

**A STUDY OF THE EFFICIENCY OF THE  
FOREIGN EXCHANGE MARKET THROUGH  
ANALYSIS OF ULTRA-HIGH FREQUENCY DATA**

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**D.Phil. Thesis  
Sub-Faculty of Economics  
Michaelmas Term 1998**

*Appendix D:  
A Collection of Abstracts of Related Work*

## PREFACE

This Appendix presents a collection of abstracts of academic work which bears some relation to the content of this D.Phil. thesis. It grew out of my background notes which I prepared when researching the relevant literature. I feel that it would be a waste discarding this database upon completion of the thesis; instead I would be pleased if interested researchers would exploit it for the benefit of their research.

The collection does not mirror the set of references actually used for completion of the thesis, although some of the references are included here. My selection is biased towards working papers or other as yet unpublished research (which the common search engines available to economists may therefore fail to identify).

The abstracts are reproduced just as written by the respective authors (apart from obvious errors). Where no abstract was available, a suitable introduction or summary found in the paper was chosen instead and is indicated as such. The order is alphabetical.

Owing to the large number of abstracts included, the collection is most useful if searched electronically by keyword. For this reason, this appendix is available only electronically from the author's homepage:

<http://users.ox.ac.uk/~econlrk>

Abhyankar, Abhay, Laurence Copeland & Woon Wong (1997), "Uncovering Nonlinear Structure in Real-Time Stock-Market Indexes: The S&P 500, the DAX, the Nikkei 225, and the FTSE-100", *Journal of Business and Economic Statistics*, vol. 15, no. 1 (January), pp. 1-14

This paper tests for the presence of nonlinear dependence and chaos in real-time returns on four of the world's major stock market indices: the FTSE-100, the S&P 500, the Nikkei 225 and the DAX. Our results suggest that GARCH-type models can explain some but not all of the observed nonlinear dependence. The neural network-based test for nonlinearity introduced by Lee, White and Granger (1993) provides conclusive evidence of a persistent nonlinear structure in the series. We also estimate Lyapunov exponents in order to test directly for chaos using both the Nychka, Ellner, Gallant, McCaffrey (1992) and the Zeng, Pielke and Eyckholt (1992) methods. We find that none of the series seem to be characterized by a low-dimensional chaotic process. Instead, the Lyapunov exponent estimates appear to be extremely sensitive to the parameter values used in estimation, a fact which in itself may be an indication that the data are dominated by a stochastic component.

Acar, Emmanuel & Pierre Lequeux (1999): "Trading Rules Profits and the Underlying Time Series Properties", forthcoming in Pierre Lequeux, ed., *Financial Markets Tick by Tick*, March, John Wiley & Sons, London; revised version of paper in *Proceedings of the First International Conference on High Frequency Data in Finance, 29-31 March 1995*, Olsen & Associates, Zürich, vol. 1

The purpose of this paper is threefold. First, a better understanding of forecasting strategies is provided using stochastic modelling. Second, tests of random walk and market efficiency are derived from the stochastic properties of rule returns. Third, previous results are applied to a set of exchange rates.

According to portfolio insurance studies, the best way to estimate the distributional properties of an investment strategy is through stochastic modelling. This paper establishes the expected value, variance and correlation coefficient of trading rule returns by assuming that underlying logarithmic returns follow a random walk. Analytical formulae apply to both linear and nonlinear forecasters. As a consequence, new tests of random walk based on the profitability of trading rules are proposed. Finally, analytical formulae to estimate the number of transactions triggered by trading rules are established such that market efficiency tests can be build. The empirical part of the paper puts forward the validity of the stochastic modelling while considering the effects of parameters such as drift and autocorrelations on the profitability of trading rules and transaction costs. High frequency exchange rates do not follow a random walk but might still be efficient because of transaction costs. When sampled every half an hour, the time series of average bid/ask prices exhibit significant negative autocorrelations for the Usd/Dem and Usd/Yen but positive autocorrelations for the Dem/Yen. However, potential profits generated by trading rules are not high enough to cover transaction costs.

Ackert, Lucy, Bryan Church & Mohamed Shehata (1997), "Market Behavior in the Presence of Costly, Imperfect Information: Experimental Evidence", *Journal of Economic Behavior and Organization*, vol. 33, no. 1 (May), pp. 61-74

We conduct 12 experimental asset markets to investigate the effects of imperfect, private information on market prices. We compute Bayesian predictions and examine whether market prices are consistent with such predictions. We also examine information dissemination and the value of imperfect information. We find some evidence that market prices are consistent with Bayes' rule. We also find that non-Bayesian prices are more likely to arise as the degree of uncertainty associated with private information increases. In addition, imperfect information is disseminated in our experimental markets. Lastly, our results suggest that traders perceive that imperfect information has value.

Aït-Sahalia, Yacine (1998), “Dynamic Equilibrium and Volatility in Financial Asset Markets”, *Journal of Econometrics*, vol. 84, no. 1 (1 May), pp. 93-127; reprinted as University of Chicago, Graduate School of Business, *Center for Research in Security Prices Reprint*, no. 331; revised version of *NBER Working Paper*, no. 5479 (March 1996)

This paper develops and estimates a continuous-time model of a financial market where investors’ trading strategies and the specialist’s rule of price adjustments are the best response to each other. We examine how far modeling market microstructure in a purely rational framework can go in explaining alleged asset pricing “anomalies.” The model produces some major findings of the empirical literature: excess volatility of the market price compared to the asset’s fundamental value, serially correlated volatility, contemporaneous volume-volatility correlation, and excess kurtosis of price changes. We implement a nonlinear filter to estimate the unobservable fundamental value, and avoid the discretization bias by computing the exact conditional moments of the price and volume processes over time intervals of any length.

Ali, Mukhtar (1996), “Distribution of the Least Squares Estimator in a First-Order Autoregressive Model”, *University of Kentucky, Center for Business and Economic Research Working Paper*, no. E-190-96 (October); revised version of E-188-96 (February)

This paper investigates the finite sample distribution of the least squares estimator of the autoregressive parameter in a first-order autoregressive model. Uniform asymptotic expansion for the distribution applicable to both stationary and nonstationary cases is obtained. Accuracy of the approximation to the distribution by a first few terms of this expansion is then investigated. It is found that the leading term of this expansion approximates well the distribution. The approximation is, in almost all cases, accurate to the second decimal place throughout the distribution. In the literature, there exists a number of approximations to this distribution which are specifically designed to apply in some special cases of this model. The present approximation compares favourably with those approximations and in fact, its accuracy is, with almost no exception, as good as or better than these other approximations. Convenience of numerical computations seems also to favour the present approximations over the others. An application of the finding is illustrated with examples.

Allen, Franklin & Risto Karjalainen (1999), “Using Genetic Algorithms to Find Technical Trading Rules”, *Journal of Financial Economics*, vol. 51, no. 2 (February), forthcoming; revised version of University of Pennsylvania, *Rodney L. White Center for Financial Research Working Paper*, no. 20-95 (9 October 1995); revised version of no. 20-93 (1993)

A genetic algorithm is used to learn technical trading rules for Standard and Poor’s composite stock index using data from 1963-69. In the out-of-sample test period 1970-1989 the rules are able to identify periods to be in the index when returns are positive and volatility is low and out when the reverse is true. Compared to a simple buy-and-hold strategy, they lead to positive excess returns after transaction costs in the period of 1970-89. Using data for other periods since 1929, the rules can identify high returns and low volatility but do not lead to excess returns after transaction costs. The results are compared to benchmark models of a random walk, an autoregressive model, and a GARCH-AR model. Bootstrapping simulations indicate that none of these models of stock returns can explain the findings.

Almeida, Alvaro, Charles Goodhart & Richard Payne (1998), "The Effects of Macroeconomic "News" on High Frequency Exchange Rate Behaviour", *Journal of Financial and Quantitative Analysis*, vol. 33, no. 3 (September), pp. 383-408; revised version of *LSE Financial Markets Group Discussion Paper*, no. 258 (February 1997)

This paper studies the high frequency reaction of the DEM/USD exchange rate to publicly announced macroeconomic information emanating from Germany and the U.S. The news content of each announcement is extracted using a set of market expectation figures supplied by MMS International. By using data sampled at a high (5 minute) frequency we are able to identify systematic impacts of most announcements on the exchange rate change in the 15 minutes post-announcement. The impacts of "news" on the exchange rate, however, can be seen to lose significance very quickly when the observation horizon for the exchange rate is increased, so that for most announcements there is little effect of "news" on the exchange rate change by the end of the three hours immediately after release. Both the responses to U.S. and German "news" are broadly consistent with a monetary authority "reaction function" hypothesis, i.e., the market expects the Fed or the Bundesbank to respond to "news" on increased real activity, for example, by raising short term interest rates in order to head off the possibility of future inflation. Further, the use of German data allows us to examine two questions the previous literature could not tackle, because, unlike U.S. announcements, German announcements are not scheduled. First, we show that the time-pattern of the reaction of the exchange rate to the U.S. scheduled announcements is different from the reaction to the German non-scheduled announcements, the former being much quicker. Second, we are able to examine the effect on the exchange rate change of the proximity of other events to the announcement. Results show that German "news" is most influential when released just prior to a Bundesbank council meeting. Finally, subsidiary results demonstrate the efficiency of the intra-day FX market with respect to these announcements and map the pattern of volatility these releases cause.

Andersen, Arrogant Torben (1996), "Return Volatility and Trading Volume: An Information Flow Interpretation of Stochastic Volatility", *Journal of Finance*, vol. 51, no. 1 (March), pp. 169-204

The paper develops an empirical return volatility-trading volume model from a microstructure framework in which informational asymmetries and liquidity needs motivate trade in response to information arrivals. The resulting system modifies the so-called "Mixture of Distribution Hypothesis" (MDH). The dynamic features are governed by the information flow, modeled as a stochastic volatility process, and generalizes standard ARCH specifications. Specification tests support the modified MDH representation and show that it vastly outperforms the standard MDH. The findings suggest that the model may be useful for analysis of the economic factors behind the observed volatility clustering in returns.

Andersen, Arrogant Torben & Tim Bollerslev (1997a), "Intraday Periodicity and Volatility Persistence in Financial Markets", *Journal of Empirical Finance*, vol. 4, no.s 2-3 (June), pp. 115-158; revised version of "Intraday Seasonality and Volatility Persistence in Financial Markets", *Proceedings of the First International Conference on High Frequency Data in Finance, 29-31 March 1995*, Olsen & Associates, Zürich, vol. 4; in turn apparently abridged version of "Intraday Seasonality and Volatility Persistence in Foreign Exchange and Equity Markets", *Kellogg Graduate School of Management Working Paper*, no. 186 (1994)

This paper studies the intraday seasonality in return volatility in foreign exchange and equity markets. The pervasive seasonal patterns are shown to have a strong impact on the dynamic properties of high frequency returns. Consequently, traditional time series models developed for the analysis of daily or lower frequency returns turn out to be grossly inadequate and may give rise to very misleading conclusions when estimated directly on raw high frequency returns. Only an explicit adjustment for the strong

intraday seasonality generally afford a meaningful analysis of the complex intraday volatility dynamics that exists both within and across different financial markets. The explicit seasonal modeling procedure developed here provides such a framework, and this also sets the stage for a formal integration of standard volatility models with market microstructure variables to allow for a more comprehensive empirical investigation of the fundamental determinants behind the volatility clustering phenomenon.

Andersen, Arrogant Torben & Tim Bollerslev (1997b), “Heterogeneous Information Arrivals and Return Volatility Dynamics: Uncovering the Long-Run in High Frequency Returns”, *Journal of Finance*, vol. 52, no. 3 (July), pp. 975-1005; revised version of *NBER Working Paper*, no. 5752 (September 1996)

Recent empirical evidence suggests that the long-run dependence in financial market volatility is best characterized by a slowly mean-reverting fractionally integrated process. At the same time, much shorter-lived volatility dependencies are typically observed with high-frequency intradaily returns. This paper draws on the information arrival, or mixture-of-distributions hypothesis interpretation of the latent volatility process in rationalizing this behavior. By interpreting the overall volatility as the manifestation of numerous heterogeneous information arrivals, sudden bursts of volatility typically will have both short-run and long-run components. Over intradaily frequencies, the short-run decay stands out most clearly, while the impact of the highly persistent processes will be dominant over longer horizons. These ideas are confirmed by our empirical analysis of a one-year time series of intradaily five-minute Deutschemark – U.S. Dollar returns. Whereas traditional time series based measures for the temporal dependencies in the absolute returns give rise to very conflicting results across different intradaily sampling frequencies, the corresponding semiparametric estimates for the order of fractional integration remain remarkably stable. Similarly, the autocorrelogram for the low-pass filtered absolute returns, obtained by annihilating periods in excess of one day, exhibit a striking hyperbolic rate of decay.

Andersen, Arrogant Torben & Tim Bollerslev (1998a), “Deutsche Mark-Dollar Volatility: Intraday Activity Patterns, Macroeconomic Announcements, and Longer Run Dependencies”, *Journal of Finance*, vol. 53, no. 1 (February), pp. 219-265; revised and abridged version of *NBER Working Paper*, no. 5783 (October 1996)

This paper characterizes the volatility in the DM-dollar foreign exchange market using an annual sample of five-minute returns. Our modeling approach explicitly captures the pronounced intraday activity patterns, the strong macroeconomic announcement effects, and the volatility persistence, or ARCH effects, familiar from lower frequency returns. The different features are separately quantified and shown, in conjunction, to account for a substantial fraction of the realized return variability, both at the intradaily and daily levels. Moreover, we demonstrate how the high frequency returns, when properly modeled, constitute an extremely valuable and vastly underutilized resource for better understanding the volatility dynamics at the daily or lower frequencies.

Andrews, Donald & Moshe Buchinsky (1997), “On the Number of Bootstrap Repetitions for Bootstrap Standard Errors, Confidence Intervals, and Tests”, Yale University, *Cowles Foundation Discussion Paper*, no. 1141R (August)

This paper considers the problem of choosing the number of bootstrap repetitions  $B$  for bootstrap standard errors, confidence intervals, and tests. For each of these problems, the paper provides a three-step method for choosing  $B$  to achieve a desired level of accuracy. Accuracy is measured by the percentage deviation of the bootstrap standard error estimate, confidence interval endpoint(s), test's critical value, or test's p-value based on  $B$  bootstrap simulations from the corresponding ideal bootstrap quantities for which  $B = \infty$ . Monte Carlo simulations show that the proposed methods work quite well. The results apply quite generally to parametric, semiparametric, and nonparametric models with independent and dependent data. The results apply to the standard nonparametric iid bootstrap, moving block bootstraps for time series data, parametric and semiparametric bootstraps, and bootstraps for regression models based on bootstrapping residuals.

Aparicio, Felipe & Javier Estrada (1997), “*Empirical Distributions of Stock Returns: European Securities Markets, 1990-95*”, Universidad Carlos III, Madrid, Departamento de Empresa, April

The assumption that daily stock returns are normally distributed has long been disputed by the data. In this article we test (and clearly reject) the normality assumption using time series of daily stock returns for thirteen European securities markets. More importantly, we fit to the data four alternative specifications, find overall support for the scaled-t distribution (and partial support for a mixture of two Normal distributions), and quantify the magnitude of the error that stems from predicting the probability of obtaining returns in specified intervals by using the Normal distribution. We conclude by arguing that normality may be a plausible assumption for monthly (but not for daily) stock returns.

Ardalan, Kavous (1996), “Game Theory, Information Economics, Rational Expectation, and Efficient Market Hypothesis: Overviews and Exposition of Interconnections”, *International Journal of Business*, vol. 1, no. 2

This paper provides overviews of interesting topics of game theory, information economics, rational expectations, and efficient market hypothesis. Then, the paper shows how these topics are interconnected, with the rational expectations topic playing the pivotal role. Finally, by way of proving a theorem in the context of the well known Kyle’s rational expectations equilibrium model, the paper provides an exposition of the interconnectedness of the topics.

Arifovic, Jasmina (1996), “The Behavior of the Exchange Rate in the Genetic Algorithm and Experimental Economies”, *Journal of Political Economy*, vol. 104, no. 3 (June)

This paper studies the behavior of the exchange rate in the Kareken-Wallace overlapping generations economy with two currencies in which decision rules are updated using the genetic algorithm. The analysis shows that a stationary monetary equilibrium of the Kareken-Wallace model is not stable under the genetic algorithm dynamics. The fluctuations in the genetic algorithm exchange rate are driven by fluctuations in the portfolio fractions, which change over time in response to the inequality between the rates of return on two currencies. Further, both the genetic algorithm simulations and the experiments with human subjects were characterized by continuing fluctuations of the exchange rate, with first-period consumption values close to a stationary value.

Arthur, Brian, John Holland, Blake LeBaron, Richard Palmer & Paul Tayler (1997), “Asset Pricing Under Endogenous Expectations in an Artificial Stock Market”, in Brian Arthur, Steven Durlauf & David Lane, eds., *The Economy as an Evolving Complex System II*, Proceedings of Santa Fe Institute Studies in the Science of Complexity, vol. 27, Addison-Wesley, pp. 15-44; reprinted as University of Wisconsin-Madison, *Social Systems Research Institute Reprint*, no. 459; revised version of University of Wisconsin-Madison, *Social Systems Research Institute Working Paper*, no. 9625 (December 1996)

We propose a theory of asset pricing based on heterogeneous agents who continually adapt their expectations to the market that these expectations aggregatively create. And we explore the implications of this theory computationally using our Santa Fe artificial stock market.

