0.002	-	109	120	-	120	-	-0.001	-0.002	***	-0.001	***
	15 - 34	12	15	-	15	-	0.003	0.003	**	0.003	**	15	15	-	15	-	-0.003	-0.003	**	-0.003	**
	>= 35	32	26	**	29	-	0.009	0.009	-	0.010	**	17	26	***	21	*	-0.009	-0.009	-	-0.008	-
	Total	142	161	-	156	-	0.008	0.008	-	0.009	*	141	161	-	156	-	-0.007	-0.008	*	-0.007	-

1) Average change in exchange rate level per day in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective period moving average.

Notes: See tables A6.

Table A8 (cont.): Non-random components of exchange rate runs during the "bull market" 2002/2004

Dollar/euro rates at 30-minutes intervals

	Run length	Upward runs										Downward runs									
		Number					Slope 1)					Number					Slope 1)				
		observed	RW-Simulation				observed	RW-Simulation				observed	RW-Simulation				observed	RW-Simulation			
			Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat
											Period 11: 2003/09/03 - 2004/01/09										
Original data	*< 3*	*838*	*793*	**	*774*	***	0.078	0.090	***	0.092	***	*845*	*794*	**	*810*	*	-0.072	-0.090	***	-0.089	***
	3 - 9	*258*	*261*	-	*278*	**	0.083	0.090	***	0.092	***	*252*	*261*	-	*243*	-	-0.076	-0.091	***	-0.088	***
	>= 10	*1*	*2*	-	*3*	-	0.082	0.090	-	0.091	-	*0*	*2*	*	*2*	-	0.000	-0.089	***	-0.089	***
	Total	*1097*	*1057*	***	*1055*	***	0.080	0.090	***	0.092	***	*1097*	*1057*	***	*1055*	***	-0.074	-0.090	***	-0.089	***
5 period moving averages 2)	*< 7*	*371*	*319*	***	*305*	***	0.023	0.029	***	0.030	***	*397*	*320*	***	*331*	***	-0.024	-0.029	***	-0.029	***
	7 - 14	*105*	*94*	*	*101*	-	0.044	0.047	**	0.048	***	*86*	*93*	-	*86*	-	-0.040	-0.047	***	-0.046	***
	>= 15	*14*	*19*	-	*24*	***	0.070	0.051	***	0.053	***	*7*	*19*	***	*14*	**	-0.054	-0.051	-	-0.050	-
	Total	*490*	*432*	***	*431*	***	0.038	0.040	**	0.042	***	*490*	*432*	***	*431*	***	-0.032	-0.040	***	-0.039	***
50 period moving averages 2)	*< 15*	*102*	*98*	-	*91*	-	0.003	0.004	-	0.004	-	*101*	*99*	-	*98*	-	-0.003	-0.004	*	-0.004	*
	15 - 34	*8*	*13*	*	*12*	-	0.005	0.008	***	0.008	***	*22*	*13*	***	*14*	**	-0.006	-0.008	***	-0.008	***
	>= 35	*28*	*20*	***	*24*	*	0.017	0.016	-	0.017	-	*14*	*20*	**	*15*	-	-0.014	-0.016	*	-0.015	-
	Total	*138*	*132*	-	*127*	-	0.014	0.013	*	0.015	-	*137*	*132*	-	*126*	-	-0.010	-0.013	***	-0.011	*
100 period moving averages 2)	*< 15*	*61*	*70*	-	*61*	-	0.002	0.002	-	0.002	-	*68*	*70*	-	*66*	-	-0.001	-0.002	**	-0.002	*
	15 - 34	*11*	*9*	-	*8*	-	0.004	0.004	-	0.004	-	*6*	*9*	-	*8*	-	-0.003	-0.004	*	-0.004	*
	>= 35	*16*	*15*	-	*17*	-	0.011	0.011	-	0.012	-	*13*	*15*	-	*11*	-	-0.009	-0.011	**	-0.009	-
	Total	*88*	*94*	-	*85*	-	0.010	0.009	-	0.011	-	*87*	*94*	-	*85*	-	-0.007	-0.009	**	-0.007	-

1) Average change in exchange rate level per day in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective period moving average.

Notes: See tables A6.

Table A8 (cont.): Non-random components of exchange rate runs during the "bull market" 2002/2004

Dollar/euro rates at 30-minutes intervals

	Run length	Upward runs: Number observed	RW-Simulation Without drift	z-stat	With drift	z-stat	Slope 1) observed	RW-Simulation Without drift	z-stat	With drift	z-stat	Downward runs: Number observed	RW-Simulation Without drift	z-stat	With drift	z-stat	Slope 1) observed	RW-Simulation Without drift	z-stat	With drift	z-stat
Period 13: 2004/05/13 - 2004/12/30																					
Original data	< 3	1524	1439	***	1417	***	0.069	0.081	***	0.082	***	1562	1439	***	1454	***	-0.066	-0.081	***	-0.080	***
	3 - 9	481	472	-	491	-	0.069	0.081	***	0.082	***	442	472	**	456	-	-0.067	-0.081	***	-0.080	***
	>= 10	1	4	*	5	*	0.057	0.081	**	0.083	***	1	4	*	3	-	-0.054	-0.080	***	-0.081	**
	Total	2006	1915	***	1913	***	0.069	0.081	***	0.082	***	2005	1915	***	1913	***	-0.066	-0.081	***	-0.080	***
5 period moving averages 2)	< 7	663	581	***	567	***	0.022	0.026	***	0.026	***	683	579	***	593	***	-0.020	-0.026	***	-0.026	***
	7 - 14	172	170	-	178	-	0.039	0.042	***	0.043	***	161	171	-	162	-	-0.036	-0.042	***	-0.042	***
	>= 15	29	33	-	38	**	0.048	0.046	-	0.047	-	20	33	***	28	**	-0.046	-0.046	-	-0.045	-
	Total	864	784	***	783	***	0.032	0.036	***	0.037	***	864	784	***	783	***	-0.029	-0.036	***	-0.035	***
50 period moving averages 2)	< 15	186	182	-	175	-	0.003	0.003	*	0.003	**	194	181	-	183	-	-0.003	-0.003	**	-0.003	**
	15 - 34	22	24	-	23	-	0.006	0.007	***	0.007	***	23	24	-	24	-	-0.005	-0.007	***	-0.007	***
	>= 35	46	36	***	41	*	0.014	0.014	-	0.015	-	36	37	-	31	-	-0.014	-0.014	-	-0.014	-
	Total	254	242	-	239	-	0.012	0.011	-	0.012	-	253	242	-	239	-	-0.010	-0.011	**	-0.011	-
100 period moving averages 2)	< 15	126	127	-	119	-	0.001	0.002	-	0.002	-	119	126	-	125	-	-0.002	-0.002	-	-0.002	-
	15 - 34	7	16	**	15	**	0.003	0.004	***	0.004	***	26	16	**	16	***	-0.003	-0.004	***	-0.004	***
	>= 35	35	27	***	30	*	0.009	0.010	-	0.010	*	22	28	*	24	-	-0.009	-0.010	-	-0.009	-
	Total	168	170	-	165	-	0.008	0.008	-	0.009	-	167	170	-	164	-	-0.007	-0.008	**	-0.007	-

1) Average change in exchange rate level per day in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective period moving average.

Notes: See tables A6.

Table A9: Non-random components of exchange rate runs during the "bear market" 1999

Dollar/euro rates at 1-minute intervals

	Run length	Upward runs										Downward runs									
		Number					Slope 1)					Number					Slope 1)				
		ob- served	RW-Simulation				ob- served	RW-Simulation				ob- served	RW-Simulation				ob- served	RW-Simulation			
			Without drift	z- stat	With drift	z- stat		Without drift	z- stat	With drift	z- stat		Without drift	z- stat	With drift	z- stat		Without drift	z- stat	With drift	z- stat
										1999/01/13 - 1999/03/04											
Original data	< 3	8650	6623	***	6654	***	0.026	0.027	***	0.027	***	8806	6623	***	6601	***	-0.027	-0.027	*	-0.027	**
	3 - 9	1788	2200	***	2174	***	0.020	0.027	***	0.027	***	1647	2199	***	2226	***	-0.022	-0.027	***	-0.027	***
	>= 10	20	17	-	17	-	0.012	0.027	***	0.027	***	6	17	***	19	***	-0.021	-0.027	***	-0.027	***
	Total	10458	8840	***	8845	***	0.024	0.027	***	0.027	***	10459	8840	***	8845	***	-0.025	-0.027	***	-0.027	***
50 period moving averages 2)	< 15	1612	842	***	842	***	0.001	0.001	***	0.001	***	1609	840	***	832	***	-0.001	-0.001	***	-0.001	***
	15 - 34	126	112	-	113	-	0.002	0.002	***	0.002	***	106	114	-	111	-	-0.002	-0.002	***	-0.002	***
	>= 35	148	168	***	164	**	0.003	0.005	***	0.005	***	171	168	-	176	-	-0.003	-0.005	***	-0.005	***
	Total	1886	1123	***	1120	***	0.002	0.004	***	0.004	***	1886	1123	***	1120	***	-0.002	-0.004	***	-0.004	***
100 period moving averages 2)	< 15	1054	593	***	596	***	0.000	0.001	***	0.001	***	1066	592	***	587	***	0.000	-0.001	***	-0.001	***
	15 - 49	115	100	-	100	*	0.001	0.001	***	0.001	***	89	101	-	99	-	-0.001	-0.001	***	-0.001	***
	>= 50	89	101	**	98	*	0.002	0.003	***	0.003	***	104	101	-	108	-	-0.002	-0.003	***	-0.003	***
	Total	1258	795	***	794	***	0.001	0.003	***	0.003	***	1259	795	***	794	***	-0.002	-0.003	***	-0.003	***
200 period moving averages 2)	< 15	788	414	***	431	***	0.000	0.000	***	0.000	***	763	417	***	424	***	0.000	0.000	***	0.000	***
	15 - 49	74	68	-	70	-	0.000	0.001	***	0.001	***	90	66	***	69	**	0.000	-0.001	***	-0.001	***
	>= 50	67	76	**	74	-	0.001	0.002	***	0.002	***	76	75	-	82	-	-0.001	-0.002	***	-0.002	***
	Total	929	558	***	574	***	0.001	0.002	***	0.002	***	929	558	***	574	***	-0.001	-0.002	***	-0.002	***
400 period moving averages 2)	< 15	570	289	***	302	***	0.000	0.000	***	0.000	***	575	292	***	297	***	0.000	0.000	***	0.000	***
	15 - 49	48	46	-	49	-	0.000	0.000	***	0.000	***	45	46	-	49	-	0.000	0.000	***	0.000	***
	>= 50	57	55	-	54	-	0.001	0.002	***	0.001	***	55	53	-	59	-	-0.001	-0.002	***	-0.002	***
	Total	675	390	***	405	***	0.001	0.001	***	0.001	***	675	390	***	405	***	-0.001	-0.001	***	-0.001	***

1) Average change in exchange rate level per per minute in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective period moving average.