Asset markets, we argue, have a recursive nature in that agents’ expectations are formed on the basis of their anticipations of other agents’ expectations, which precludes expectations being formed by deductive means. Instead traders continually hypothesize – continually explore – expectational models, buy or sell on the basis of those that perform best, and confirm or discard these according to their performance. Thus individual beliefs or expectations become endogenous to the market, and constantly

compete within an ecology of others' beliefs or expectations. The ecology of beliefs co-evolves over time.

Computer experiments with this endogenous-expectations market explain one of the more striking puzzles in finance: that market traders often believe in such concepts as technical trading, "market psychology," and bandwagon effects, while academic theorists believe in market efficiency and a lack of speculative opportunities. Both views, we show, are correct, but within different regimes. Within a regime where investors explore alternative expectational models at a low rate, the market settles into the rational-expectations equilibrium of the efficient-market literature. Within a regime where the rate of exploration of alternative expectations is higher, the market self-organizes into a complex pattern. It acquires a rich psychology, technical trading emerges, temporary bubbles and crashes occur, and asset prices and trading volume show statistical features – in particular, GARCH behavior – characteristic of actual market data.

Baestaens, Dirk-Emma, Willem Max van den Bergh & H. Vaudrey (1995), "The Marginal Contribution of News to the DEM/USD Swap Rate", *Proceedings of the First International Conference on High Frequency Data in Finance, 29-31 March*, Olsen & Associates, Zürich, vol. 3

This paper attempts to estimate the return on the DM/USD money market swap rate by both a linear regression and nonlinear neural network model. Since all variables strongly exhibited an hour of the (statistical) week effect both within- and out-of-sample, variables have been adjusted to remove this effect. The residual return pattern then is mainly driven by strongly negative autocorrelated lagged returns as well as by the "impact effect" of Reuter's Money Market Headline newsflashes. This effect has been measured by pairing standardised news sentences to successive return patterns in the train set and applying this information to predict the residual return out-of-sample. Some news flashes systematically generate positive (negative) residual returns. The set of 51,000 standardised news sentences established during the first six months accounted for most news flashes occurring during the second half of the dataset. News flashes therefore display a sufficiently systematic pattern to be useful for prediction. The neural network model outperforms the regression model on the basis of the standard mean squared error again highlighting the fact that nonlinear modelling appears to be the most promising avenue to deal with this high-frequency dataset.

Ball, Ray, S.P. Kothari & Jay Shanken (1995a), "Problems in Measuring Portfolio Performance – An Application to Contrarian Investment Strategies", *Journal of Financial Economics*, vol. 38, pp. 79-107

We document problems in measuring raw and abnormal five-year contrarian portfolio returns. "Loser" stocks are low-priced and exhibit skewed return distributions. Their 163% mean return is due largely to their lowest-price quartile position. A 1% price increase reduces the mean by 25%, highlighting their sensitivity to micro-structure/liquidity effects. Long positions in low-priced loser stocks occur disproportionately after bear markets and thus induce expected-return effects. A contrarian portfolio formed at June-end earns negative abnormal returns, in contrast with the December-end portfolio. This conclusion is not limited to a particular version of the CAPM.

Ball, Ray, S.P. Kothari & Charles Wasley (1995b), "Can We Implement Research on Stock Trading Rules? The Case of Short-Term Contrarian Strategies", *Journal of Portfolio Management*, Winter, pp. 54-63; reprinted as *University of Rochester, Bradley Policy Research Center, Financial Research and Policy Reprint*, no. FR-R-210

Research on trading rule profitability usually simulates trading on historical data. These data usually are obtained from files such as CRSP, which estimate closing prices as the last trade (at the closing bid or the closing ask, or neither), or the bid-ask average (in the absence of a last trade). A trading rule could not normally be implemented at these prices, for even a smaller number of shares. A simulated



contrarian strategy transforms noise in closing price estimates into return biases, by buying at predominantly bid prices and shorting at ask, which is not implementable for most investors. The bias in estimated contrarian portfolio returns is severe. For example, when returns are calculated from successive bid prices of NASDAQ stocks, short-term contrarian profits largely disappear.

Barberis, Nicholas, Andrei Shleifer & Robert Vishny (1998), “A Model of Investor Sentiment”, *Journal of Financial Economics*, vol. 49, no. 3 (1 September), pp. 307-343; revised version of *NBER Working Paper*, no. 5926 (February 1997); also University of Chicago, Graduate School of Business, *Center for Research in Security Prices Working Paper*, no. 443 (December 1996)

Recent empirical research in finance has uncovered two families of pervasive regularities: *underreaction* of stock prices to news such as earnings announcements; and *overreaction* of stock prices to a series of good or bad news. In this paper, we present a parsimonious model of investor sentiment – that is, of how investors form beliefs – that is consistent with the empirical findings. The model is based on psychological evidence and produces both underreaction and overreaction for a wide range of parameter values.

Barkoulas, John, Christopher Baum & Nickolaos Travlos (1998a), “Long Memory in the Greek Stock Market”, *Applied Financial Economics*, forthcoming; revised version of *Boston College Working Papers in Economics*, no. 356 (August 1997)

We test for stochastic long memory in the Greek stock market, an emerging capital market. The fractional differencing parameter is estimated using the spectral regression method. Contrary to findings for major capital markets, significant and robust evidence of positive long-term persistence is found in the Greek stock market. As compared to benchmark linear models, the estimated fractional models provide improved out-of-sample forecasting accuracy for the Greek stock returns series over longer forecasting horizons.

Baum, Christopher & John Barkoulas (1996), “Long Term Dependence in Stock Returns”, *Economics Letters*, vol. 53, no. 3 (December), pp. 253-259; revised version of “Testing for Fractal Structure in Stock Returns”, *Boston College Working Papers in Economics*, no. 314 (April)

This paper investigates the presence of fractal dynamics in stock returns. We improve upon existing literature in two ways: i) instead of rescaled-range analysis, we use the more efficient semi-nonparametric procedure suggested by Geweke and Porter-Hudak (GPH, 1983), and ii) to ensure robustness, we apply the GPH test to a variety of aggregate and sectoral stock indices and individual companies' stock returns series at both daily and monthly frequencies. Our results indicate that fractal structure is not exhibited by stock indices, but it may characterize the behavior of some individual stock returns series.

Belsley, David (1998), “*Mathematica* as an Environment for Doing Economics and Econometrics”, *Computational Economics*, forthcoming; revised version of *Boston College Working Papers in Economics*, no. 364 (20 March 1997)

A case is made that today's graduate students in economics must master early on a computational environment suitable for their research needs. The virtues of *Mathematica* for this purpose are highlighted. Descriptions of its elements that are particularly suited for this need are given along with examples of the kind of economic research successfully accomplished in the environment.

Berg, Lennart & Johan Lyhagen (1998), “Short and Long Run Dependence in Swedish Stock Returns”, *Applied Financial Economics*, vol. 8, no. 4, pp. 435-443; revised version of *Uppsala University Department of Economics Working Paper*, no. 1996:19 (September 1996)

The behavior of Swedish stock returns over short and long run horizons is analyzed. Using monthly data from 1919 to 1995 and, weekly and daily data for the 1980s and first part of the 1990s we hardly found any evidence of long run dependence. Using three different tests that are robust to short term dependence and conditional heteroskedasticity we found that the modified R/S (rescaled range) test and ARFIMA-GARCH tests provide no support for long run memory in Swedish stock returns. Only the fractional differencing test, GPH, gave a significant result in two cases: for nominal monthly stock returns for the full and the first half of sample at rather high frequency for the spectral analysis.

Berkowitz, Jeremy & Lutz Kilian (1996), “Recent Developments in Bootstrapping Time Series”, *Board of Governors of the Federal Reserve System, Finance and Economics Discussion Series*, no. 96-45 (8 November)

In recent years, several new parametric and nonparametric bootstrap methods have been proposed for time series data. Which of these methods should applied researchers use? We provide evidence that for many applications in time series econometrics parametric methods are more accurate, and we identify directions for future research on improving nonparametric methods. We explicitly address the important, but often neglected issue of model selection in bootstrapping. In particular, we emphasize the advantages of the AIC over other lag order selection criteria and the need to account for lag order uncertainty in resampling. We also show that the block size plays an important role in determining the success of the block bootstrap, and we propose a data-based block size selection procedure.

Bessembinder, Hendrik & Kalok Chan (1995), “Do the Profits From Technical Trading Rules Reflect Inefficiencies?”, Arizona State University, Department of Finance, working paper

We investigate whether the demonstrated effectiveness of technical analysis for forecasting equity returns can be reconciled with market efficiency. We find that evidence supportive of technical sell signals identifying periods of negative expected returns is confined to the pre-1940 subsamples. On average, transactions costs eliminate any additional returns to traders using the technical rules. We also demonstrate that technical analysis of an index constructed from CRSP returns, which is not typically observed by practising technicians, is as useful for forecasting returns as is technical analysis of the widely observed DJIA. Finally, we show that, while technical analysis of individual equity price histories can forecast returns, it does not provide the ability to “beat the market”. On balance, we conclude that there is little or no reason to view the evidence of technical forecast power as inconsistent with market efficiency.

Bessembinder, Hendrik & Kalok Chan (1998), “Market Efficiency and the Returns to Technical Analysis”, *Financial Management*, vol. 27, no. 2 (Summer), pp. 5-18; revised version of “Do the Profits from Technical Trading Rules Reflect Inefficiencies?”, Arizona State University, College of Business, working paper, January 1994

We further investigate and provide interpretation for the intriguing Brock, Lakonishok, and LeBaron (1992) finding that simple forms of technical analysis contain significant forecast power for US equity index returns. We document that the forecast ability is partially, but not solely, attributable to return measurement errors arising from non-synchronous trading. We argue that the evidence supporting technical forecast power need not be inconsistent with market efficiency. “Break-even” one-way trading costs are computed to be 0.39% for the full sample and 0.22% since 1975, which are small compared to recent estimates of actual trading costs. Further, we test but fail to reject a key restriction that most

equilibrium models place on return forecast ability: that the technical rules should not reliably identify periods of negative market risk premia.

Blair, Bevan, Ser-Huang Poon & Stephen Taylor (1997), "Modelling S&P 100 Volatility: The Information Content of Stock Returns", *Lancaster University, Working Papers in Accounting and Finance*, no. 97/005

Hitherto, index volatility has been modelled using the history of index returns but not the returns histories of the stocks that define the index. Theoretical models that relate volatility to the quantity of information are extended to a multi-asset setting and it is deduced that stock returns may or may not have incremental information when modelling index volatility, depending on the sources of information that move stock prices. The first empirical study that can help resolve this theoretical uncertainty is presented. A detailed analysis of the daily volatility of the S&P 100 index from 1983 to 1992 shows that there is some incremental volatility information in the returns from the 100 shares that define the index. ARCH models are estimated, that incorporate leverage effects, dummy variables for the 1987 crash and aggregate measures of stock return volatility. Parameter estimates for the stock measures reject the null hypothesis that the measures are irrelevant, at the 5% level, for the ten years considered. Mixed results are obtained for sub-periods. Significant differences between estimated volatilities are found, leaving open the possibility that the new volatility estimates may price options differently, by amounts that are of economic significance.

Blair, Bevan, Ser-Huang Poon & Stephen Taylor (1998), "Asymmetric and Crash Effects in Stock Volatility for the S&P 100 Index and its Constituents", *Lancaster University, Working Papers in Accounting and Finance*, no. 98/003

The volatility processes of the S & P 100 index and all its constituent stocks are compared after estimating ARCH models from ten years of daily returns, from 1983 to 1992. The leverage effect of Black (1976) is estimated from an extension of the asymmetric volatility model of Glosten et al (1993) that isolates the effects of the crash in October 1987. The index and the majority of stocks have a greater volatility response to negative returns than to positive returns and the asymmetry is higher for the index than for most stocks. Conclusions about volatility asymmetry and persistence change when the crash is considered to be an extraordinary event.

Bloomfield, Robert (1996), "Quotes, Prices, and Estimates in a Laboratory Market", *Journal of Finance*, vol. 51, no. 5 (December), pp. 1791-1808; apparently revised version of "Under-Reactions, Information Dissemination and Bid-Ask Spreads in the Laboratory", Cornell University, working paper, 1994

This study examines the behavior of laboratory markets in which two uninformed market makers compete to trade with heterogeneously informed investors. The data provide three main results. First, market makers set quotes to protect against adverse selection and to control inventory. Second, when investors are less well-informed, their trades are less reliable measures of their information, and market makers respond to those trades with greater skepticism. Third, errors in market makers' reactions to trades cause the time-series behavior of quotes and prices to depend on the information environment in ways beyond those captured in extant theory.

Bollerslev, Tim, Ian Domowitz & Jianxin Wang (1997), "Order Flow and the Bid-Ask Spread: An Empirical Probability Model of Screen-Based Trading", *Journal of Economic Dynamics and Control*, vol. 21, no.s 8-9 (18 June), pp. 1471-1491; revised version of *Kellogg Graduate School of Management, Department of Finance Working Paper*, no. 176, 1994

A probabilistic framework for the analysis of screen-based trading activity in financial markets is presented. Conditional probability functions are derived for the stationary distributions of the best bid

and offer in the market, given the order flows and the acceptance rates of bids and offers. These flows are conditioned on observable screen information. A two-step method is developed for the estimation of the conditional probability functions. The estimation allows for the separate identification of the unobservable order and acceptance flows, which in turn may be used to predict the stationary distributions of the bid-ask spreads, transaction prices, and other market statistics. A formal comparison of the predicted and the sample bid-ask spread distribution provides a stringent test of the model. The necessary econometric methods for conducting such a test, taking into account the parameter estimation error uncertainty, is developed. The methodology is applied to the scree-based interbank foreign exchange market, using a newly available dataset that consists of continuously recorded bid and ask quotes on the Deutschemark/U.S. Dollar exchange rate. The model is found to provide a good description of the salient probabilistic features of the market structure, even though the formal prediction based test for the spread distribution, with more than 29,000 out-of-sample quotations, rejects the exact parametric formulation of the order flows.

Bossaerts, Peter, Christian Hafner & Wolfgang Härdle (1996), “Exchange Rates Have Surprising Volatility”, Chapter 2 in Peter Robinson and Murray Rosenblatt, eds., *Athens Conference on Applied Probability and Time Series Analysis*, vol. 2 (Time Series Analysis in Memory of E.J. Hannan), Springer, Berlin, pp. 55-72; revised version of Bossaerts & Härdle, “Foreign Exchange Rates Have Surprising Volatility”, *Proceedings of the First International Conference on High Frequency Data in Finance, 29-31 March 1995*, Olsen & Associates, Zürich, vol. 2

Local Polynomial Estimation (LPE) is implemented on a dataset of high-frequency foreign exchange (FX) quotes. In order to correct for seasonal heteroscedasticity, the data are sampled over time intervals which were deformed as a function of the number of quote revisions. Assuming a conditionally heteroscedastic nonlinearly autoregressive (CHARN) model, estimates of the mean and volatility functions in deformed time are reported. The mean function displays pronounced reversion; little deviation from linearity is discovered, except for the JPY/DEM quotes, which displays substantial asymmetric reversion. In contrast, the volatility function exhibits pronounced nonlinearities when conditioning only on past quote changes. Substantial asymmetry in the volatility function is discovered for the DEM/USD and a bimodal shape for the YEN/DEM. In contrast, the volatility function for the YEN/USD is essentially flat.

Boudoukh, Jacob (1994), “Can Market-Timers Time Markets? Evidence on the Predictability of Stock Returns from Asset Allocation Funds”, *New York University Salomon Center Working Paper*

Data on the portfolio weights of asset allocators allows us to address the following two questions: (i) can market timers time markets? and, if so, (ii) can they predict returns over and above predetermined predictive economic variables? A priori, if no evidence of market timing ability can be detected in the portfolio weight changes, further doubt is casted on predictability. Conversely, documenting a link between the shifts in the weights of asset allocators and predetermined variables reinforces the notion of predictability. Moreover, if the information in portfolio weight changes can be shown to subsume the set of predetermined variables commonly used, this could be interpreted as evidence of nonlinearity and/or nonstationarity, better captured by rational learners in the marketplace than by econometricians.

The evidence is largely mixed. While many of the point estimates point in the direction of predictability of excess returns, the estimates are most often statistically insignificant. The inference is, hence, critically dependent on one's priors.

Bouman, Sven & Ben Jacobsen (1997), “The Halloween Indicator: Sell in May and Go Away”, University of Amsterdam, Faculty of Economics and Econometrics, working paper, November

We test a trading strategy of (national) tactical asset allocation based on the popular market wisdom “Sell in May and go away” also known as the “Halloween indicator”. With this simple market timing strategy one holds a market portfolio of stocks during November through April and short term government bonds during May through October. While this strategy is, measured by its standard deviation, less risky than a buy and hold market portfolio, we find that this simple market timing rule outperforms these market portfolios in almost all 17 countries in our study. Annualized returns in excess of returns on market indices in these countries are substantial: the average out-performance is almost 3 percent. We show that this trading strategy has statistically significant market timing ability. The strategy forecasts half year bull and bear markets correctly up to 75 percent of the time over a 24 year period. When we correct for risk (using beta) we are able to reject mean variance efficiency of stock market indices for many countries in our study. In this mean variance framework the out-performance as measured by Jensen’s alpha, ranges between 1.5 and 9 percent. These results are puzzling as this strategy seems to be too simple to be true. We investigate many potential explanations for this puzzle but do not find one that makes sense. We find no evidence that these results can be explained by the specific time period under consideration, specific sectors in the economy, the January effect or other calendar anomalies, the stock market crash of 1987, seasonality in dividend payments or time varying risk premia. In comparison with other (calendar) anomalies the potential benefits of the Halloween indicator are extremely large. They might also be interesting for practitioners as these benefits are obtainable by just two trades a year and therefore not wiped out by transactions costs.