Notes: See tables A6.

Table A9 (cont.): Non-random components of exchange rate runs during the "bear market" 1999

Dollar/euro rates at 1-minute intervals

	Run length	Upward runs										Downward runs									
		Number					Slope 1)					Number					Slope 1)				
		ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation			
			Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat
										1999/03/17 - 1999/05/03											
Original data	*< 3*	*7819*	*5780*	***	*5800*	***	0.025	0.026	***	0.026	**	*7896*	*5782*	***	*5776*	***	-0.026	-0.026	*	-0.026	-
	3 - 9	*1477*	*1921*	***	*1907*	***	0.021	0.026	***	0.026	***	*1399*	*1920*	***	*1929*	***	-0.021	-0.026	***	-0.026	***
	>= 10	*2*	*15*	***	*14*	***	0.008	0.026	***	0.026	***	*3*	*15*	***	*16*	***	-0.027	-0.026	-	-0.026	-
	Total	*9298*	*7716*	***	*7721*	***	0.024	0.026	***	0.026	***	*9298*	*7716*	***	*7721*	***	-0.025	-0.026	***	-0.026	***
50 period moving averages 2)	*< 15*	*1424*	*740*	***	*739*	***	0.001	0.001	***	0.001	***	*1419*	*738*	***	*730*	***	-0.001	-0.001	***	-0.001	***
	15 - 34	*110*	*98*	-	*97*	*	0.002	0.002	***	0.002	***	*119*	*99*	**	*98*	**	-0.001	-0.002	***	-0.002	***
	>= 35	*136*	*147*	*	*144*	-	0.003	0.005	***	0.005	***	*133*	*148*	**	*152*	***	-0.003	-0.005	***	-0.005	***
	Total	*1670*	*985*	***	*981*	***	0.002	0.004	***	0.004	***	*1671*	*985*	***	*981*	***	-0.002	-0.004	***	-0.004	***
100 period moving averages 2)	*< 15*	*1153*	*522*	***	*519*	***	0.000	0.001	***	0.001	***	*1158*	*519*	***	*515*	***	0.000	-0.001	***	-0.001	***
	15 - 49	*109*	*87*	**	*87*	**	0.001	0.001	***	0.001	***	*100*	*88*	-	*86*	*	-0.001	-0.001	***	-0.001	***
	>= 50	*79*	*89*	*	*87*	**	0.002	0.003	***	0.003	***	*83*	*89*	-	*93*	**	-0.002	-0.003	***	-0.003	***
	Total	*1341*	*697*	***	*693*	***	0.001	0.003	***	0.003	***	*1341*	*697*	***	*693*	***	-0.002	-0.003	***	-0.003	***
200 period moving averages 2)	*< 15*	*757*	*366*	***	*369*	***	0.000	0.000	***	0.000	***	*742*	*368*	***	*365*	***	0.000	0.000	***	0.000	***
	15 - 49	*66*	*61*	-	*60*	-	0.000	0.001	***	0.001	***	*68*	*60*	-	*60*	-	0.000	-0.001	***	-0.001	***
	>= 50	*59*	*67*	*	*64*	-	0.001	0.002	***	0.002	***	*72*	*66*	-	*69*	-	-0.001	-0.002	***	-0.002	***
	Total	*882*	*495*	***	*494*	***	0.001	0.002	***	0.002	***	*882*	*494*	***	*494*	***	-0.001	-0.002	***	-0.002	***
400 period moving averages 2)	*< 15*	*414*	*264*	***	*268*	***	0.000	0.000	***	0.000	***	*414*	*263*	***	*265*	***	0.000	0.000	***	0.000	***
	15 - 49	*38*	*42*	-	*42*	-	0.000	0.000	***	0.000	***	*40*	*43*	-	*42*	-	0.000	0.000	***	0.000	***
	>= 50	*52*	*49*	-	*47*	-	0.001	0.001	***	0.001	***	*51*	*48*	-	*50*	-	-0.001	-0.001	***	-0.001	***
	Total	*504*	*355*	***	*357*	***	0.001	0.001	***	0.001	***	*505*	*355*	***	*357*	***	-0.001	-0.001	***	-0.001	***

1) Average change in exchange rate level per per minute in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective period moving average.

Notes: See tables A6.

Table A9 (cont.): Non-random components of exchange rate runs during the "bear market" 1999

Dollar/euro rates at 1-minute intervals

	Run length	Upward runs: Number ob-served	Number RW-Simulation Without drift	z-stat	With drift	z-stat	Slope 1) ob-served	Slope 1) RW-Simulation Without drift	z-stat	With drift	z-stat	Downward runs: Number ob-served	Number RW-Simulation Without drift	z-stat	With drift	z-stat	Slope 1) ob-served	Slope 1) RW-Simulation Without drift	z-stat	With drift	z-stat
											1999/05/06 - 1999/06/07										
	< 3	5328	3878	***	3888	***	0.027	0.027	**	0.027	***	5302	3876	***	3868	***	-0.027	-0.027	-	-0.027	-
Original data	3 - 9	917	1279	***	1275	***	0.020	0.027	***	0.027	***	941	1281	***	1294	***	-0.022	-0.027	***	-0.027	***
	>= 10	1	10	***	9	***	0.040	0.027	***	0.026	***	3	10	***	11	***	-0.021	-0.027	***	-0.026	***
	Total	6246	5167	***	5172	***	0.025	0.027	***	0.027	***	6246	5167	***	5172	***	-0.025	-0.027	***	-0.027	***
	< 15	1121	491	***	500	***	0.001	0.001	***	0.001	***	1134	491	***	494	***	-0.001	-0.001	***	-0.001	***
50 period moving averages 2)	15 - 34	102	67	***	67	***	0.002	0.002	***	0.002	***	61	67	-	67	-	-0.001	-0.002	***	-0.002	***
	>= 35	66	99	***	96	***	0.003	0.005	***	0.005	***	94	99	-	102	*	-0.003	-0.005	***	-0.005	***
	Total	1289	657	***	662	***	0.002	0.004	***	0.004	***	1289	657	***	662	***	-0.002	-0.004	***	-0.004	***
	< 15	758	353	***	351	***	0.000	0.001	***	0.001	***	757	352	***	347	***	0.000	-0.001	***	-0.001	***
100 period moving averages 2)	15 - 49	83	59	***	59	***	0.001	0.001	***	0.001	***	72	60	*	58	*	-0.001	-0.001	***	-0.001	***
	>= 50	48	60	***	58	**	0.002	0.003	***	0.003	***	59	61	-	63	-	-0.002	-0.003	***	-0.003	***
	Total	889	473	***	468	***	0.001	0.003	***	0.003	***	888	473	***	468	***	-0.002	-0.003	***	-0.003	***
	< 15	572	249	***	255	***	0.000	0.000	***	0.000	***	573	248	***	252	***	0.000	0.000	***	0.000	***
200 period moving averages 2)	15 - 49	64	40	***	42	***	0.000	0.001	***	0.001	***	49	41	-	40	-	0.000	-0.001	***	-0.001	***
	>= 50	37	46	**	43	*	0.001	0.002	***	0.002	***	50	45	-	47	-	-0.001	-0.002	***	-0.002	***
	Total	673	335	***	340	***	0.001	0.002	***	0.002	***	672	335	***	340	***	-0.001	-0.002	***	-0.002	***
	< 15	410	182	***	181	***	0.000	0.000	***	0.000	***	398	182	***	179	***	0.000	0.000	***	0.000	***
400 period moving averages 2)	15 - 49	25	29	-	29	-	0.000	0.000	***	0.000	***	30	29	-	29	-	0.000	0.000	***	0.000	***
	>= 50	33	33	-	32	-	0.001	0.001	***	0.001	***	39	34	-	34	-	-0.001	-0.001	***	-0.002	***
	Total	468	245	***	242	***	0.001	0.001	***	0.001	***	467	245	***	242	***	-0.001	-0.001	***	-0.001	***

1) Average change in exchange rate level per per minute in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective period moving average.

Notes: See tables A6.

Table A9 (cont.): Non-random components of exchange rate runs during the "bear market" 1999