Brenner, Robin & Kenneth Kroner (1995), “Arbitrage, Cointegration, and Testing the Unbiasedness Hypothesis in Financial Markets”, *Journal of Financial and Quantitative Analysis*, vol. 30, no. 1 (May), pp. 23-42

We use a no-arbitrage, cost-of-carry asset pricing model to show that the existence of cointegration between spot and forward (futures) prices depends on the time-series properties of the cost-of-carry. We argue that the conditions for cointegration are more likely to hold in currency markets than in commodity markets, explaining many of the empirical results in the literature. We also use this model to demonstrate why the forward rate forecast error, the bias, and the forward premium are serially correlated, and to develop econometric tests of the “unbiasedness hypothesis” (sometimes called the “simple efficiency hypothesis”) in various financial markets. The unbiasedness hypothesis is so prevalent in the finance literature that many tests for it have been developed. We examine four of the common tests and use our cointegration results to demonstrate why each of these tests *should* reject the null hypothesis of unbiasedness. We find strong support for our hypothesis in the existing empirical literature.

Brock, William & Blake LeBaron (1995), “A Dynamic Structural Model for Stock Return Volatility and Trading Volume”, *NBER Working Paper*, no. 4988 (January), shortened version of “Using Structural Modeling in Building Statistical Models of Volatility and Volume of Stock Market Returns: Unabridged Version”, University of Wisconsin, Madison, *Social Science Research Institute Working Paper*, 1993, apparently forthcoming as “Using Structural Modelling in Building Statistical Models of Volatility and Volume of Stock Market Returns”, *Review of Economics and Statistics*

This paper seeks to develop a structural model that can let data on asset returns and trading volume speak to whether volatility autocorrelation comes from the fundamental that the trading process is pricing or, is caused by the trading process, itself. Returns and volume data argue, in the context of our model, that persistent volatility is caused by traders experimenting with different belief systems based upon past profit experience and their estimates of future profit experience.

A major theme of our paper is to introduce adaptive agents in the spirit of Sargent (1993) but have them adapt their strategies on a time scale that is slower than the time scale on which the trading process takes place. This will lead to positive autocorrelation in volatility and volume on the time scale of the trading process which generates the returns and volume data. Positive autocorrelation of volatility and volume is caused by persistence of strategy patterns that are associated with high volatility and high volume.

At a rough level, the model is able to qualitatively reproduce the following features seen in the data: (i) The autocorrelation function of a measure of volatility such as squared returns or absolute value of returns is positive with a slowly decaying tail. (ii) The autocorrelation function of a measure of trading activity such as volume or turnover is positive with a slowly decaying tail. (iii) The cross correlation function of a measure of volatility such as squared returns is approximately zero for squared returns with past and future volumes and is positive for squared returns with current volume. (iv) Abrupt changes in prices and returns occur which are hard to attach to “news”. The last feature is obtained by a version of the model where the Law of Large Numbers fails in the large economy limit.

Brunnermeier, Markus Konrad (1998), “Prices, Price Processes, Volume and their Information – A Survey of the Market Microstructure Literature”, *LSE Financial Markets Group Discussion Paper*, no. 270 (March)

This paper provides an up-to-date review and summary of the existing literature on the informational aspects of price processes. A common feature of these models is that prices reflect information that is dispersed among many traders. The paper begins by contrasting the Rational Expectation Equilibrium concept with the Bayesian Nash Equilibrium concept, and then draws a connection between market completeness and information revelation. The No-Speculation Theorem and the No-Trade Theorems are also explained. The No-Trade Theorems describe circumstances where asymmetric information can lead to market breakdown even though there are gains from trade. The paper also examines situations under which bubbles can occur even when all traders are rational and forward looking. The second part of the survey addresses CARA-Gaussian market microstructure models. These models are classified into five groups. A distinction is drawn between limit order models and market order models. These models are further subdivided into models with strategic or competitive traders. Dynamic models are used to illustrate a rationale for technical/chart analysis. The various types of herding models are described in the final section.

Buser, Stephen, Andrew Karolyi & Anthony Sanders (1996), “Adjusted Forward Rates as Predictors of Future Spot Rates”, *Journal of Fixed Income*, vol. 6, December, pp. 29-42; revised version of Ohio State University, *Charles A. Dice Center for Research in Financial Economics Working Paper*, no. 96-5 (April)

Prior studies indicate that the predictive power of implied forward rates for future spot rates is weak over long sample periods and typically varies dramatically across different sub-periods. Fama (1976, 1984) conjectures that the low forecast power is due to a failure to control for the term premium embedded in forward rates. We show that Fama’s conjecture is consistent with the data using any of four different models of the term premium. We measure the term premium using a variety of ex ante instruments, including the junk bond premium, bid-ask spreads in Treasury bills, the Standard & Poor’s 500 stock index’s dividend yield and the conditional volatility of interest rate changes using an Autoregressive Conditionally Heteroscedastic (ARCH) process. Forward rates adjusted for the term premium are reliable predictors of future spot rates over the entire 1963-1993 period.

Bushan, Ravi, David Brown & Antonio Mello (1997), “Do Noise Traders ‘Create Their Own Space?’”, *Journal of Financial and Quantitative Analysis*, vol. 32, no. 1 (March), pp. 25-45

We analyze myopic-trader models of noisy prices in financial markets. Unlike extant analysis, such as De Long et al. (1990a), a classical equilibrium exists in our analysis, e.g., a riskless perpetuity is priced by arbitrage and its price does not vary with noise. Only when (a) noise traders’ beliefs are rational

regarding volatility and irrational regarding expected returns, and (b) noise traders may hold infinite positions, does a unique noisy equilibrium exist. In the absence of these strong assumptions, multiple noisy equilibria may coexist with the classical equilibrium, but these equilibria exhibit conflicting comparative statics. Furthermore, the price of a long-lived asset with risky cash flows may vary with noise even when investors are not myopic. One conclusion is that myopia is neither a necessary nor a sufficient condition for noisy prices. A second is that it is difficult, if not impossible, to use myopic-trader models to derive implications for investment or regulatory policy.

Calvet, Laurent, Adlai Fisher & Benoît Mandelbrot (1997), “Large Deviations and the Distribution of Price Changes”, Yale University, *Cowles Foundation Discussion Paper*, no. 1165 (15 September)

The Multifractal Model of Asset Returns (See Mandelbrot, Fisher, and Calvet, 1997) proposes a class of multifractal processes for the modelling of financial returns. In that paper, multifractal processes are defined by a scaling law for moments of the processes’ increments over finite time intervals. In the present paper, we discuss the local behavior of multifractal processes. We employ local Holder exponents, a fundamental concept in real analysis that describes the local scaling properties of a realized path at any point in time. In contrast with the standard models of continuous time finance, multifractal processes contain a multiplicity of local Holder exponents within any finite time interval. We characterize the distribution of Holder exponents by the multifractal spectrum of the process. For a broad class of multifractal processes, this distribution can be obtained by an application of Cramer’s Large Deviation Theory. In an alternative interpretation, the multifractal spectrum describes the fractal dimension of the set of points having a given local Holder exponent. Finally, we show how to obtain processes with varied spectra. This allows the applied researcher to relate an empirical estimate of the multifractal spectrum back to a particular construction of the stochastic process.

Cecen, Aydin & Cahit Erkal (1996), “Distinguishing between Stochastic and Deterministic Behavior in Foreign Exchange Rate Returns: Further Evidence”, *Economic Letters*, vol. 51, no. 3 (June), pp. 323-329

The nature of non-linear dependence in hourly exchange rate returns is scrutinized. While the Brock, Dechert and Scheinkman (BDS) test results reject i.i.d. behavior, various correlation dimension estimates reveal little evidence in favor of a low-dimensional attractor in the time series.

Chan, Louis, Narasimhan Jegadeesh & Josef Lakonishok (1996), “Momentum Strategies”, *Journal of Finance*, vol. 51, no. 5 (December)

We examine whether the predictability of future returns from past returns is due to the market’s underreaction to information, in particular to past earnings news. Past returns and past earnings surprise each and predict large drifts in future returns after controlling for the other. Market risk, size and book-to-market effects do not explain the drifts. There is little evidence of subsequent reversals in the returns of stocks with high price and earnings momentum. Security analysts’ earnings forecasts also respond sluggishly to past news, especially in the case of stocks with the worst past performance. The results suggest a market that responds only gradually to new information.

Chang, Rosita, Ghon Rhee, Shuh-Tzy Hsu & Nai-Kuan Huang (1995), “The Effects of Trading Methods on Volatility and Liquidity”, *Proceedings of the First International Conference on High Frequency Data in Finance, Zürich, 29-31 March*, vol. 1

This study empirically contrasts the call and continuous auction markets by examining volatility and liquidity. A number of important results emerge from our analysis. First, significant differences in market volatility exist between the two trading methods. Price volatility under the call market method is, on average, one-half of that under the continuous auction method. Second, the call market method

works more effectively in reducing price volatility of high-volume stocks rather than low-volume stocks. This contradicts conventional wisdom which suggests that the call market method is better for thinly traded stocks, while the continuous auction method is preferred for heavily traded stocks. Third, the call auction method does not impair market liquidity. For example, based on French-Roll variance ratios, we find that price discovery is more efficient in the call market than in the continuous auction market. Furthermore, we find no appreciable difference between the two trading methods, when we compare the price impact of large order imbalances.

Chang, Yuanchen & Stephen Taylor (1996), "Information Arrivals and Intraday Exchange Rate Volatility", *Lancaster University, Working Papers in Accounting and Finance*, no. 96/006 (October)

This paper investigates the link between information arrivals and intraday DEM/\$ volatility. Information arrivals are measured by the numbers of news items that appeared in the Reuters News Service. We separate news stories into different categories and find that total headline news counts have the most significant impact on DEM/\$ volatility, following by US macroeconomic news. News related to the US Federal Reserve, German Bundesbank and German macroeconomic variables appears to have little impact during the sample period. The conclusions are obtained from ARCH models that incorporate intraday seasonal volatility terms.

Chen, Nai-Fu, Raymond Kan & Chu Zhang (1997), "A Critique of the Use of *t*-Ratios in Model Selection", University of Toronto, working paper, October

It is a common practice to use *t*-ratios to select models in empirical asset pricing. In this paper, we show that such a practice could lead to the acceptance of very poor models. As an illustration, we examine a simple version of the widely used cross-sectional regression methodology and find analytically that variables with the highest *t*-ratios may not be highly correlated with expected returns. Contrary to common belief, a high *t*-ratio may in fact be evidence of low explanatory power. The results in this study cast doubt on the economic significance of variables selected only on the basis of high *t*-ratios and suggest that we should include other diagnostics in addition to *t*-ratios in model selection.

Cheung, Yin-Wong & Menzie Chinn (1998), "Integration, Cointegration and the Forecast Consistency of Structural Exchange Rate Models", *Journal of International Money and Finance*, vol. 17, no. 5, pp. 813-830; revised version of *University of California, Santa Cruz Working Paper*, no. 314 (March 1995)

Exchange rate forecasts are generated using some popular monetary models of exchange rates. We propose an alternative set of criteria for evaluating forecast rationality, which entails the following requirements: the forecast and the actual series i) have the same order of integration, ii) are cointegrated, and iii) have a cointegrating vector consistent with long run unitary elasticity of expectations. When these conditions hold, we consider the forecasts to be "consistent". These criteria appear to be more appropriate for forecasts generated by structural models than typical measures of forecast rationality, since such models rely upon serially correlated measures of the fundamentals.

We find that it is fairly easy for the generated forecasts to pass the first requirement of consistency that the series be of the same order of integration. However, cointegration fails to hold the farther out the forecasts extend. Finally, of the cointegrated pairs, the restriction of unitary elasticity of forecasts with respect to actual appears not to be rejected in general.

Cho, Jin-Wan (1994), "State-Space Representation and Estimation of Market Microstructure Models", Georgia Institute of Technology, *DuPree College of Management Finance Working Paper Series*, no. 94-14

This paper proposes a way to estimate and test market microstructure models. The methodology entails taking advantage of the special structures these models impose and relating those characteristics to a



state-space model. I develop a theoretical model of speculative trading between a market maker and an informed trader. In this model, the informed trader acts strategically with his long-lived private information which evolves randomly not only overnight but also during a trading day. Then, Kalman filtering is applied to perform a maximum likelihood estimation using adjusted quote mid-points, and three related hypotheses implied by the equilibrium restrictions are tested.

Dacorogna, Michel, Ulrich Müller & Olivier Pictet (1991), “A Measure of the Trading Model Performance with a Risk Component”, Olsen & Associates, Zürich, working paper, 1 October

[Introduction] The purpose of this paper is to suggest a new measure of trading model performance which accounts for the following requirements: 1. a high total return, 2. a smooth behavior around a straight line, 3. a small clustering of losses, 4. no bias towards low-frequency trading models. It is important to define a value which describes the performance well in order to minimize the risk of over-fitting in the in-sample period and to be able to compare different trading models with each other.

In section 2 of this paper, we discuss the Sharpe index, a measure frequently used to evaluate portfolio models. We show that it does not account for all of the above requirements. In section 3, we propose a new measure based on a risk-averse trading profile and the utility function formalism of Keeney and Raiffa (1976). This measure is numerically more stable than the Sharpe index and exhibits fewer deficiencies. In section 4, this measure is extended to a multi-horizon measure in order to be able to account for the clustering of losses in the return curve. In the same section, some numerical aspects of the computation of this variable are discussed.

Dacorogna, Michel, Ulrich Müller, Robert Nagler, Richard Olsen & Olivier Pictet (1993), “A Geographical Model for the Daily and Weekly Seasonal Volatility in the Foreign Exchange Market”, *Journal of International Money and Finance*, vol. 12, no. 4 (August), pp. 413-438

The daily and weekly seasonality of foreign exchange volatility is modeled by introducing an activity variable. This activity is explained by a simple model of the changing and sometimes overlapping market presence of geographical components (East Asia, Europe, and America).

Integrating this activity over time results in the new  $\vartheta$  time scale, characterized by non-seasonal volatility. This scale, applied to dense datastreams of absolute prices changes, succeeds in removing most of the seasonal heteroscedasticity in an autocorrelation study. Unexpectedly, the positive autocorrelation is found to decline hyperbolically rather than exponentially as a function of the lag.

Dacorogna, Michel, Ulrich Müller, Olivier Pictet & Casper de Vries (1995b), “The Distribution of Extremal Foreign Exchange Rate Returns in Extremely Large Data Sets”, Olsen & Associates, Zürich, working paper, 17 March

This study is based on an exceptionally large and automatically filtered data set containing most of the quoted prices on Reuters over 7 years. We employ semi-parametric extremal analysis. A bias reduction is attained by bootstrapping on resamples. The empirical results demonstrate the existence of the unconditional second moment of the distribution but the non-convergence of the fourth moment. Studies of cross-rates among European Monetary System currencies show a smaller tail index indicating a higher probability on extreme returns relative to the scale. The theory is subsequently applied to calculating the probabilities on as yet unseen extreme returns. This provides information to the treasurers of currency desks.

Dacorogna, Michel, Ulrich Müller, Paul Embrechts & Gennady Samorodnitsky (1998b), “How Heavy Are the Tails of a Stationary HAR(1) Process?”, in Ioannis Karatzas, Balram Rajput & Murad Taqqu, eds., *Stochastic Processes and Related Topics: In Memory of Stamatis Cambanis 1943-1995*, Trends in Mathematics, Birkhäuser/Springer, pp. 69-103; revised version of Embrechts, Dacorogna, Samorodnitsky & Müller, “How Heavy Are the Tails of a Stationary HAR(1) Process? A Study of the Moments”, Olsen & Associates, Zürich, working paper, 11 September 1996; revised version of “Moment Condition for HAR(1) Models”, 1995

Probabilistic properties of HAR(1) processes, as special stochastic volatility models, are investigated. We present necessary and sufficient conditions for existence of a stationary version of a HAR(1) process with finite  $(2m)$ th moments,  $m \geq 1$ . Our approach is based on the general Markov chain techniques of (Meyn and Tweedie, 1990). The conditions are explicit in the case of second moments, and also in the case of 4th moments of the HAR(1) process. We also deduce explicit necessary and explicit sufficient conditions for higher order moments of general HAR(1) models. We start by studying the HAR(1) process (in which case our results are the most explicit) and then generalize the results to a general HAR(1) process.

Dacorogna, Michel, Ulrich Müller, Richard Olsen & Olivier Pictet (1998a), “Modelling Short-Term Volatility With GARCH and HAR(1) Models”, in Christian Dunis & Bin Zhou, eds., *Nonlinear Modelling of High Frequency Financial Time Series*, John Wiley & Sons, Chichester, England

In this paper we present both a new formulation of the HAR(1) process and a study of the forecasting accuracy of ARCH-type models for predicting short-term volatility.

Using high frequency data, the market volatility is expressed in terms of partial volatilities which are formally exponential moving averages of squared returns measured at different frequencies. This new formulation is shown to produce more accurate fits to the data and, at the same time, to be easier to compute than the earlier version of the HAR(1) process. This is obtained without losing the nice property of the HAR(1) process to identify different market components.