Dollar/euro rates at 1-minute intervals

	Run length	Upward runs: Number observed	RW-Simulation Without drift	z-stat	RW-Simulation With drift	z-stat	Slope 1) observed	RW-Simulation Without drift	z-stat	RW-Simulation With drift	z-stat	Downward runs: Number observed	RW-Simulation Without drift	z-stat	RW-Simulation With drift	z-stat	Slope 1) observed	RW-Simulation Without drift	z-stat	RW-Simulation With drift	z-stat
											1999/11/06 - 1999/07/12										
Original data	< 3	6340	3991	***	4006	***	0.027	0.027	-	0.027	*	6320	3989	***	3993	***	-0.027	-0.027	-	-0.027	*
	3 - 9	713	1325	***	1316	***	0.020	0.027	***	0.027	***	732	1327	***	1327	***	-0.021	-0.027	***	-0.027	***
	>= 10	0	10	***	10	***	0.000	0.027	***	0.027	***	0	9	***	11	***	0.000	-0.027	***	-0.027	***
	Total	7053	5326	***	5331	***	0.025	0.027	***	0.027	***	7052	5326	***	5331	***	-0.026	-0.027	***	-0.027	***
50 period moving averages 2)	< 15	1234	516	***	513	***	0.001	0.001	***	0.001	***	1231	514	***	510	***	-0.001	-0.001	***	-0.001	***
	15 - 34	98	68	***	70	***	0.001	0.002	***	0.002	***	83	70	*	68	**	-0.001	-0.002	***	-0.002	***
	>= 35	76	101	***	98	***	0.003	0.005	***	0.005	***	94	101	-	104	*	-0.003	-0.005	***	-0.005	***
	Total	1408	684	***	681	***	0.002	0.004	***	0.004	***	1408	685	***	681	***	-0.002	-0.004	***	-0.004	***
100 period moving averages 2)	< 15	874	356	***	359	***	0.000	0.001	***	0.001	***	912	355	***	357	***	0.000	-0.001	***	-0.001	***
	15 - 49	108	60	***	60	***	0.001	0.001	***	0.001	***	58	60	-	60	-	-0.001	-0.001	***	-0.001	***
	>= 50	45	62	***	60	***	0.002	0.003	***	0.003	***	56	62	*	64	**	-0.002	-0.003	***	-0.003	***
	Total	1027	477	***	480	***	0.001	0.003	***	0.003	***	1026	477	***	480	***	-0.001	-0.003	***	-0.003	***
200 period moving averages 2)	< 15	549	251	***	256	***	0.000	0.000	***	0.000	***	577	251	***	255	***	0.000	0.000	***	0.000	***
	15 - 49	72	41	***	43	***	0.000	0.001	***	0.001	***	46	40	-	41	-	0.000	-0.001	***	-0.001	***
	>= 50	46	46	-	45	-	0.001	0.002	***	0.002	***	43	47	-	48	-	-0.001	-0.002	***	-0.002	***
	Total	667	337	***	344	***	0.001	0.002	***	0.002	***	666	337	***	344	***	-0.001	-0.002	***	-0.002	***
400 period moving averages 2)	< 15	363	179	***	187	***	0.000	0.000	***	0.000	***	342	178	***	186	***	0.000	0.000	***	0.000	***
	15 - 49	35	29	-	31	-	0.000	0.000	***	0.000	***	35	29	-	30	-	0.000	0.000	***	0.000	***
	>= 50	24	33	**	33	**	0.001	0.001	***	0.001	***	45	33	***	35	**	-0.001	-0.002	***	-0.002	***
	Total	422	240	***	251	***	0.001	0.001	***	0.001	***	422	240	***	251	***	-0.001	-0.001	***	-0.001	***

1) Average change in exchange rate level per per minute in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective period moving average.

Notes: See tables A6.

Table A10: Non-random components of exchange rate runs during the "bull market" 2002

Dollar/euro rates at 1-minute intervals

	Run length	Upward runs										Downward runs									
		Number					Slope 1)					Number					Slope 1)				
		ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation			
			Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat
										2002//01/31 - 2002/04/08											
Original data	< 3	14321	10249	***	10228	***	0.016	0.017	-	0.017	-	14402	10241	***	10241	***	-0.016	-0.017	*	-0.017	-
	3 - 9	2487	3399	***	3415	***	0.014	0.017	***	0.017	***	2406	3405	***	3401	***	-0.014	-0.017	***	-0.017	***
	>= 10	4	25	***	28	***	0.017	0.017	-	0.016	-	4	27	***	28	***	-0.018	-0.016	***	-0.017	**
	Total	16812	13673	***	13670	***	0.016	0.017	***	0.017	***	16812	13673	***	13670	***	-0.016	-0.017	***	-0.017	***
50 period moving averages 2)	< 15	3135	1295	***	1299	***	0.000	0.001	***	0.001	***	3112	1300	***	1310	***	0.000	-0.001	***	-0.001	***
	15 - 34	222	177	***	181	***	0.001	0.002	***	0.002	***	247	173	***	174	***	-0.001	-0.001	***	-0.002	***
	>= 35	205	263	***	264	***	0.002	0.003	***	0.003	***	204	263	***	260	***	-0.002	-0.003	***	-0.003	***
	Total	3562	1735	***	1744	***	0.001	0.002	***	0.002	***	3563	1735	***	1744	***	-0.001	-0.002	***	-0.002	***
100 period moving averages 2)	< 15	2356	910	***	916	***	0.000	0.000	***	0.000	***	2349	912	***	921	***	0.000	0.000	***	0.000	***
	15 - 49	198	153	***	156	***	0.001	0.001	***	0.001	***	201	151	***	156	***	-0.001	-0.001	***	-0.001	***
	>= 50	137	161	***	161	***	0.001	0.002	***	0.002	***	141	161	***	156	***	-0.001	-0.002	***	-0.002	***
	Total	2691	1225	***	1233	***	0.001	0.002	***	0.002	***	2691	1225	***	1233	***	-0.001	-0.002	***	-0.002	***
200 period moving averages 2)	< 15	1484	668	***	650	***	0.000	0.000	***	0.000	***	1476	669	***	655	***	0.000	0.000	***	0.000	***
	15 - 49	155	110	***	110	***	0.000	0.000	***	0.000	***	147	107	***	108	***	0.000	0.000	***	0.000	***
	>= 50	113	119	-	120	-	0.001	0.001	***	0.001	***	128	121	-	117	*	-0.001	-0.001	***	-0.001	***
	Total	1752	897	***	881	***	0.001	0.001	***	0.001	***	1751	897	***	881	***	-0.001	-0.001	***	-0.001	***
400 period moving averages 2)	< 15	959	468	***	457	***	0.000	0.000	***	0.000	***	962	470	***	457	***	0.000	0.000	***	0.000	***
	15 - 49	97	76	**	74	***	0.000	0.000	***	0.000	***	93	74	*	75	**	0.000	0.000	***	0.000	***
	>= 50	101	88	**	89	*	0.001	0.001	***	0.001	***	103	88	**	88	**	0.000	-0.001	***	-0.001	***
	Total	1157	632	***	620	***	0.000	0.001	***	0.001	***	1158	632	***	620	***	0.000	-0.001	***	-0.001	***

1) Average change in exchange rate level per day in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective moving average.

Notes: See tables A6.

Table A10 (cont.): Non-random components of exchange rate runs during the "bull market" 2002

Dollar/euro rates at 1-minute intervals

	Run length	Upward runs										Downward runs									
		Number					Slope 1)					Number					Slope 1)				
		ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation				ob-served	RW-Simulation			
			Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat
									2002/04/08 - 2002/05/03												
Original data	< 3	5713	3997	***	3971	***	0.016	0.016	-	0.016	-	5775	3995	***	4011	***	-0.016	-0.016	*	-0.016	**
	3 - 9	926	1321	***	1342	***	0.014	0.016	***	0.016	***	863	1322	***	1304	***	-0.013	-0.016	***	-0.016	***
	>= 10	1	11	***	12	***	0.021	0.016	***	0.016	***	1	11	***	10	***	-0.022	-0.016	***	-0.016	***
	Total	6640	5328	***	5325	***	0.016	0.016	***	0.016	***	6639	5328	***	5325	***	-0.016	-0.016	***	-0.016	***
50 period moving averages 2)	< 15	1341	509	***	506	***	0.000	0.001	***	0.001	***	1365	511	***	513	***	0.000	-0.001	***	-0.001	***
	15 - 34	92	69	***	68	***	0.001	0.001	***	0.001	***	84	69	**	70	**	-0.001	-0.001	***	-0.001	***
	>= 35	81	102	***	107	***	0.002	0.003	***	0.003	***	65	101	***	97	***	-0.002	-0.003	***	-0.003	***
	Total	1514	681	***	680	***	0.001	0.002	***	0.002	***	1514	681	***	680	***	-0.001	-0.002	***	-0.002	***
100 period moving averages 2)	< 15	892	363	***	356	***	0.000	0.000	***	0.000	***	925	365	***	363	***	0.000	0.000	***	0.000	***
	15 - 49	112	60	***	61	***	0.001	0.001	***	0.001	***	86	60	***	61	***	0.000	-0.001	***	-0.001	***
	>= 50	53	63	**	65	***	0.001	0.002	***	0.002	***	45	61	***	58	***	-0.001	-0.002	***	-0.002	***
	Total	1057	486	***	482	***	0.001	0.002	***	0.002	***	1056	486	***	482	***	-0.001	-0.002	***	-0.002	***
200 period moving averages 2)	< 15	597	258	***	255	***	0.000	0.000	***	0.000	***	602	258	***	258	***	0.000	0.000	***	0.000	***
	15 - 49	53	42	*	42	*	0.000	0.000	***	0.000	***	53	43	*	42	*	0.000	0.000	***	0.000	***
	>= 50	50	47	-	48	-	0.001	0.001	***	0.001	***	45	46	-	44	-	-0.001	-0.001	***	-0.001	***
	Total	700	347	***	345	***	0.001	0.001	***	0.001	***	700	347	***	345	***	0.000	-0.001	***	-0.001	***
50 period moving averages 2)	< 15	391	186	***	176	***	0.000	0.000	***	0.000	***	373	187	***	179	***	0.000	0.000	***	0.000	***
	15 - 49	34	30	-	29	-	0.000	0.000	***	0.000	***	48	30	***	29	***	0.000	0.000	***	0.000	***
	>= 50	30	35	-	35	-	0.001	0.001	***	0.001	***	33	35	-	31	-	0.000	-0.001	***	-0.001	***
	Total	455	251	***	239	***	0.001	0.001	***	0.001	***	454	251	***	239	***	0.000	-0.001	***	-0.001	***

1) Average change in exchange rate level per day in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective moving average.

Notes: See tables A6.

Table A10 (cont.): Non-random components of exchange rate runs during the "bull market" 2002