In a second part, some performance measures of forecasting accuracy are discussed and the ARCH-type models are shown to be good predictors of the short-term hourly historical volatility with the new formulation of the HAR(1) process being the best predictor.

Daniel, Kent, David Hirshleifer & Avanidhar Subrahmanyam (1998a), “Investor Psychology and Security Market Under- and Overreactions”, *Journal of Finance*, vol. 53, no. 6 (December), pp. 1839-1885; revised version of “A Theory of Overconfidence, Self-Attribution, and Security Market Under- and Over-Reactions”, Northwestern University, Kellogg School of Management, working paper, 6 October 1997

We propose a theory based on investor overconfidence and biased self-attribution to explain several of the securities returns patterns that seem anomalous from the perspective of efficient markets with rational investors. The theory is based on two premises derived from evidence in psychological studies. The first is that individuals are overconfident about their ability to evaluate securities, in the sense that they overestimate the precision of their private information signals. The second is that investors' confidence changes in a biased fashion as a function of their decision outcomes. The first premise implies (1) negative long-lag autocorrelations (long-run “overreaction”), and (2) excess volatility, and, when managerial actions are correlated with stock mispricing, post-corporate event stock price “drift”. Adding the second premise leads to (3) positive short-lag autocorrelations (“momentum”), and (4) short-run post-earnings announcement “drift”, and negative correlation between future stock returns and long-term measures of past accounting performance. The model also offers several untested empirical implications and implications for corporate financial policy.

Danielsson, Jon & Casper de Vries (1997), "Tail Index and Quantile Estimation with Very High Frequency Data", *Journal of Empirical Finance*, vol. 4, no.s 2-3 (June), pp. 241-257; revised version of "Robust Tail Index and Quantile Estimation", *Proceedings of the First International Conference on High Frequency Data in Finance, 29-31 March 1995*, Olsen & Associates, Zürich, vol. 2

Precise estimation of the tail shape of forex returns is of critical importance for proper risk assessment. We improve upon the efficiency of conventional estimators that rely on first order expansions of the tail shape, by using a second order expansion. Here we advocate a moments estimator of this term. The paper uses both Monte Carlo simulations and the high frequency foreign exchange recordings collected by the Olsen corporation to illustrate the technique.

Darbellay, Georges (1995), "Testing for Deterministic Dynamics in the Financial Markets", *Proceedings of the First International Conference on High Frequency Data in Finance, Zürich, 29-31 March*, vol. 3

In order to investigate whether the evolution of the foreign exchange and the interest rate markets possesses a predictable deterministic component, we use a technique drawn from the field of nonlinear dynamics, namely the state-space reconstruction with time-delay embedding. We apply this approach to the intra-day data of several major foreign exchange rates and three month interest rate futures. Both univariate and multivariate studies are conducted. The results of our predictive model are compared to a null hypothesis, a random walk. We find that the forecasting error of our model is almost always inferior to that of a random walk. However, it appears impossible to generate trading profits, because the evidenced short-term predictability is overcome by the transaction costs. Moreover, if the variance of the return is used as a measure of risk, we see that the risk/return ratio is very unfavourable, even if the transaction costs are neglected.

Davé, Rakhal & Gerhard Stahl (1997), "On the Accuracy of VaR Estimates Based on the Variance-Covariance Approach", Olsen & Associates, Zürich, working paper, August

We present a thorough empirical study (based on over 8 years of daily data) of candidate models for forecasting losses in relation to positions held against individual risk factors as well as losses in relation to a portfolio of risk factors. As part of the study, we also define various measures and visualization techniques to evaluate the performance of the candidate models in the context of risk management and introduce two innovations: 1) tail emphasized model optimization and 2) implied covariance forecasting. Finally, we highlight the important issue of the estimation error of the co-variance matrix in relation to its dimension and the number of datum from which it is estimated and outline a framework for handling this problem.

Dechert, Dee & Ramazan Gencay (1992), "Lyapunov Exponents as a Nonparametric Diagnostic for Stability Analysis", *Journal of Applied Econometrics*, vol. 7, Supplement (*Nonlinear Dynamics and Econometrics*), also Paper 3 in Pesaran & Potter (1993), pp. 33-52

[Summary] The common observation made in the empirical nonlinear dynamics literature is the constraints imposed by the availability of a limited number of observations in the implementation of the existing algorithms of Lyapunov exponents. The algorithm discussed here can estimate all  $n$  Lyapunov exponents of an unknown  $n$ -dimensional dynamical system accurately with limited number of observations. This makes the algorithm attractive for applications to economic as well as financial time-series data. The implementation of the algorithm is carried out by multilayer feedforward networks which are capable of approximating any function and its derivatives to any degree of accuracy.

DeChow, Patricia & Richard Sloan (1997), “Returns to Contrarian Investment Strategies: Tests of Naive Expectations Hypotheses”, *Journal of Financial Economics*, vol. 43, no. 1, pp. 3-27

We test competing explanations for the higher stock returns generated by “contrarian” investment strategies. Potential explanations include naive expectations about future earnings growth and higher expected returns to compensate for risk. Inconsistent with Lakonishok, Shleifer and Vishny (1994) we find no systematic evidence that the returns stem from naive extrapolation of past growth. Consistent with La Porta (1995), we find prices do appear to naively impound analysts’ forecasts of future earnings growth. However, we find that this accounts for only one half of the returns to contrarian investment strategies. Finally, we show that the remaining returns can be explained by estimates of expected return generated using a simple valuation model.

DeGennaro, Ramon & Ronald Shrieves (1997), “Public Information Releases, Private Information Arrival and Volatility in the Foreign Exchange Market”, *Journal of Empirical Finance*, vol. 4, no. 4 (December), pp. 295-315; revised version of paper in *Proceedings of the First International Conference on High Frequency Data in Finance, 29-31 March 1995*, Olsen & Associates, Zürich, vol. 1

This paper uses a GARCH framework to estimate the impact of a class of information events on volatility of returns in the foreign exchange market. An information event is defined as news arrival that separates time intervals which differ in the degree and pattern of informational asymmetry, thus altering the potential for informed trading, hence volatility. Information events may also result in opportunistic trades by investors with superior access to the market. Results reflect a significant decrease in volatility during and after the hour of news arrival, even after controlling for the influence of quote activity levels. There is also some evidence of increases in volatility in the hour prior to news arrival. The findings thus corroborate the role of informed trading in the price formation process, as well as provide evidence of a volatility moderating impact of news arrival.

de Jong, Frank & Theo Nijman (1995), “Information Flows Between Financial Markets: An Analysis of Irregularly Spaced Data”, *Proceedings of the First International Conference on High Frequency Data in Finance, Zürich, 29-31 March*, vol. 4

High frequency data and transaction data are often observed at irregular intervals. This creates some problems in calculating auto-correlations and cross-correlations. In this paper we propose a covariance estimator that uses all available transactions to calculate information flows in clock time. The estimator is able to deal with any observed pattern of irregularly spaced observations. This allows us to choose an arbitrary small trading interval without causing additional non-trading bias. We apply the estimator to estimate the lead-lag relationship between the SP500 index and index futures.

De Jong, Frank, Ronald Mahieu & Peter Schotman (1998a), “Price Discovery in the Foreign Exchange Market: An Empirical Analysis of the Yen/DMark Rate”, *Journal of International Money and Finance*, vol. 17, no. 1 (February), pp. 5-27; revised version of “The Dynamics of the Actual and Dollar Implied Yen/DMark Cross Exchange Rate”, *Proceedings of the First International Conference on High Frequency Data in Finance, 29-31 March 1995*, Olsen & Associates, Zürich, vol. 3

This paper uses Reuters exchange rate data to investigate the dynamic relations between the direct quotes of the yen/dmark rate and the rate implied by yen/dollar and dmark/dollar rates. Since these high frequency data are observed at irregular intervals, some technical problems arise in calculating auto-correlations and cross-relations. In this paper we propose a covariance estimator that uses all available transactions to calculate information flows in clock time. The estimator is able to deal with any observed

pattern of irregular spaced observations. This allows us to choose an arbitrary small trading interval without causing additional non-trading bias.

Demos, Antonis & Christos Vassilicos (1994), “The Multifractal Structure of High Frequency Foreign Exchange Rate Fluctuations”, *LSE Financial Markets Group Discussion Paper Series*, no. 195 (September)

Exchange rates, like many other asset prices, exhibit some particular statistical properties. There tend to be periods when such markets are quiescent and prices move sluggishly, and other periods when the markets are extremely active with large price movements. Accordingly, the time series for such changes in exchange rates (and other asset prices) is not normal (non-Gaussian) and exhibits kurtosis, that is more very large *and* small price changes than would be expected in a normally distributed time series. Moreover, such measured kurtosis tends to increase as the frequency with which the raw data are sampled increases.

In previous studies we had examined continuous, tick-by-tick exchange rate data for the presence of chaos (FMG Discussion Papers 86, 120 and 143), and had failed to find any evidence of chaotic behaviour. This is a study of whether and to what extent multifractals can characterise the statistical properties described above.

Our main results indicate that the bivariate process for the timing and prices of spot exchange rate quotations over Reuters FAFX screens for the Dollar/Deutschmark has a well-defined multifractal scaling structure within time intervals of less than 10 minutes. The univariate process for the timing of quotations also has well-defined multifractal scaling properties within the same intervals. These properties explain why the kurtosis  $K$  of price changes  $\Delta p$  increases with sampling frequency over this range of very high frequencies, and can form the basis for improved predictive models of foreign exchange rate fluctuations.

den Hertog, René (1995), “Differences in Pricing Between Permanent and Transitory Volatility Components: A Latent Variable Approach”, *Journal of International Financial Markets, Institutions and Money*, vol. 5, no. 2/3

This study extends the analysis of the risk-return trade-off. Whereas previous studies regress asset returns on estimates of total volatility, this study distinguishes between permanent and transitory volatility components. To decompose I use a latent variable model for squared residuals. An empirical analysis is presented for holding returns on long-term government bonds from the U.S. and France. The results indicate that both permanent and transitory components are needed to account adequately for the heteroskedasticity of these returns, but only the permanent components are priced.

Dimson, Elroy & Paul Marsh (1998), “Murphy’s Law and Market Anomalies”, in Donald Keim & William Ziemba, eds., *Security Market Imperfections in World Wide Equity Markets*, Publications of the Newton Institute, no. 9, Cambridge University Press; similar version forthcoming in *Journal of Portfolio Management*, Winter 1999; revised version of *LBS Institute of Finance and Accounting Working Paper*, no. 275 (August)

Many researchers have uncovered empirical regularities in stock market returns. If these regularities persist, investors can expect to achieve superior performance. Unfortunately, nature can be perverse. Once an apparent anomaly is publicised, only too often it disappears or goes into reverse. The latter seems to have happened to the small firm premium. After the UK size premium was documented and disseminated, a historical small-cap premium of six percent was followed by a small-cap discount of around six percent. This study presents evidence of and some explanations for the disappearance of the small firm premium.

Dimson, Elroy & Massoud Mussavian (1998), “A Brief History of Market Efficiency”, *European Financial Management*, vol. 4, no. 1, pp. 91-103

Every finance professional employs the concept of market efficiency. The theory, evidence and counter-evidence focus on a couple of dozen highly influential articles published during the twentieth century. We summarise the origins of and inter-linkages between these contributions to the history of finance.

Dominguez, Kathryn (1997), “The Market Microstructure of Central Bank Intervention”, University of Michigan, School of Public Policy, *Research Seminar in International Economics Discussion Paper*, no. 412 (July)

One of the great unknowns in international finance is the process by which new information influences exchange rate behavior. Until recently, data constraints have limited our ability to examine this issue. The Olsen and Associates high-frequency spot market data greatly expand the range of testable hypotheses regarding the influence of information. This paper focuses on one important source of information to the foreign exchange markets, the intervention operations of the G-3 central banks. Previous studies using daily and weekly foreign exchange rate data suggest that central bank intervention operations can influence both the level and variance of exchange rates, but little is known about how exactly traders learn about these operations and whether intra-daily market conditions influence their effectiveness. Using high-frequency data, this paper will examine the relationship between the efficacy of intervention operations and the “state of the market” at the moment that the operation is made public to traders.

Dow, James & Gary Gorton (1995), “Stock Market Efficiency and Economic Efficiency: Is There a Connection?”, University of Pennsylvania, *Rodney L. White Center for Financial Research Working Paper*, no. 16-95 (29 July)

In a capitalist economy prices serve to equilibrate supply and demand for goods and services, continually changing to reallocate resources to their most efficient uses. However, secondary stock market prices, often viewed as the most “informationally efficient” prices in the economy, have no direct role in the allocation of equity capital since managers have discretion in determining the level of investment. What is the link between stock price informational efficiency and economic efficiency?

We present a model of the stock market in which: (i) managers have discretion in making investments and must be given the right incentives; and (ii) stock market traders may have important information that managers do not have about the value of prospective investment opportunities. In equilibrium, information in stock prices will guide investment decisions because managers will be compensated based on informative stock prices in the future.

The stock market indirectly guides investment by transferring two kinds of information: information about investment opportunities and information about managers’ past decisions. The fact that stock prices only have an indirect role suggests that the stock market may not be a necessary institution for the efficient allocation of equity. We emphasize this by providing an example of a banking system that performs as well.

Duan, Jun-Chuan & Jason Wei (1995), “Pricing Foreign Currency and Cross-Currency Options Under GARCH”, University of Saskatchewan, working paper, August

This paper generalizes the GARCH option pricing methodology in Duan (1995, *Mathematical Finance*) to a two-country setting. Specifically, we assume a bivariate nonlinear GARCH system for the exchange rate and the foreign asset price, and generalize the local risk-neutral valuation relationship in Duan (1995). We derive the equilibrium GARCH processes for the exchange rate and the foreign asset price in the two-country economy. Foreign currency options and cross-currency options can then be valued using the well-known risk-neutral valuation technique. Our setup allows rich empirical regularities such as stochastic volatility, “fat tails”, and the so-called “leverage effect”. We also run simulations to price quanto options and find that when the true environment is GARCH a constant variance model is not

reliable in most cases. The proposed equilibrium valuation framework to price foreign currency and cross-currency options is the first of its kind in the literature.

Easley, David, Nicholas Kiefer & Maureen O'Hara (1997a), "The Information Content of the Trading Process", *Journal of Empirical Finance*, vol. 4, no.s 2-3 (June), pp. 159-186; revised version of paper in *Proceedings of the First International Conference on High Frequency Data in Finance, 29-31 March 1995*, Olsen & Associates, Zürich, vol. 2

The trade process is a stochastic process of transactions interspersed with periods of inactivity. The realizations of this process are a source of information to market participants. They cause prices to move as they affect the market maker's beliefs about the value of the stock. We fit a model of the trade process that allows us to ask whether trade size is important, in that large and small trades may have different information content (they do, but this varies across stocks); whether uninformed trade is iid (it is not); and, whether large buys and large sells are equally informative (they differ only marginally). The model is fitted by maximum likelihood using transactions data on six stocks over 60 days.

Easley, David, Nicholas Kiefer & Maureen O'Hara (1997b), "One Day in the Life of a Very Common Stock", *Review of Financial Studies*, vol. 10, no. 3 (Fall), pp. 805-835

Using the model structure of Easley and O'Hara [1992], we demonstrate how the parameters of the market maker's beliefs can be estimated from trade data. We show how to extract information from both trades and no-trading intervals, and how intraday and interday data provide information. We derive and evaluate tests of model specification and estimate the information content of differential trade sizes. Our work provides a framework for testing extant microstructure models, shows how to extract the information contained in the trading process, and demonstrates the empirical importance of asymmetric information models for asset prices.

Ederington, Louis & Jae Ha Lee (1993), "How Markets Process Information: News Releases and Volatility", *Journal of Finance*, vol. 48, no. 4 (September), pp. 1161-1191

We examine the impact of scheduled macroeconomic news announcements on interest rate and foreign exchange futures markets. We find these announcements are responsible for most of the observed time-of-day and day-of-week volatility patterns in these markets. While the bulk of the price adjustment to a major announcement occurs within the first minute, volatility remains substantially higher than normal for roughly fifteen minutes and slightly elevated for several hours. Nonetheless, these subsequent price adjustments are basically independent of the first minute's return. We identify those announcements with the greatest impact on these markets.

Ederington, Louis & Jae Ha Lee (1995), "The Short-Run Dynamics of the Price Adjustment to New Information", *Journal of Financial and Quantitative Analysis*, vol. 30, no. 1 (March), pp. 117-134

We examine how prices in interest rate and foreign exchange futures markets adjust to the new information contained in scheduled macroeconomic news releases in the very short run. Using 10-second returns and tick-by-tick data, we find that prices adjust in a series of numerous small, but rapid, price changes that begin within 10 seconds of the news release and are basically completed within 40 seconds of the release. There is some evidence that prices overreact in the first 40 seconds but that this is corrected in the second or third minute after the release. While volatility tends to be higher than normal just before the news release, there is no evidence of information leakage. In our analysis, we correct for the biases created by bid-ask spreads and tick-by-tick data.

Edison, Hali (1996), “The Reaction of Exchange Rates and Interest Rates to News Releases”, *Board of Governors of the Federal Reserve System International Finance Discussion Papers*, no. 570 (October)

This paper examines the response of exchange rates and interest rates – U.S. and foreign – to economic news. The news is associated with the surprise component of the monthly release of six U.S. macroeconomic variables. The results suggest that dollar exchange rates systematically react to news about real economic activity – a surprise of 100,000 on nonfarm payroll employment leads to a 0.2 percent appreciation of the exchange rate. In general, exchange rates do not react systematically to news on inflation. By contrast, U.S. interest rates respond to both types of news, although the response continues to be extremely small, on the order of 1 to 2 basis points. Finally, Japanese interest rates systematically react, but to a very minor extent, to news about U.S. real economic activity, while German rates, in general, do not.