Dollar/euro rates at 1-minute intervals

	Run length	Upward runs										Downward runs									
		Number					Slope 1)					Number					Slope 1)				
		observed	RW-Simulation				observed	RW-Simulation				observed	RW-Simulation				observed	RW-Simulation			
			Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat		Without drift	z-stat	With drift	z-stat
2002/05/14 - 2002/06/04																					
Original data	< 3	4626	3389	***	3407	***	0.018	0.018	-	0.018	-	4610	3389	***	3436	***	-0.018	-0.018	*	-0.018	-
	3 - 9	823	1131	***	1134	***	0.016	0.018	***	0.018	***	841	1131	***	1105	***	-0.016	-0.018	***	-0.018	***
	>= 10	3	9	**	10	**	0.018	0.018	-	0.018	-	1	9	***	9	***	-0.013	-0.018	***	-0.018	***
	Total	5452	4529	***	4550	***	0.018	0.018	***	0.018	***	5452	4529	***	4550	***	-0.017	-0.018	***	-0.018	***
50 period moving averages 2)	< 15	946	432	***	425	***	0.001	0.001	***	0.001	***	967	432	***	431	***	-0.001	-0.001	***	-0.001	***
	15 - 34	76	57	***	57	**	0.001	0.002	***	0.002	***	66	58	-	58	-	-0.001	-0.002	***	-0.002	***
	>= 35	80	87	-	90	**	0.002	0.003	***	0.003	***	68	86	***	83	***	-0.002	-0.003	***	-0.003	***
	Total	1102	577	***	572	***	0.002	0.003	***	0.003	***	1101	577	***	572	***	-0.001	-0.003	***	-0.003	***
100 period moving averages 2)	< 15	653	306	***	293	***	0.000	0.000	***	0.000	***	653	306	***	297	***	0.000	0.000	***	0.000	***
	15 - 49	61	51	-	49	*	0.001	0.001	***	0.001	***	70	51	***	50	***	-0.001	-0.001	***	-0.001	***
	>= 50	56	53	-	56	-	0.002	0.002	***	0.002	***	47	52	-	51	-	-0.001	-0.002	***	-0.002	***
	Total	770	409	***	397	***	0.001	0.002	***	0.002	***	770	409	***	397	***	-0.001	-0.002	***	-0.002	***
200 period moving averages 2)	< 15	505	214	***	209	***	0.000	0.000	***	0.000	***	518	215	***	213	***	0.000	0.000	***	0.000	***
	15 - 49	61	35	***	34	***	0.000	0.000	***	0.000	***	56	35	***	34	***	0.000	0.000	***	0.000	***
	>= 50	43	39	-	42	-	0.001	0.002	***	0.002	***	36	38	-	38	-	-0.001	-0.002	***	-0.001	***
	Total	609	288	***	285	***	0.001	0.001	***	0.001	***	610	288	***	284	***	-0.001	-0.001	***	-0.001	***
50 period moving averages 2)	< 15	391	149	***	154	***	0.000	0.000	***	0.000	***	383	148	***	156	***	0.000	0.000	***	0.000	***
	15 - 49	27	24	-	24	-	0.000	0.000	***	0.000	***	37	24	**	25	**	0.000	0.000	***	0.000	***
	>= 50	29	28	-	30	-	0.001	0.001	***	0.001	***	27	28	-	27	-	-0.001	-0.001	***	-0.001	***
	Total	447	201	***	208	***	0.001	0.001	***	0.001	***	447	201	***	208	***	0.000	-0.001	***	-0.001	***

1) Average change in exchange rate level per day in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective moving average.

Notes: See tables A6.

Table A10 (cont.): Non-random components of exchange rate runs during the "bull market" 2002

Dollar/euro rates at 1-minute intervals

	Run length	Upward runs: Number: ob-served	Upward runs: Number: RW-Simulation: Without drift	z-stat	With drift	z-stat	Upward runs: Slope 1): ob-served	Upward runs: Slope 1): RW-Simulation: Without drift	z-stat	With drift	z-stat	Downward runs: Number: ob-served	Downward runs: Number: RW-Simulation: Without drift	z-stat	With drift	z-stat	Downward runs: Slope 1): ob-served	Downward runs: Slope 1): RW-Simulation: Without drift	z-stat	With drift	z-stat
											2002/06/17 - 2002/06/28										
Original data	< 3	2569	2086	***	2065	***	0.020	0.021	***	0.021	***	2584	2088	***	2103	***	-0.019	-0.021	***	-0.021	***
	3 - 9	597	693	***	713	***	0.020	0.021	***	0.021	***	585	691	***	676	***	-0.020	-0.021	***	-0.021	***
	>= 10	2	5	*	6	*	0.018	0.021	*	0.021	*	0	5	***	5	**	0.000	-0.021	***	-0.021	***
	Total	3168	2784	***	2783	***	0.020	0.021	***	0.021	***	3169	2784	***	2783	***	-0.019	-0.021	***	-0.021	***
50 period moving averages 2)	< 15	334	265	***	259	***	0.001	0.001	***	0.001	***	354	264	***	267	***	-0.001	-0.001	***	-0.001	***
	15 - 34	41	35	-	35	-	0.001	0.002	***	0.002	***	38	36	-	37	-	-0.001	-0.002	***	-0.002	***
	>= 35	57	53	-	58	-	0.003	0.004	***	0.004	***	41	53	***	48	**	-0.003	-0.004	***	-0.004	***
	Total	432	353	***	352	***	0.002	0.003	***	0.003	***	433	353	***	352	***	-0.002	-0.003	***	-0.003	***
100 period moving averages 2)	< 15	287	186	***	182	***	0.000	0.000	***	0.000	***	313	186	***	187	***	0.000	0.000	***	0.000	***
	15 - 49	39	31	*	31	*	0.001	0.001	***	0.001	***	29	31	-	32	-	-0.001	-0.001	***	-0.001	***
	>= 50	40	32	***	35	*	0.002	0.003	***	0.003	***	24	32	***	29	*	-0.002	-0.003	**	-0.003	-
	Total	366	249	***	247	***	0.002	0.002	***	0.002	***	366	249	***	247	***	-0.002	-0.002	***	-0.002	***
200 period moving averages 2)	< 15	174	132	**	127	**	0.000	0.000	**	0.000	***	189	132	***	131	***	0.000	0.000	***	0.000	***
	15 - 49	27	21	-	21	-	0.000	0.001	***	0.001	***	25	21	-	21	-	0.000	-0.001	***	-0.001	***
	>= 50	33	24	***	26	**	0.001	0.002	**	0.002	***	19	24	*	21	-	-0.001	-0.002	**	-0.002	*
	Total	234	177	***	174	***	0.001	0.002	**	0.002	***	233	177	**	174	***	-0.001	-0.002	***	-0.001	**
400 period moving averages 2)	< 15	103	93	-	87	-	0.000	0.000	-	0.000	-	110	93	-	90	-	0.000	0.000	*	0.000	*
	15 - 49	15	15	-	14	-	0.000	0.000	-	0.000	-	16	15	-	15	-	0.000	0.000	-	0.000	-
	>= 50	20	18	-	18	-	0.001	0.001	*	0.001	***	11	18	**	15	-	-0.001	-0.001	-	-0.001	-
	Total	138	125	-	119	-	0.001	0.001	-	0.001	**	137	125	-	119	-	-0.001	-0.001	*	-0.001	-