Elliott, Graham & Takatoshi Itō (1995), “Heterogeneous Expectations and Tests of Efficiency in the Yen/Dollar Forward Foreign Exchange Rate Market”, *NBER Working Paper*, no. 5376 (December)

This paper examines the efficiency of the forward yen/dollar market using micro survey data. We first argue that the conventional tests of efficiency (unbiasedness) of the forward rate or of the survey forecasts do not correspond directly to the zero-profit condition. Instead, we use the survey data to calculate directly potential profits of individual forecasters based on a natural trading rule. We find that although the survey data are not the best predictor of future spot rate in terms of typical mean square forecast error criteria, the survey data can be used to obtain on average positive profits. However, these profits are small and highly variable. We also examine profits generated by a trading rule using regression forecasts, where forward premium is an explanatory variable. These profits are also small and highly variable.

Elliott, Graham & Takatoshi Itō (1998), “Heterogeneous Expectations and Tests of Efficiency in the Yen/Dollar Forward Exchange Rate Market”, *University of California, San Diego, Department of Economics, Discussion Paper*, no. 98-06 (February); revised and shortened version of Elliot & Itō (1995)

This paper examines the efficiency of the forward yen/dollar market using micro survey data. Conventional tests of unbiasedness do not correspond directly to the zero-profit condition. Instead, we use the survey data to calculate potential profits of individual forecasters based on a natural trading rule. We find that although the survey data are not the best predictor of future spot rates in terms of typical mean square forecast error criteria, the survey data can be used to obtain on average positive profits. However, these profits are small and highly variable. Similar results are found when we examine profits generated by a trading rule using regression forecasts. The profits are found to be correlated with risk type variables but not other available information.

Elton, Edwin, Martin Gruber & Christopher Blake (1996), “The Persistence of Risk-Adjusted Mutual Fund Performance”, *Journal of Business*, vol. 69, no. 2 (April), pp. 133-158; revised version of *New York University Salomon Center Working Paper*, no. S-95-13 (May 1995)

This paper examines mutual fund predictability for common stock funds, using a sample free of survivorship bias, and measures performance using risk-adjusted returns. We reconfirm the hot hands result that high return can predict high return in the short run. Like Hendricks, Patel and Zeckhauser, we find that past performance is predictive of future risk-adjusted performance in both the short run and longer run. Furthermore, when we utilize modern portfolio theory (MPT) techniques to allocate capital among funds, we can construct a portfolio of funds based on prior data that significantly outperforms a rule based on past rank alone and that produces a positive risk-adjusted excess return. In addition, we



demonstrate the improvement in performance using MPT by selecting a combination of actively managed portfolios that has the same risk as a portfolio of index funds but has higher mean return. While consistent with past studies, our study finds that expenses account for only part of the differences in performance across funds. We find that there is still predictability even after the major impacts of expenses have been removed. Throughout our study we are able to construct portfolios of funds that have small but statistically significant positive risk-adjusted returns during a period where mutual funds in general had negative risk-adjusted returns.

Engel, Charles (1996), "The Forward Discount Anomaly and the Risk Premium: A Survey of Recent Evidence", *Journal of Empirical Finance*, vol. 3, no. 2 (June), pp. 123-192; revised version of "Why Is the Forward Exchange Rate Forecast Biased? A Survey of Recent Evidence", *Research Division, Federal Reserve Bank of Kansas City, Research Working Paper*, no. 95-06 (September 1995)

Forward exchange rate unbiasedness is rejected in tests from the current floating exchange rate era. This paper surveys advances in this area since the publication of Hodrick's (1987) survey. It documents that the change in the future exchange rate is generally negatively related to the forward premium. Properties of the expected forward forecast error are reviewed. Issues such as the relation of uncovered interest parity to real interest parity, and the implications of uncovered interest parity for cointegration of various quantities are discussed. The modeling and testing for risk premiums is surveyed. Included in this area are tests of the consumption CAPM, tests of the latent variable model, and portfolio-balance models of risk premiums. General equilibrium models of the risk premium are examined and their empirical implications explored. The survey does not cover the important areas of learning and peso problems, tests of rational expectations based on survey data, or the models of irrational expectations and speculative bubbles.

Engle, Robert (1996), "The Econometrics of Ultra-High Frequency Data", *NBER Working Paper*, no. 5816 (November); revised version of *University of California, San Diego, Department of Economics, Discussion Paper*, no. 96-15 (May)

Ultra-high frequency data are complete transactions data which inherently arrive at random times. Marked point processes provide a theoretical framework for analysis of such data sets. The ACD model developed by Engle and Russell (1995) is then applied to IBM transactions data to develop semi-parametric hazard estimates and measures of instantaneous conditional variances. The variances are negatively influenced by surprisingly long durations as suggested by some of the market micro-structure literature.

Engle, Robert & Jeffrey Russell (1997), "Forecasting the Frequency of Changes in Quoted Foreign Exchange Prices with the Autoregressive Conditional Duration Model", *Journal of Empirical Finance*, vol. 4, no.s 2-3 (June), pp. 187-212; revised version of supplementary typescript to *Proceedings of the First International Conference on High Frequency Data in Finance, 29-31 March 1995*, Olsen & Associates, Zürich, *NBER Working Paper*, no. 4966 (December 1994), and *University of California, San Diego, Department of Economics, Discussion Paper*, no. 94-27 (December 1994)

This paper will apply the ACD model to Foreign Exchange quotes arriving on Reuter's screens. The Autoregressive Conditional Duration model, developed in Engle and Russell (1994), is a new statistical model for the analysis of data that does not arrive in equal time intervals. In contrast to fixed interval analysis, the model treats the time between observation arrivals as a stochastic time varying process. The paper seeks to measure and forecast the time intervals between price changes in the Dollar/Deutschmark. A new stylized fact of duration clustering is discovered for these data. The model focuses on the intertemporal correlations of duration events and models this stochastic component. The

model allows tests that other variables might be useful in forecasting these price based durations. Generally, little support is found for price leadership but other variables influence the arrival rates.

Estrada, Javier (1997), “*Random Walks and the Temporal Dimension of Risk*”, Universidad Carlos III, Madrid, Departamento de Empresa, April

The assumption that stock prices follow a random walk has critical implications for investors and firms. Among those implications is the fact that data frequencies and investment horizons are irrelevant (as defined below) when evaluating the risk of a security. However, if stock prices do not follow a random walk, ignoring either issue may lead investors to make misleading decisions. Using data from the first half of the decade for thirteen European securities markets, I first argue that stock prices in these markets (not surprisingly) do not follow a random walk. Then, I show that investors that assume otherwise are bound to underestimate the total and systematic risk (and overestimate the compound and risk-adjusted returns) of European stocks. The underestimation of risk ranges between .53% and 2.94% a month, and averages 1.25% a month.

Evans, Martin (1998), “The Microstructure of Foreign Exchange Dynamics”, *Proceedings of the Second International Conference on High Frequency Data in Finance, 1-3 April*, Olsen & Associates, Zürich, vol. 1

This paper studies the high frequency behavior of the interbank foreign exchange market with a newly created data set that provides the most comprehensive picture of activity across the market in existence. My analysis indicates that trade activity within the interbank market is distinct from the posting of indicative quotes. Trading and quote-making decisions are linked, but the links are complicated and poorly understood. I also document the existence of strong relationship between exchange rate movements and a measure of excess Dollar demand. A trading model is analyzed to show how the structure of the market could give rise to such a microstructure effect. Empirically, this effect appears important in the determination of exchange rates at high frequencies and over longer time spans relevant in international macroeconomics.

Evertsz, Carl (1995), “Self-Similarity of High-Frequency USD-DEM Exchange Rates”, *Proceedings of the First International Conference on High Frequency Data in Finance, Zürich, 29-31 March*, vol. 3

High frequency DEM-USD exchange rate data (resolution  $> 2$  seconds) are analyzed for their scaling behaviour as a function of the time lag. Motivated by the finding that the distribution of 1-quote returns is rather insensitive to the physical time duration between successive quotes, lags are measured in units of quotes. The mean absolute returns over lags of different sizes, shows three different regimes. The smallest time scales show no scaling, followed by two scaling regimes characterized by Hurst exponents  $H = 0.45$  and  $H = 0.56$ , with a crossover occurring at lags of  $\approx 500$  quotes. The up-down correlation coefficient, defined here, shows strong anti-correlations on scales smaller than 500. The lack of convergence to a large deviation rate function, convex tails in the logarithm of the probability distributions, strong up-down correlations and  $H < 0.5$ , show that the dynamics on small scales is more complicated than random walk models with i.i.d. increments. Nevertheless, for both scaling regimes there is a very high degree of distributional self-similarity. For the  $H = 0.56$  this self-similarity satisfies the same scaling rules at those for stable distributions with characteristic exponent  $\alpha = 1/H$ . The large deviation analysis shows that the probabilities for large returns (negative or positive) decays less fast than exponentially as a function of the lag. This sets the DEM-USD rates in a higher risk-class than suggested by the Gaussian.

Fama, Eugene (1998), “Market Efficiency, Long-Term Returns, and Behavioral Finance”, *Journal of Financial Economics*, vol. 49, no. 3 (1 September), pp. 283-306; reprinted as University of Chicago, *Center for Research in Security Prices Reprint*, no. 340; revised version of University of Chicago, Graduate School of Business, *Center for Research in Security Prices Working Paper*, no. 448 (February 1997)

Market efficiency survives the challenge from the literature on long-term return anomalies. Consistent with the market efficiency hypothesis that the anomalies are chance results, apparent over-reaction to information is about as common as under-reaction. And post-event continuation of pre-event abnormal returns is about as frequent as post-event reversal. Consistent with the market efficiency prediction that apparent anomalies can also be due to methodology, the anomalies are sensitive to the techniques used to measure them, and many disappear with reasonable changes in technique.

Ferson, Wayne & Robert Korajczyk (1995), “Do Arbitrage Pricing Models Explain the Predictability of Stock Returns?”, *Journal of Business*, vol. 68, no. 3 (July), pp. 309-349; revised version of *Kellogg Graduate School of Management Working Paper*, no. 115 (May 1991)

This article studies predictability in U.S. stock returns for multiple investment horizons. We measure to what extent predictability is driven by premiums for economy-wide risk factors, comparing two standard methods for factor selection. We study single-beta models and multiple-beta models. We show how to estimate the fraction of the predictability in returns captured by the model, simultaneously with the other parameters. Our analysis indicates that the models capture a large fraction of the predictability for all of the investment horizons. The performances of the principal components and the prespecified-factor approaches are broadly similar.

Fisher, Adlai, Laurent Calvet & Benoît Mandelbrot (1997), “Multifractality of DeutscheMark/US Dollar Exchange Rates”, Yale University, *Cowles Foundation Discussion Paper*, no. 1166 (17 September)

This paper presents the first empirical investigation of the Multifractal Model of Asset Returns (“MMAR”). The MMAR, developed in Mandelbrot, Fisher, and Calvet (1997), is an alternative to ARCH-type representations for modelling temporal heterogeneity in financial returns. Typically, researchers introduce temporal heterogeneity through time-varying conditional second moments in a discrete time framework, or time-varying volatility in a continuous time framework. Multifractality introduces a new source of heterogeneity through time-varying local regularity in the price path. The concept of local Holder exponent describes local regularity. Multifractal processes bridge the gap between locally Gaussian (Itô) diffusions and jump-diffusions by allowing a multiplicity of Holder exponents. This paper investigates multifractality in DeutscheMark/US Dollar currency exchange rates. After finding evidence of multifractal scaling, we show how to estimate the multifractal spectrum via the Legendre transform. The scaling laws found in the data are replicated in simulations. Further simulation experiments test whether alternative representations, such as FIGARCH, are likely to replicate the multifractal signature of the DeutscheMark/US Dollar data. On the basis of this evidence, the MMAR hypothesis appears more likely. Overall, the MMAR is quite successful in uncovering a previously unseen empirical regularity. Additionally, the model generates realistic sample paths, and opens the door to new theoretical and applied approaches to asset pricing and risk valuation. We conclude by advocating further empirical study of multifractality in financial data, along with more intensive study of estimation techniques and inference procedures.

Fishman, Michael & Kathleen Hagerty (1995), “The Mandatory Disclosure of Trades and Market Liquidity”, *Review of Financial Studies*, vol. 8, no. 3; revised version of *Kellogg Graduate School of Management Working Paper*, no. 107 (July 1994)

Financial market regulations require various “insiders” to disclose their trades after the trades are made. We show that such mandatory disclosure rules can increase insiders’ expected trading profits. This is because disclosure leads to profitable trading opportunities for insiders even if they possess no private information on the asset’s value. We also show that insiders will generally not voluntarily disclose their trades, so for disclosure to be forthcoming, it must be mandatory. Key to the analysis is that the market cannot observe whether an insider is trading on private information regarding asset value or is trading for personal portfolio reasons.

Flood, Mark (1994), “Market Structure and Inefficiency in the Foreign Exchange Market”, *Journal of International Money and Finance*, vol. 13, no. 2 (April), pp. 131-158

This paper investigates the intradaily operational efficiency of the US foreign exchange market by conducting computer simulation experiments with market structure (the number of market-makers, brokers and customers). The results indicate significant operational inefficiencies which can be explained by temporary inventory imbalances inherent in a decentralized market. The results also suggest that much of this inefficiency could be alleviated through a centralization of price information.

Flood, Mark, Ronald Huisman, Kees Koedijk & Richard Lyons (1998), “Search Costs: The Neglected Spread Component”, *Proceedings of the Second International Conference on High Frequency Data in Finance, Zürich, 1-3 April*, Olsen & Associates, Zürich, vol. 1

This paper examines trading costs in markets where dealers search for price quotes (such as multiple-dealer equity markets and foreign exchange). Using an experimental market, we compare four popular models for estimating effective spreads. The theoretical implications of “bid-ask bounce” are borne out with remarkable accuracy in the time series of transaction prices. More important, the cost of bilateral price search is a significant component of the effective spread (roughly 40 percent using the Roll (1984) measure). These search costs are a distinct component of the spread that has not been considered in the literature.

Fluck, Zsuzsanna, Burton Malkiel & Richard Quandt (1997), “The Predictability of Stock Returns: A Cross-Sectional Simulation”, *Review of Economics and Statistics*, vol. 79, no. 2 (May), pp. 176-183; revised version of *New York University Salomon Center Working Paper*, no. S-95-9

This paper investigates whether predictable patterns that previous empirical work in finance have isolated appear to be persistent and exploitable by portfolio managers. On a sample that is free from survivorship bias we construct a test wherein we simulate the purchases and sales an investor would undertake to exploit the predictable patterns, charging the appropriate transaction costs for buying and selling and using only publicly available information at the time of decisionmaking. We restrict investment to large companies only to assure that the full cost of transactions is properly accounted for. We confirmed on our sample that contrarian strategies yield sizable excess returns after adjusting for risk, as measured by beta. Using analysts’ estimates of long term growth we construct a test of the Lakonishok, Shleifer and Vishny (1994) hypothesis. We reach the conclusion that, contrary to Lakonishok et al. (1994), the superior performance of contrarian strategies can not be explained by the superior performance of stocks with low estimated growth rates.

Fong, Wai Mun & Sam Ouliaris (1995), “Spectral Tests of the Martingale Hypothesis for Exchange Rates”, *Journal of Applied Econometrics*, vol. 10, pp. 255-271

A new family of spectral shape tests was proposed recently by Durlauf (1991) for testing the martingale hypothesis. Unlike the widely used variance ratio test, spectral tests are consistent against *all* stationary non-white-noise alternatives from the martingale null. In this paper we examine the finite sample properties of the spectral shape tests and find that the tests have good size and power properties even from small samples. We apply the tests to examine the martingale hypothesis for five major currencies *vis-à-vis* the US dollar for the period 1974-89. The results indicate that most currencies violate the martingale hypothesis. It appears that some rejections are due to long-memory influences.

Foster, Douglas & S. Viswanathan (1996), “Strategic Trading when Agents Forecast the Forecasts of Others”, *Journal of Finance*, vol. 51, no. 4 (September), pp. 1437-1478

We analyze a multi-period model of trading with differentially informed traders, liquidity traders and a market maker. Each informed traders’ initial information is a noisy estimate of the long-term value of the asset, and the different signals received by informed traders can have a variety of correlation structures. With this setup informed traders not only compete with each other for trading profits, they also learn about other traders’ signals from the observed order flow. Our work suggests that the initial correlation among the informed traders’ signals has a significant effect on the informed traders’ profits and the informativeness of prices.

Frenkel, Michael (1997), “Exchange Rate Dynamics with Chartists, Fundamentalists and Rational Speculators in the Foreign Exchange Market”, *International Journal of Business*, vol. 2, no. 1, pp. 1-24

This paper extends previous work on speculative dynamics in the foreign exchange market. The analysis shows how the behavior of chartists, fundamentalists and rational speculators, together with uncertainty about the long-run equilibrium exchange rate level, can result in fluctuations of the spot rate triggered by a random shock to the market. Although the exact exchange rate path depends on the extent of the shock and on specific values of model parameters, the heterogeneity of expectations can explain several characteristics of short-term exchange rate developments, which have often been emphasized in empirical studies on exchange rate dynamics.

Gallant, Ronald & George Tauchen (1996), “EMM: A Program for Efficient Method of Moments Estimation – Version 1.2 – User’s Guide”, *Duke Economics Working Paper*, no. 95-27 (July)

This Guide shows how to use the computer package EMM, which implements the estimator described in “Which Moments to Match” (Gallant and Tauchen, 1994). The term EMM refers to Efficient Method of Moments. The Guide provides an overview of the estimator, instructions on how to acquire the software, and a description of the package. It also walks the reader through a worked example.

Gallant, Ronald & George Tauchen (1996), “SNP: A Program for Nonparametric Time Series Analysis – Version 8.5 User’s Guide”, University of North Carolina & Duke University, Departments of Economics, technical report (October)

SNP is a method of nonparametric time series analysis. The method employs a Hermite polynomial series expansion to approximate the conditional density of a multivariate process. An appealing feature of this expansion is that it is a nonlinear nonparametric model that directly nests the Gaussian VAR model, the semiparametric VAR model, the Gaussian ARCH model, and the semiparametric ARCH model. The SNP model is fitted using conventional maximum likelihood together with a model selection strategy that determines the appropriate degree of the polynomial.

A Fortran program implementing the SNP method is available via anonymous ftp at ftp.econ.duke.edu in directory pub/arg/snp or from the Carnegie-Mellon University e-mail server by sending the e-mail message “send snp from general” to statlib@lib.stat.cmu.edu. The code is provided at no charge for research purposes without warranty.

The program has switches that allow direct computation of functionals of the fitted density such as conditional means, conditional variances, and points for plotting the density. Other switches generate simulated sample paths which can be used to compute nonlinear functionals of the density by Monte Carlo integration, notably the nonlinear analogs of the impulse-response mean and volatility profiles used in traditional VAR and ARCH analysis. Simulated sample paths can also be used to set bootstrapped sup-norm confidence bands on these and other functionals.

The purpose of this Guide is to provide an expositional review of the underlying methodology and to walk the user through an application. Our intent is that the Guide be self contained and that little reference to the cited literature will be required to use the program and the SNP method.

Ghose, Devajyoti & Kenneth Kroner (1995), “Temporal Aggregation of High Frequency Financial Data”, *Proceedings of the First International Conference on High Frequency Data in Finance, Zürich, 29-31 March*, vol. 2

[Conclusion] In this paper we examined the temporal aggregation properties of the second moments of high frequency financial data. We first demonstrated several empirical anomalies that exist at high frequencies, using high-frequency currency data. For example, we demonstrated the failure of Drost and Nijman’s (1993) aggregation results at high frequencies. We also demonstrate the failure of Nelson’s (1990) theorem that GARCH converges to IGARCH as the frequency increases. We then propose an explanation for these anomalies, which is that high-frequency returns data consists of both the true return and noise. Finally, we demonstrate that once noise is purged from the data, these anomalies disappear.

Ghysels, Eric & Joanna Jasiak (1995), “Stochastic Volatility and Time Deformation: An Application to Trading Volume and Leverage Effects”, Université de Montréal, Centre Interuniversitaire de Recherche en Analyse des Organisations (CIRANO), *Scientific Series*, no. 95s-31 (June)

In this paper, we study stochastic volatility models with time deformation. Such processes relate to the early work by Mandelbrot and Taylor (1967), Clark (1973), Tauchen and Pitts (1983), among others. In our setup, the latent process of stochastic volatility evolves in an operational time which differs from calendar time. The time deformation can be determined by past volume of trade, past returns, possibly with an asymmetric leverage effect, and other variables setting the pace of information arrival.

The econometric specification exploits the state-space approach for stochastic volatility models proposed by Harvey, Ruiz and Shephard (1994) as well as the matching moment estimation procedure using SNP densities of stock returns and trading volume estimated by Gallant, Rossi and Tauchen (1992). Daily data on returns and trading volume of the NYSE are used in the empirical application. Supporting evidence for a time deformation representation is found and its impact on the behavior of returns and volume is analyzed. We find that increases in volume accelerate operational time, resulting in volatility being less persistent and subject to shocks with a higher innovation variance. Downward price movements have similar effects while upward price movements increase the persistence in volatility and decrease the dispersion of shocks by slowing down market time. We present the basic model as well as several extensions; in particular, we formulate and estimate a bivariate return-volume stochastic volatility model with time deformation. The latter is examined through bivariate impulse response profiles following the example of Gallant, Rossi and Tauchen (1993).

Ghysels, Eric, Christian Gouriéroux & Joanna Jasiak (1998a), “Market Time and Asset Price Movements: Theory and Estimation”, in D. Hand & S. Jacka, eds., *Statistics in Finance*, Edward Arnold, London; revised version of Université de Montréal, Centre Interuniversitaire de Recherche en Analyse des Organisations (CIRANO), *Scientific Series*, no. 95s-32 (June 1995)

Subordinated stochastic processes, also called time deformed stochastic processes, have been proposed in a variety of contexts to describe asset price behavior. They are used when the movement of prices is tied to the number of market transactions, trading volume or the more elusive concept of information arrival. The aim of the paper is to present a comprehensive treatment of the stochastic process theory as well as the statistical inference of subordinated processes. Numerous applications in finance are provided to illustrate the use of the processes to model market behavior and asset returns.

Ghysels, Eric, Christian Gouriéroux & Joanna Jasiak (1998b), “High Frequency Financial Time Series Data: Some Stylized Facts and Models of Stochastic Volatility”, in Dunis & Zhou (1998); apparently revised version of “Trading Patterns, Time Deformation and Stochastic Volatility in Foreign Exchange Markets”, Université de Montréal, Centre Interuniversitaire de Recherche en Analyse des Organisations (CIRANO), *Scientific Series*, no. 95s-42 (October 1995); revised version of paper without Gouriéroux in *Proceedings of the First International Conference on High Frequency Data in Finance, Zürich, 29-31 March*, Olsen & Associates, Zürich, vol. 1

Globalization of trading in foreign exchange markets is a principle source of the daily and weekly seasonality in market volatility. One way to model such phenomena is to adopt a framework where market volatility is tied to the intensity of (world) trading through a subordinated stochastic process representation. In this paper we combine elements from Clark (1973), Dacorogna et al. (1993) and Ghysels and Jasiak (1994), and present a stochastic volatility model for foreign exchange markets with time deformation. The time deformation is based on daily patterns of arrival quotes and bid-ask spreads as well as returns. For empirical estimation we use the QMLE algorithm of Harvey et al. (1994), adopted by Ghysels and Jasiak for time deformed processes, and applied to the Olsen and Associates high frequency data set.

Glodjo, Arman & Campbell Harvey (1995), “Forecasting Foreign Exchange Market Movements Via Entropy Coding”, *Proceedings of the First International Conference on High Frequency Data in Finance, Zürich, 29-31 March*, vol. 1

This paper bridges the important recent work in computer science on information theory and data quantization to the forecasting of high frequency financial data. The technique of vector quantization has found its primary application in data compression algorithms. We argue that this technique is ideally suited for forecasting. Indeed, our paper shows that popular forecasting techniques such as, neural nets, are sub-classes of the more general vector quantization. Importantly, the neural nets are not just subclasses but are surely suboptimal. The vector quantization provides much more flexibility and a framework for efficient algorithmic approximation. In addition, vector quantization provides a way to incorporate conditioning information into the forecasting exercises. While much of our proposal details the theoretical motivation for entropy (amount of information) based coding, our empirical work is designed to implement forecasting models on intraday exchange rate data.

Goodhart, Charles & Maureen O'Hara (1997), "High Frequency Data in Financial Markets: Issues and Applications", *Journal of Empirical Finance*, vol. 4, no.s 2-3 (June), pp. 73-114; based on "Introductory Lecture: A Survey of High Frequency Micro-Market Structure Studies" given at the *First International Conference on High Frequency Data in Finance*, Olsen & Associates, Zürich, 29-31 March 1995

The development of high frequency data bases allows for empirical investigations of a wide range of issues in the financial markets. In this paper, we set out some of the many important issues connected with the use, analysis, and application of high-frequency data sets. These include the effects of market structure on the availability and interpretation of the data, methodological issues such as the treatment of time, the effects of intra-day seasonals, and the effects of time-varying volatility, and the information content of various market data. We also address using high frequency data to determine the linkages between markets and to determine the applicability of temporal trading rules. The paper concludes with a discussion of the issues for future research.

Goodhart, Charles & Richard Payne (1996), "Microstructural Dynamics in a Foreign Exchange Electronic Broking System", *Journal of International Money and Finance*, vol. 15, no. 6 (December), pp. 829-852

This paper explores the relationships between quotations, spreads and transactions in the Foreign Exchange market. Such interactions have been the subject of much work in markets such as the NYSE, but until now have gone unexamined in the FX market owing to lack of data. Using a 7 hour, transactions-based data set we examine the determinants of both quote revisions and spreads. The results indicate that trades are a major factor in spread determination and quote revision. Furthermore, there is evidence that the widely documented negative auto-correlation in quote returns is at least partially caused by the "thinness" of this particular segment of the FX market.

Goodhart, Charles, Steven Hall, Brian Henry & Bahram Pesaran (1993), "News Effects in a High-Frequency Model of the Sterling-Dollar Exchange Rate", *Journal of Applied Econometrics*, vol. 8, no.s 1-2 (January-March), pp. 1-13; reprinted as Paper 12 in Hashem Pesaran & Simon Potter, eds., *Nonlinear Dynamics, Chaos and Econometrics*, John Wiley & Sons, Chichester, England, pp. 199-211; revised version of *LSE Financial Markets Group Discussion Paper*, no. 119 (May 1991)

[Summary] This paper uses an extremely high frequency data set on the dollar-sterling exchange rate to investigate the impact of news events on the very short-term movements in exchange rates. The data set is a continuous record of the quoted price for the exchange rate on the Reuters screen. As such it records some 130,000 observations over an 8-week period. The paper investigates the time-series properties of the data using orthodox regression models, and then by making allowance for a time-varying conditional variance. The conclusions vary significantly in moving to this more sophisticated model. The exercises are repeated now incorporating news announcement effects, letting these affect the level of the exchange rate and then the conditional variance process. Again it is found that the conclusions are radically altered in moving to the increasingly sophisticated model.

Guillaume, Dominique, Michel Dacorogna & Olivier Pictet (1995a), "On the Intra-Day Performance of GARCH Processes", *Proceedings of the First International Conference on High Frequency Data in Finance, Zürich, 29-31 March*, vol. 3

In this paper, we show that the use of an alternative time scale can eliminate the inefficiencies in the estimation of a GARCH model caused by intra-daily seasonal patterns. Even so, however, the temporal aggregation properties of the GARCH model do not hold at the intra-daily frequencies, revealing the presence of several time-horizons components. Besides, distinct characteristics were identified in the very short (less than 2 hours) and the very long (several months) run. Finally, the out-of-sample



predictive power of GARCH for the volatility was found to be lower than the historical volatility itself implying the presence of other sources of heterogeneity.

Guillaume, Dominique, Olivier Pictet, Ulrich Müller & Michel Dacorogna (1995b), “Unveiling Non Linearities Through Time Scale Transformations”, Olsen & Associates, Zürich, working paper, 20 September

In this paper, we show that intra-daily foreign exchange rate returns exhibit even stronger non-linearities than daily or weekly returns. These nonlinearities result from the intra-daily seasonality and the presence of market participants with different time-horizons. Moreover, we present some evidence that both these nonlinearities and the autocorrelation patterns of the volatility can successfully be accounted for by successive time scale transformations.

Guillaume, Dominique, Michel Dacorogna, Rakhal Davé, Ulrich Müller, Richard Olsen & Olivier Pictet (1997), “From the Bird’s Eye to the Microscope: A Survey of New Stylized Facts of the Intra-Daily Foreign Exchange Markets”, *Finance and Stochastics*, vol. 1, no. 2, pp. 95-129

This paper presents stylized facts concerning the spot intra-daily foreign exchange markets. It first describes intra-daily data and proposes a set of definitions for the variables of interest. Empirical regularities of the foreign exchange intra-daily data are then grouped under three major topics: the distribution of price changes, the process of price formation and the heterogeneous structure of the market. The stylized facts surveyed in this paper shed new lights on the market structure that appears composed of heterogeneous agents. It also poses several challenges such as the definition of price and of the time-scale, the concepts of risk and efficiency, the modeling of the markets and the learning process.

Harrison, Paul (1998), “Similarities in the Distribution of Stock Market Price Changes between the Eighteenth and Twentieth Centuries”, *Journal of Business*, vol. 71, no. 1 (January), pp. 55-79; revised version of “Are All Financial Time-Series Alike? Evidence from 18th Century Stock Markets”, Brandeis University, Graduate School of International Economics and Finance, working paper, November 1996

Are all financial time-series alike? This work raises that question by establishing that 18th and 20th century equity market time series behave similarly. The distribution of price changes now and then both exhibit the same patterns or regularities. In particular, the distribution of price changes is leptokurtic and fluctuations in variance are persistent. Also, no strong evidence is found supporting the hypothesis that price changes have an asymmetric effect on volatility. This paper provides further evidence that financial market regularities are stable, and not contingent on certain time varying influences. This suggests the importance of the institutional structure of the exchange and the behavior of actual investors, both of which are relatively unchanged across the centuries, in determining market regularities.

Hart, Sergiu & Yair Tauman (1996), “Market Crashes Without External Shocks”, Hebrew University of Jerusalem, *Center for Rationality Discussion Paper*, no. 124 (December)

It is shown here that market crashes and bubbles can arise without external shocks. Sudden changes in behavior may be the result of endogenous information processing. Except for the daily observation of the market, there is no new information, no communication and no coordination between the participants.

Hasbrouck, Joel (1996), “*The Dynamics of Discrete Bid and Ask Quotes*”, New York University, Stern School of Business, working paper, 2 December draft

This paper describes a general approach to the estimation of security price dynamics when the phenomena of interest are of the same scale or smaller than the tick size. The model views discrete bid and ask quotes as arising from three continuous random variables: the efficient price of the security, a cost of quote exposure (information and processing costs) on the bid side and a similar cost of quote exposure on the ask side. The bid quote is the efficient price less the bid cost rounded down to the next tick; the ask quote is the efficient price plus the ask cost rounded up to the next tick. To deal with situations in which the cost of quote exposure possesses both stochastic and deterministic components and the increments of the efficient price are nonstationary, the paper employs a nonlinear state-space estimation method. The method is applied to intraday quotes at fifteen-minute intervals for Alcoa (a randomly chosen Dow stock). The results confirm the existence of persistent intraday volatility. More importantly they establish the existence of a persistent stochastic component of quote exposure costs that is large relative to the deterministic intraday “U” component.

Hasbrouck, Joel (1997), “*Security Bid/Ask Dynamics with Discreteness and Clustering: Simple Strategies for Modeling and Estimation*”, New York University, Stern School of Business, working paper, 3 October draft

The short-term movements of a security price reflect the latent efficient price (conditional expectation of terminal value) and also components arising from the trading mechanism itself. Observed bid and ask quotes are but rough signals of these unobserved quantities. The bid and ask quotes in the \$/DM market considered here, for example, are discrete, with a tick size that is not trivial relative to the spread. Furthermore, the distribution of these quotes is clustered, with a greater-than-expected incidence of five-tick multiples. This paper suggests a simple framework for handling discrete, clustered quotes. Despite the simplicity of the model, estimation by traditional (likelihood or moment) methods is difficult. As an alternative, the paper implements a Gibbs sampler approach that proves to be quick and effective. This strategy opens the door for the investigation of a broad class of structural microstructure models.

Hasbrouck, Joel (1996), “Modeling Market Microstructure Time Series”, in G.S. Maddala & Radhakrishna Rao, eds., *Handbook of Statistics*, vol. 14 (Statistical Methods in Finance), North-Holland, Amsterdam; revised version of New York University, Leonard N. Stern School of Business, working paper, 12 December

Microstructure data typically consist of trades and bid and offer quotes for financial securities that are collected at fine sampling intervals (often within the day). This paper reviews approaches taken to modeling these data. The emphasis is on techniques of stationary multivariate time series analysis: autoregressive and moving average representations of standard microstructure models, vector autoregressive estimation, random-walk decompositions and cointegration. The paper also discusses the challenges posed by irregular observation frequencies, discreteness and nonlinearity.

Hasbrouck, Joel, George Sofianos & Deborah Sosebee (1993), “New York Stock Exchange Systems and Trading Procedures”, *NYSE Working Paper*, no. 93-01 (“Draft 1.2”, 27 April), expanded and updated version of *NYSE Working Paper “Orders, Trades, Reports and Quotes at the New York Stock Exchange”*

This paper provides a selective description of New York Stock Exchange systems, trading rules and procedures. The paper’s primary objective is to provide researchers with a detailed institutional framework for studying quote and transaction data generated by U.S. securities trading. It is also meant to serve as a guide to the New York Stock Exchange system, for economics, business and legal scholars needing a reference aid for their research. Among the topics examined are: order entry and execution, trade and quote reporting, the audit trail, SuperDot, the Intermarket Trading System, crossing orders and the

upstairs positioning of large block trades. The paper provides descriptions of New York Stock Exchange systems, rules and procedures that are constantly changing, as they were at the beginning of 1993.