1) Average change in exchange rate level per day in cents. - 2) Before being classified, the observed exchange rate series as well as the 1000 random walk series are smoothed by the respective moving average.

Notes: See tables A6.

Table A10 (cont.): Non-random components of exchange rate runs during the "bull market" 2002

Dollar/euro rates at 1-minute intervals

	Run length	Upward runs: Number observed	Number RW-Simulation: Without drift	z-stat	With drift	z-stat	Slope 1) observed	Slope 1) RW-Simulation: Without drift	z-stat	With drift	z-stat	Downward runs: Number observed	Number RW-Simulation: Without drift	z-stat	With drift	z-stat	Slope 1) observed	Slope 1) RW-Simulation: Without drift	z-stat	With drift	z-stat
										2002/07/05 - 2002/07/19											
Original data	*< 3*	*2897*	*2349*	***	*2353*	***	0.021	0.021	*	0.021	*	*2947*	*2346*	***	*2379*	***	-0.020	-0.021	***	-0.021	**
	3 - 9	*687*	*780*	***	*794*	***	0.019	0.021	***	0.021	***	*637*	*783*	***	*768*	***	-0.019	-0.021	***	-0.021	***
	>= 10	*2*	*6*	**	*6*	**	0.022	0.021	-	0.021	-	*2*	*6*	**	*5*	*	-0.016	-0.021	**	-0.021	**
	Total	*3586*	*3135*	***	*3152*	***	0.020	0.021	***	0.021	***	*3586*	*3135*	***	*3152*	***	-0.020	-0.021	***	-0.021	***
50 period moving averages 2)	*< 15*	*457*	*300*	***	*299*	***	0.001	0.001	***	0.001	***	*452*	*300*	***	*304*	***	-0.001	-0.001	***	-0.001	***
	15 - 34	*46*	*41*	-	*40*	-	0.002	0.002	***	0.002	***	*59*	*41*	***	*42*	***	-0.002	-0.002	***	-0.002	***
	>= 35	*58*	*60*	-	*63*	-	0.003	0.004	***	0.004	***	*50*	*60*	***	*55*	-	-0.003	-0.004	***	-0.004	***
	Total	*561*	*401*	***	*401*	***	0.002	0.003	***	0.003	***	*561*	*401*	***	*401*	***	-0.002	-0.003	***	-0.003	***
100 period moving averages 2)	*< 15*	*296*	*216*	***	*205*	***	0.000	0.000	**	0.000	**	*300*	*215*	***	*209*	***	0.000	0.000	***	0.000	**
	15 - 49	*45*	*37*	*	*35*	*	0.001	0.001	***	0.001	***	*42*	*37*	-	*36*	-	-0.001	-0.001	***	-0.001	***
	>= 50	*30*	*36*	**	*39*	***	0.002	0.003	**	0.003	***	*29*	*37*	**	*33*	*	-0.002	-0.003	***	-0.002	***
	Total	*371*	*289*	***	*278*	***	0.002	0.002	***	0.002	***	*371*	*289*	***	*278*	***	-0.001	-0.002	***	-0.002	***
200 period moving averages 2)	*< 15*	*210*	*152*	***	*145*	***	0.000	0.000	**	0.000	**	*217*	*152*	***	*147*	***	0.000	0.000	**	0.000	**
	15 - 49	*24*	*25*	-	*23*	-	0.000	0.001	***	0.001	***	*19*	*25*	-	*24*	-	0.000	-0.001	***	-0.001	***
	>= 50	*27*	*28*	-	*28*	-	0.002	0.002	-	0.002	**	*25*	*28*	-	*25*	-	-0.001	-0.002	***	-0.002	***
	Total	*261*	*205*	**	*196*	***	0.001	0.001	-	0.002	**	*261*	*205*	**	*196*	***	-0.001	-0.001	***	-0.001	***
50 period moving averages 2)	*< 15*	*111*	*109*	-	*100*	-	0.000	0.000	-	0.000	-	*115*	*109*	-	*102*	-	0.000	0.000	-	0.000	-
	15 - 49	*16*	*17*	-	*16*	-	0.000	0.000	-	0.000	-	*11*	*18*	*	*16*	-	0.000	0.000	-	0.000	-
	>= 50	*20*	*20*	-	*20*	-	0.001	0.001	*	0.001	***	*21*	*20*	-	*18*	-	-0.001	-0.001	***	-0.001	***
	Total	*147*	*147*	-	*137*	-	0.001	0.001	-	0.001	**	*147*	*147*	-	*136*	-	-0.001	-0.001	***	-0.001	***

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Notes: See tables A6.