Hedvall, Kaj & Jonas Niemyer (1994), "Order Flow Dynamics: Evidence from the Helsinki Stock Exchange", Swedish School of Economics and Business Administration, Helsinki, *Meddelanden Working Papers*, no. 290 (December), also in *Proceedings of the First International Conference on High Frequency Data in Finance, Zürich, 29-31 March 1995*, vol. 3

We investigate the dynamic order flow in a limit order book (LOB). In contrast to previous studies, our data set from the Helsinki Stock Exchange encompasses the entire LOB structure, including the dealer identities. This enables us to focus on the order behavior of individual dealers. We first classify the different types of events. Secondly, using contingency tables, the structure of subsequent events initiated by the same dealer is compared to the overall event structure. We find that order splitting is more frequent than order imitation. Furthermore, trade induced spread increases are quickly restored by new limit orders. We conclude that there exists a body of potential limit orders outside the formal LOB (i.e. there is a high degree of resiliency in our LOB market). As a logical consequence, a large dealer strategically splits his order, in order for the market to supply additional liquidity. One interpretation of our results is that a LOB structure gives room for informed traders to successively trade on their information. Another interpretation is that prices only slowly incorporate new information.

Holden, Craig & Avanidhar Subrahmanyam (1991), "Risk Aversion, Liquidity, and Endogenous Short Horizons", *Review of Financial Studies*, vol. 9, no. 2, pp. 691-722

We analyze a competitive model in which different information signals get reflected in value at different points in time. If investors are sufficiently risk averse, we obtain an equilibrium in which all investors focus exclusively on the short-term. In addition, we show that increasing the variance of informationless trading increases market depth but causes a greater proportion of investors to focus on the short-term signal, which decreases the informativeness of prices about the long-run. Finally, we also explore parameter spaces under which long-term informed agents wish to voluntarily disclose their information.

Hsieh, David (1989), "Testing for Nonlinear Dependence in Daily Foreign Exchange Rate Changes", *Journal of Business*, vol. 62, no. 3 (July), pp. 339-368

The purpose of this article is to investigate whether daily changes in five major foreign exchange rates contain any nonlinearities. Although the data contain no linear correlation, evidence indicates the presence of substantial nonlinearity in a multiplicative rather than additive form. Further examination reveals that a generalized autoregressive conditional heteroskedasticity (GARCH) model can explain a large part of the nonlinearities for all five exchange rates.

Huang, Roger & Ronald Masulis (1999), "FX Spreads and Dealer Competition Across the 24 Hour Trading Day", *Review of Financial Studies*, vol. 12, no. 1 (Spring), forthcoming; revised version of "Spreads, Dealer Competition, and Market Regimes: A Market Microstructure Analysis of FX Trading", *Proceedings of the First International Conference on High Frequency Data in Finance, 29-31 March 1995*, Olsen & Associates, Zürich, vol. 4

This study examines the impact of competition on bid-ask spreads in the spot foreign exchange market. We measure competition primarily by the number of dealers active in the market and find that bid-ask spreads decrease with an increase in competition, even after controlling for the effects of volatility. The expected level of competition is time-varying, is highly predictable, and displays a strong seasonal component that in part is induced by geographic concentration of business activity over the 24-hour trading day. Our estimates show that the expected addition of one more competing dealer lowers the average quoted spread by 1.7%.

Huisman, Ronald, Kees Koedijk, Clemens Kool & Franz Palm (1997), “Fat Tails in Small Samples”, Maastricht University, Limburg Institute of Financial Economics, working paper, September

It is a well-known stylized fact that financial returns are non-normal and tend to have fat-tailed distributions. This paper presents a methodology that accurately estimates the degree of fat-tailedness, characterized by the tail-index, in small samples. We present a simple approach based on the Hill estimator. Our estimator is a weighted average of a set of Hill estimators, with weights obtained by using simple least squares techniques. The estimator produces unbiased estimates for the tail-index in small samples and we also provide appropriate standard errors. Using this estimator we produce tail-index estimates for returns on stocks and exchange rates that are close to estimates obtained from extremely large datasets. The results indicate that many documented conclusions about the tail behavior of financial series have over-estimated their fat-tailedness in small samples.

Huisman, Ronald, Kees Koedijk, Clemens Kool & François Nissen (1998a), “Extreme Support of Uncovered Interest Parity”, *Journal of International Money and Finance*, vol. 17, no. 1 (February), pp. 211-228; apparently revised version of “The Unbiasedness Hypothesis from a Panel Perspective”, Maastricht University, Limburg Institute of Financial Economics, working paper, November 1996

Risk premia, peso-problems and market-inefficiencies have been suggested as candidate explanations for the apparent rejection of the unbiased hypothesis. If various explanations interact, a panel approach is called for. In this paper we estimate different panel models, that allow for cross-sectional dependence of exchange rates, for fifteen currencies between 1979 and 1996. We show that the deviation from uncovered interest parity is smaller than commonly presumed. Estimates of the slope coefficients of the forward premium appear to be positive but still significantly different from unity. In addition it is shown that this coefficient is close to unity if only five to ten percent of the largest changes in the forward premium are taken into account. These findings point to the importance of peso-problems and inactivity bands as explanations for the apparent rejection of the uncovered interest parity relationship.

Huisman, Ronald, Kees Koedijk, Clemens Kool & Franz Palm (1998b), “The Fat-Tailedness of FX Returns”, Maastricht University, Limburg Institute of Financial Economics, working paper, 25 February

It is well known that returns on foreign exchange rates are not normal and tend to have fat-tailed distributions. Although the precise magnitude of the tail-fatness is crucial for applications such as risk analysis, little consensus exists in this respect due to estimation problems. In this paper, we apply a recent method to obtain unbiased inferences from the tails to re-examine the fat-tailedness of FX returns and show that the amount of fat-tailedness has been overestimated considerably. Additionally, goodness-of-fit statistics provide evidence of the appropriateness of assuming that a Student-t distribution underlies the data-generating process of FX returns. Both conclusions appear to hold more for floating than for fixed exchange rates.

Itō, Takatoshi, Richard Lyons & Tim Melvin (1998), “Is There Private Information in the FX Market? The Tokyo Experiment”, *Journal of Finance*, vol. 53, no. 3 (June), pp. 1111-1130; revised version of Federal Reserve Bank of San Francisco, *Pacific Basin Working Paper*, no. PB97-04 (May 1997); also *NBER Working Paper*, no. 5986 (February 1997); also Columbia University, *Center on Japanese Economy and Business Working Paper*, no. 128 (January 1997)

It is a common view that private information in the foreign exchange market does not exist. We provide evidence against this view. The evidence comes from the introduction of trading in Tokyo over the lunch hour. Lunch return variance doubles with the introduction of trading, which cannot be due to public information since the flow of public information did not change with the trading rules. We then

exploit recent results in microstructure to discriminate between the two alternatives: private information and pricing errors. Three key results support the predictions of private-information models. First, the volatility U-shape flattens: greater revelation over lunch leaves a smaller share for the morning and afternoon. Second, the U-shape tilts upward, an implication of information whose private value is transitory. Finally, the morning exhibits a clear U-shape when Tokyo closes over lunch, and it disappears when trading is introduced.

Jones, Charles & Gautam Kaul (1995), “On the Use of Variance Ratios”, *Proceedings of the First International Conference on High Frequency Data in Finance, Zürich, 29-31 March*, vol. 1

We show that the variance-ratio methodology, when used to study the behavior of the volatility of *individual* securities, suffers from several statistical biases. Specifically, the use of finite samples, the non-normality of returns, measurement errors in transaction prices, and the prevalent practice of reporting the cross-sectional means of the variance ratios of individual securities leads to severe biases. These different effects operate in complex ways which makes it difficult to *ex ante* identify either the direction or the magnitude of the bias in the cross-sectional mean of any particular variance ratio reported in the literature. Using intraday (ISSM) data for a large sample of NYSE/AMEX firms, we demonstrate how the biases in commonly reported variance ratios could lead to erroneous and misleading inferences. We also suggest specific procedures to correct for each of the biases and display the effectiveness of these procedures using actual data. These procedures, though computationally intensive, can easily be tailored to any specific variance ratio under consideration.

Jorion, Philippe (1995), “Predicting Volatility in the Foreign Exchange Market”, *Journal of Finance*, vol. 50, no. 2 (June)

Measures of volatility implied in option prices are widely believed to be the best available volatility forecasts. In this paper, we examine the information content and predictive power of Implied Standard Deviations (ISD's) derived from CME options on foreign currency futures. The paper finds that statistical time-series models, even when given the advantage of “ex post” parameter estimates, are outperformed by ISD's. ISD's, however, also appear to be biased volatility forecasts. Using simulations to investigate the robustness of these results, the paper finds that measurement errors and statistical problems can substantially distort inferences. Even accounting for these, however, ISD's appear to be too variable relative to future volatility.

Kandel, Eugene & Neil Pearson (1995), “Differential Interpretation of Information and Trade in Speculative Markets”, *Journal of Political Economy*

Most models of trade in speculative markets make the assumption that agents interpret public information identically. We provide empirical evidence that this assumption is overly restrictive. We begin by investigating the relation between the volume of trade and stock returns (NYSE, AMEX and NASDAQ-listed stocks) around anticipated public announcements, and find that there is a significant abnormal volume even when prices do not change in response to the announcement. We argue that this is likely due to the differences in interpretation of public information by investors. We then develop a model of trade which incorporates differential interpretations and show that its predictions are consistent with the observed volume-return relation. We go on to present a simple model of beliefs revision, which underlies our and many other models of trade and test it on the stock brokerage research analyst's earning forecasts taken from the I/B/E/S Detail Tape. The hypothesis that agents use the same model to interpret public announcements is inconsistent with the forecast revisions in this data.

Kandel, Shmuel & Robert Stambaugh (1996), “On the Predictability of Stock Returns: An Asset-Allocation Perspective”, *Journal of Finance*, vol. 51, no. 2 (June); revised version of *Rodney L. White Center for Financial Research Working Paper*, no. 27-94 (October 1995)

Sample evidence about the predictability of monthly stock returns is considered from the perspective of an investor allocating funds between stocks and cash. A regression of stock returns on a set of predictive variables might seem weak when described by usual statistical measures, but such measures can fail to convey the economic significance of the sample evidence when it is used by a risk-averse Bayesian investor to update prior beliefs about the regression relation and to compute an optimal asset allocation. Even when those prior beliefs are weighted substantially against predictability, the current values of the predictive variables can exert a strong influence on the portfolio decision.

Kanzler, Ludwig (1995), *A Study of the Microeconomic Working of the Foreign Exchange Market*, University of Oxford, Bodleian Library, M.Phil. Thesis in Economics

The aim of this thesis is to shed some light on the microeconomic behaviour of exchange rates. Tick-by-tick indicative quotes from the spot market are used to test the proposition that exchange rates follow a random walk. The tests differentiate between periods in which important news arrives and periods in which no relevant information is announced. The random-walk hypothesis is typically accepted for periods with important news, but it is generally rejected for no-news periods as well as the complete sample. The first part of the thesis concludes that the efficient-markets hypothesis is violated. A method is proposed to test for the existence of fractal patterns in exchange rates. The second part examines why and how well heterogeneity in information and behaviour, bounded rationality and irrationality can explain the perceived inefficiency of the foreign exchange market. Particular emphasis is placed on the fact that market participants differ profoundly in their optimisation objectives and constraints. Moreover, the ability to evaluate complex information rationally varies from trader to trader. There is consequently no reason to suppose that investors attach similar private values to foreign exchange and that price necessarily equals fundamental value, as the efficient-markets hypothesis asserts.

Kirby, Chris (1997), “Measuring the Predictable Variation in Stock and Bond Returns”, *Review of Financial Studies*, vol. 10, no. 3 (Fall), pp. 579-630

Recent studies show that when a regression model is used to forecast stock and bond returns, the sample  $R^2$  increases dramatically with the length of the return horizon. These studies argue, therefore, that long-horizon returns are highly predictable. This paper presents evidence that suggests otherwise. Long-horizon regressions can easily yield large values of the sample  $R^2$ , even if the population  $R^2$  is small or zero. Moreover, long-horizon regressions with a small or zero population  $R^2$  can produce t-ratios that might be interpreted as evidence of strong predictability. In general, the analysis provides little support for the view that long-horizon returns are highly predictable.

Kohers, Theodor, Vivek Pandey & Gerald Kohers (1997), “Using Nonlinear Dynamics to Test for Market Efficiency Among the Major U.S. Stock Exchanges”, *Quarterly Review of Economics and Finance*, vol. 37, no. 2 (Summer), pp. 523-545

The existing evidence on the influence of low dimensional chaotic dynamics in U.S. stock market returns is spotty and inconclusive. This study contributes to the existing evidence by examining the returns in the New York Stock Exchange, the American Stock Exchange, and the Over-the-Counter Market. Moreover, in light of the significance of the “size effect” which recently has received renewed attention in the literature, this study examines portfolios categorized by firm size. The results suggest that the NYSE large firm-portfolio is driven by a low-dimensional deterministic influence, making it potentially predictable.

Koppl, Roger & Carlo Nardone (1997), “The Angular Distribution of Asset Returns in Delay Space”, Fairleigh Dickinson University, Madison, Department of Economics and Finance, working paper, February

We develop and apply a set of hypothesis tests with which to study changes in the angular distribution of points in delay space. Crack and Ledoit (J. Finance, 1996) plotted daily stock returns against themselves with one day’s lag. (This might be described as a plot in “delay space”.) The graph shows these points collected along several rays from the origin. They correctly attribute this “compass rose” pattern to discreteness in the data. Our testing procedures allow one to test for changes in Crack and Ledoit’s compass rose pattern. Our case study gives an example of such a change in distribution being caused by a change in regime. We plot the number of points along a given ray of the compass rose against the angle of that ray. This creates a “theta histogram” which describes the angular distribution of the points in delay space. We compare this distribution to a standard theta histogram created by a simple bootstrap procedure. The  $X^2$  test is then performed in order to estimate quantitatively the consistency of the actual data with the standard theta histogram. Extensions of this technique are discussed.

We apply our technique to an important episode of Russian monetary history. Generally, the finance ministry actively intervened to influence the ruble exchange rate. The one exception was during Nicolai Bunge’s tenure as finance minister. Bunge’s successor, Ivan Vyshnegradsky, was an unusually vigorous interventionist. Hypothesis tests support the view that Vyshnegradsky’s activism caused a disproportionate number of points of the compass rose to accumulate on the main diagonals in delay space. The theory of “Big Players” (Koppl and Yeager 1996) helps to explain why. Our results are consistent with those of Broussard and Koppl (1996) who use a GARCH(1,1) model.

Kuan, Chung-Ming & Tung Liu (1995), “Forecasting Exchange Rates Using Feedforward and Recurrent Neural Networks”, *Journal of Applied Econometrics*, vol. 10, pp. 347-364

In this paper we investigate the out-of-sample forecasting ability of feedforward and recurrent neural networks based on empirical foreign exchange rate data. A two-step procedure is proposed to construct suitable networks, in which networks are selected based on the predictive stochastic complexity (PSC) criterion, and the selected networks are estimated using both recursive Newton algorithms and the method of nonlinear least squares. Our results show that PSC is a sensible criterion for selecting networks and for certain exchange rate series, some selected network models have significant market timing ability and/or significantly lower out-of-sample mean squared prediction error relative to the random walk model.

Kurz, Mordecai (1994b), “On the Structure and Diversity of Rational Beliefs”, *Economic Theory*, vol. 4, pp. 877-900; reprinted as Chapter 2 in Mordecai Kurz, ed. (1997a), *Endogenous Economic Fluctuations: Studies in the Theory of Rational Belief*, Studies in Economic Theory Series, no. 6, Springer, Berlin

The paper proposes that the theory of expectations be reformulated under the assumption that agents do not know the structural relations (such as equilibrium prices) of the economy. Instead, we postulate that they can observe past data of the economy and form probability beliefs based on the data generated by the economy. Using past data agents can compute relative frequencies and the basic assumption of the theory is that the system which generates the data is stable in the sense that the empirically computed relative frequencies converge. It is then shown that the limit of these relative frequencies induce a probability on the space of indefinite sequences of the observables in the economy. This probability is stationary. A *belief* of an agent is a probability on the space of infinite sequences of the observable variables in the economy. Such a probability represents the “theory” or “hypothesis” of the agent about the mechanism which generates the data. A belief is said to be *compatible with the data* if under the proposed probability belief the economy would generate the same limit of the relative frequencies as computed from the real data. A theory which is “compatible with the data” is a theory which cannot be rejected by the data. A belief is said to be a *Rational Belief* if it is (i) compatible with the data and

(ii) satisfies a certain technical condition. The Main Theorem provides a characterization of all Rational Beliefs.

Kurz, Mordecai (1997b), “Asset Prices with Rational Beliefs”, in Mordecai Kurz, ed. (1997a), *Endogenous Economic Fluctuations: Studies in the Theory of Rational Belief*, Studies in Economic Theory Series, no. 6, Springer, Berlin; revised version of *CEPR Publication*, no. 375 (1994)

This paper introduces the concept of Rational Belief Equilibrium (RBE) as a basis for a new theory of asset pricing. Rational Beliefs are probability beliefs about future economic variables which cannot be contradicted by the data generated by the economy. RBE is an equilibrium in which the diverse beliefs of all the agents induce an equilibrium stochastic process of prices and quantities and these beliefs are, in general, wrong in the sense that they are different from the true probability of the equilibrium process. These beliefs are, however, rational. Consequently, in an RBE agents use the wrong forecasting functions and their forecasting mistakes play a crucial role in the analysis. First, we show that these mistakes are the reason why stock returns are explainable in retrospect and forecastable whenever the environment remains unchanged over a long enough time interval for agents to learn the forecasting function. Second, the aggregation of these mistakes generates Endogenous Uncertainty: it is that component of the variability of stock prices and returns which is endogenously induced by the beliefs and actions of the agents rather than by the standard exogenous state variables. The paper develops some basic propositions and empirical implications of the theory of RBE. Based on the historical background of the post world war II era, we formulate an econometric model of stock returns which allows non-stationarity in the form of changing environments (“regimes”). A sequence of econometric hypotheses are then formulated as implications of the theory of RBE and tested utilizing data on common stock returns in the post war period. Apart from confirming the validity of our theory, the empirical analysis shows that

- (i) common stock returns are forecastable within each environment but it takes time for agents to learn and approximate the forecasting functions. For some agents the time is too short so that it is too late to profit from such learning;
- (ii) the equilibrium forecasting functions change from one environment to the other in an unforecastable manner so that learning the parameters of one environment does not improve the ability to forecast in the subsequent environments.
- (iii) more than 2/3 of the variability of stock returns is due to endogenous uncertainty rather than exogenous causes.

The paper analyzes one example of a gross market overvaluation which was induced in the 1960’s by an aggregation of agent’s Mistakes.

Kurz, Mordecai (1997b), “Endogenous Uncertainty: A Unified View of Market Volatility”, *Stanford Economics Working Paper*, no. 97-027 (9 September)

It is argued that the theory of Rational Belief Equilibria (RBE) provides a unified paradigm for explaining market volatility by the effect of “Endogenous Uncertainty” on financial markets. This uncertainty is propagated within the economy (hence “endogenous”) by the beliefs of the agents who trade assets. The theory of RBE was developed in a sequence of papers assembled in a recently published book entitled *Endogenous Economic Fluctuations: Studies in the Theory of Rational Beliefs*, M. Kurz (Ed.), Springer Verlag, 1997. The present paper provides a non-mathematical exposition of both the main ideas of the theory of RBE as well as a summary of the main results of the book regarding market volatility.

The structure of the paper is as follows. Section I starts by reviewing the standard assumptions underlying models of rational expectations equilibria (REE) and their implications to the study of market volatility. The paper then reviews four basic problems which have constituted puzzles or anomalies in relation to the assumptions of REE: (i) Why are asset prices much more volatile than their underlying fundamentals? (ii) The equity premium puzzle: why under REE the predicted riskless rate is so high and the equity risk premium so low? (iii) Why do asset prices exhibit the “GARCH” behavior without exogenous fundamental variables to explain it? (iv) the “Forward Discount Bias” in foreign exchange



markets: why are interest rate differentials such poor predictors of future changes in the exchange rates? Section II outlines the basic ideas and assumptions of the theory of RBE and the main propositions which it implies in relation to the problems of market volatility. Section III first develops the simulation models of RBE which are used in the analysis of the four problems above and explains that the domestic economy is calibrated, as in Mehra and Prescott [1985], to the U.S. economy. Then for each of the four problems the relevant simulation results of the RBE are presented and compared both to the results predicted by a corresponding RBE as well as to the actual empirical observations in the U.S.

The conclusion of the paper is that the main cause of market volatility is the distribution of beliefs and expectations of agents. The theory of RBE shows that if agents disagree then the state of belief of each agent, represented by his conditional probability, must fluctuate over time. Hence the nature of the distribution of the individual states of belief in the market is the root cause of all phenomena of market volatility. The paper shows that the GARCH phenomenon of time varying variance of asset prices is explained in the simulation model by the presence of both persistence in the states of beliefs of agents as well as correlation among the states of beliefs of the agents. Correlation makes beliefs either narrowly distributed (i.e. "consensus") or widely distributed (i.e. "non-consensus"). When a belief regime of consensus is established (and due to persistence it remains in place for a while) then agents seek to buy or sell the same portfolio leading to high volatility. On the other hand, the widespread disagreement in a belief regime of non-consensus entails a balance between sellers and buyers leading to low market volatility. In short, the theory proposes that the GARCH phenomenon is the result of shifts in the distribution of beliefs in the market and these shifts are caused by the dynamics of the states of beliefs of the agents.

Turning to the equity risk premium, it is clear that the key question is what are the conditions on the distribution of beliefs which will ensure that the average riskless rate is low and hence the average equity risk premium is high. It turns out that the key condition requires that on average the majority of agents are relatively optimistic about the prospects of capital gains in the subsequent period. Consequently, the rationality of belief conditions require the pessimists (who are in the minority) to be on the average more intensely pessimistic. In this narrow sense of having higher intensity of beliefs, the pessimists tend to have a stronger impact on the market a significant fraction of time. When this occurs they protect their endowment by shorting the stock and increasing their purchases of the safe riskless bill. This tends to bid up the price of the bill and lowers the price of the stock resulting in a lower riskless rate and a higher equity risk premium.

The "Forward Discount Bias" in foreign exchange markets is explained by the same model used to explain the other three phenomena. It is the result of the fact that in an RBE agents often make the wrong forecasts although they are right on the average. Hence, in an RBE the exchange rate fluctuates excessively due to the errors of the agents and hence at almost no date is the interest differential between two countries an unbiased estimate of the rate of depreciation of the exchange rate one period later. The bias is positive since agents who invest in foreign currency demand a risk premium on endogenous uncertainty which is above and beyond the risk which exists in an REE. Hence the size of the bias is equal to the added risk premium due to endogenous uncertainty.

Kurz, Mordecai & Andrea Beltratti (1997), "The Equity Premium is No Puzzle", Chapter 11 in Mordecai Kurz, ed. (1997a), *Endogenous Economic Fluctuations: Studies in the Theory of Rational Belief*, Studies in Economic Theory Series, no. 6, Springer, Berlin

We examine the equity premium puzzle with the perspective of the theory of Rational Beliefs Equilibrium (RBE) and show that from the perspective of this theory there is no puzzle. In an RBE agents need to be compensated for the endogenously propagated price uncertainty which is not permitted under rational expectations. It is then argued that endogenous uncertainty is the predominant uncertainty of asset returns and its presence provides a natural explanation of the observed premium. Utilizing data on the asset allocation of 63 U.S. mutual funds, we test some empirical implications of the theory of rational beliefs as well as estimate the parameters of risk aversion of mutual fund managers. Our tests show that the predictions of the theory are consistent with the empirical evidence. We then construct a simple two agent model of the U.S. economy in which the agents hold rational beliefs and calibrate it to the empirical experience in accord with the parameters of the Mehra and Prescott (1985) paper.

The result of our calculations show that for a large set of parameter values the model predictions fit closely the historical record.

Kurz, Mordecai & Martin Schneider (1996), “Coordination and Correlation in Markov Rational Belief Equilibria”, *Economic Theory*, vol. 8, pp. 489-520

This paper studies the effect of correlation in the rational beliefs of agents on the volatility of asset prices. We use the technique of generating variables to study stable and non-stationary processes needed to characterize rational beliefs. We then examine how the stochastic interaction among such variables affects the behavior of a wide class of Rational Belief Equilibria (RBE). The paper demonstrates how to construct a consistent price state space and then shows the existence of RBE for any economy for which such price state space is constructed. Next, the results are used to study the volatility of asset prices via numerical simulations of a two agents model. If beliefs of agents are uniformly dispersed and independent, we would expect heterogeneity of beliefs to have a limited impact on the fluctuations of asset prices. On the other hand, our results show that correlation across agents can have a complex and dramatic effect on the volatility of prices and thus can be the dominant factor in the fluctuation of asset prices. The mechanism generating this effect works through the clustering of beliefs in states of different levels of agreement. In states of agreement the conditional forecasts of the agents tend to fluctuate *together* inducing more volatile prices. In states of disagreement the conditional forecasts fluctuate *in diverse directions* tending to cancel each other's effect on market demand and resulting in reduced price volatility.

Küsters, Ulrich & Jens Peter Steffen (1996), “Matrix Programming Languages for Statistical Computing: A Detailed Comparison of GAUSS, MATLAB, and Ox”, *Diskussionsbeiträge der Katholischen Universität Eichstätt, Wirtschaftswissenschaftliche Fakultät Ingolstadt, Germany*, no. 75 (25 October)

This paper describes and compares the matrix programming languages GAUSS, MATLAB, and Ox. Emphasis is laid on issues which are especially important for statisticians, econometricians, biometricians, and analysts of sociological data. These issues include hardware and operating system platforms, programming environments, language structures, matrix operations, numerical and statistical libraries as well as speed. Furthermore we describe the documentations, online-help facilities, and the available technical support. GAUSS, MATLAB, and Ox implementations of a maximum likelihood factor analysis are provided as detailed examples.

LeBaron, Blake (1992a), “Do Moving Average Trading Rule Results Imply Non-linearities in Foreign Exchange Markets?”, University of Wisconsin-Madison, *Social Systems Research Institute Working Paper*, no. 9222 (March)

This paper tests whether fitted linear models can replicate results from moment tests inspired by moving average technical trading rules for weekly foreign exchange series. Estimation is performed using standard OLS and maximum likelihood methods, along with a simulated method of moments technique which incorporates the trading rule moments into the estimation procedure. Results show that linear models are capable of replicating the trading rule moments along with the small autocorrelations observed in these series. This result holds for parameter values estimated using SMM and GARCH disturbances, but not for parameters estimated using maximum likelihood. The estimated models are simulated to examine the amount of predictability over long horizons.

LeBaron, Blake (1992b), “Forecast Improvements Using a Volatility Index”, *Journal of Applied Econometrics*, vol. 7, Supplement (Nonlinear Dynamics and Econometrics), pp. 137-150; reprinted as Paper 8 in Hashem Pesaran & Simon Potter, eds., *Nonlinear Dynamics, Chaos and Econometrics*, John Wiley & Sons, Chichester, England, pp. 129-141; revised version of University of Wisconsin-Madison, *Social Systems Research Institute Working Paper*, no. 9105 (May 1991)

[Summary] This paper explores the possibility of improved out of sample forecasting for stock returns and foreign exchange rates using observed nonlinearities in the two series. Forecasting is done using nonparametric techniques where important information is obtained from the current level of volatility in the series. For both series forecast improvements are observed, but for stock returns the improvements are only marginal. These results indicate the usefulness and stability of some types of nonlinear modelling for financial markets.

LeBaron, Blake (1994), “Chaos and Nonlinear Forecastability in Economics and Finance”, *Philosophical Transactions of the Royal Society of London, Series A*, no. 348, pp. 397-404; reprinted as Chapter 6 in Howell Tong, ed. (1995), *Chaos and Forecasting: Proceedings of the Royal Society Discussion Meeting*, World Scientific, Singapore, pp. 129-143; reprinted also as University of Wisconsin-Madison, *Social Systems Research Institute Reprint*, no. 448; revised version of University of Wisconsin-Madison, *Social Systems Research Institute Working Paper*, no. 9446 (October 1994)

Both academic and applied researchers studying financial markets and other economic series have become interested in the topic of chaotic dynamics. The possibility of chaos in financial markets opens important questions for both economic theorists as well as financial market participants. This paper will clarify the empirical evidence for chaos in financial markets and macroeconomic series. It will also compare these two concepts from a financial market perspective contrasting the objectives of the practitioner with those of economic researchers. Finally, the paper will speculate on the impact of chaos and nonlinear modeling on future economic research.

LeBaron, Blake (1995), “*Experiments in Evolutionary Finance*”, University of Wisconsin-Madison, Department of Economics, working paper, November

Combining ideas from evolution and learning to understand empirical puzzles in financial markets is a growing area of interest in economic research. This paper provides a short survey of some of the ongoing work in this area with special attention paid to computational models relying on artificial intelligence methods. Also, specific experiments will be analyzed using the Santa Fe Artificial Stock Market. The conclusions tie some of the results from these very different modeling approaches together, and suggest paths for future research.

LeBaron, Blake (1997b), “A Fast Algorithm for the BDS Statistic”, *Studies in Nonlinear Dynamics and Econometrics*, vol. 2, no. 2 (July), pp. 53-59; reprinted as University of Wisconsin-Madison, *Social Systems Research Institute Reprint*, no. 458

The BDS statistic has proved to be one of several useful nonlinear diagnostics. It has been shown to have good power against many nonlinear alternatives, and its asymptotic properties as a residual diagnostic are well understood. Furthermore, extensive monte-carlo results have proved it useful in relatively small samples. However, the BDS test is not trivial to calculate, and is even more difficult to deal with if one wants the speed necessary to make bootstrap resampling feasible. This short paper presents a fast algorithm for the BDS statistic, and outlines how these speed improvements are achieved. Source code in the c programming language is included.

LeBaron, Blake (1997c), “An Evolutionary Bootstrap Approach to Neural Network Pruning and Generalization”, University of Wisconsin-Madison, *Social Systems Research Institute Working Paper*, no. 9718 (August)

This paper combines techniques drawn from the literature on evolutionary optimization algorithms along with bootstrap based statistical tests. Bootstrapping is used as a general framework for estimating objectives out of sample by redrawing subsets from a training sample. Evolution is used to search the large number of potential network architectures. The combination of these two methods creates a network estimation and selection procedure which finds parsimonious network structures which generalize well. The bootstrap methodology also allows for objective functions other than usual least squares, since it can estimate the in sample bias for any function. Examples are given for forecasting chaotic time series contaminated with noise.

LeBaron, Blake (1997e), “Technical Trading Rules and Regime Shifts in Foreign Exchange”, in Emmanuel Acar & Stephen Satchell, eds., *Advanced Trading Rules*, Butterworth-Heinemann, pp. 5-40; reprinted as University of Wisconsin-Madison, *Social Systems Research Institute Reprint*, no. 464; revised version of University of Wisconsin-Madison, *Social Systems Research Institute Working Paper*, no. 9118 (May 1991)

This paper performs tests on several different foreign exchange series using a methodology inspired by technical trading rules. Moving average based rules are used as specification tests on the process for foreign exchange rates. Several models for regime shifts and persistent trends are simulated and compared with results from the actual series. The results show that these simple models can not capture some aspects of the series studied. Finally, the economic significance of the trading rule results are tested. Returns distributions from the trading rules are compared with returns on risk free assets and returns from the U.S. stock market.

LeBaron, Blake (1998), “Technical Trading Rule Profitability and Foreign Exchange Intervention”, *Journal of International Economics*, forthcoming; revised version of *NBER Working Paper*, no. 5505 (March 1996); also University of Wisconsin-Madison, *Social Systems Research Institute Working Paper*, no. 9445R (March 1996); revised version of University of Wisconsin-Madison, *Social Systems Research Institute Working Paper*, no. 9445 (July 1994)

There is reliable evidence that simple rules used by traders have some predictive value over the future movement of foreign exchange prices. This paper will review some of this evidence and discuss the economic magnitude of this predictability. The profitability of these trading rules will then be analyzed in connection with central bank activity using intervention data from the Federal Reserve. The objective is to find out to what extent foreign exchange predictability can be confined to periods of central bank activity in the foreign exchange market. The results indicate that after removing periods in which the Federal Reserve is active, exchange rate predictability is dramatically reduced.

LeBaron, Blake & Andreas Weigend (1998), “A Bootstrap Evaluation of the Effect of Data Splitting on Financial Time Series”, *IEEE Transactions on Neural Networks*, vol. 9, no. 1 (January), pp. 213-220; revised version of New York University, *Leonard N. Stern School of Business Working Paper*, no. IS-97-013 (1997); in turn revised version of “Evaluating Neural Network Predictors by Bootstrapping”, University of Wisconsin-Madison, *Social Systems Research Institute Working Paper*, no. 9447 (1994)

This article exposes problems of the commonly used technique of splitting the available data into training, validation, and test sets that are held fixed, warns about drawing too strong conclusions from such static splits, and shows potential pitfalls of ignoring variability across splits. Using a bootstrap or resampling method, we compare the uncertainty in the solution stemming from the data splitting with neural network specific uncertainties (parameter initialization, choice of number of hidden units, etc.). We present two results on data from the New York Stock Exchange. First, the variation due to different resamplings is significantly larger than the variation due to different network conditions. This result implies that it is important to not over-interpret a model, or an ensemble of models, estimated on one specific split of the data. Second, on each split, the neural network solution with early stopping is very close to a linear model; no significant nonlinearities are extracted. The data set used in this article is available from the web sites of the authors.

Levich, Richard & Lee Thomas, III (1993), “The Significance of Technical Trading-Rule Profits in the Foreign Exchange Market: A Bootstrap Approach”, *Journal of International Money and Finance*, vol. 12, no. 5 (October), pp. 451-474

In this paper, we present new evidence on the profitability and statistical significance of technical trading rules in the foreign exchange market. We utilize a new data base, currency futures contracts for the period 1976-1990, and we implement a new testing procedure based on bootstrap methodology. Our results suggest that simple technical trading rules have very often led to profits that are highly unusual. Splitting the entire sample period into three 5-year periods reveals that on average the profitability of some trading rules declined in the latest period although profits remained positive (on average) and significant in many cases.

Lewellen, Jonathan & Jay Shanken (1998), “Market Efficiency, Rational Expectations, and Estimation Risk”, University of Rochester, William E. Simon Graduate School of Business Administration, working paper, June

In asset pricing, estimation risk refers to investor uncertainty about the parameters of the return or cash-flow process. We show that estimation risk can significantly affect the time-series and cross-sectional behavior of asset prices. In particular, parameter uncertainty will tend to induce price reversals and negative serial correlation in returns. Prices can violate familiar “volatility bounds” when investors are rational. Cross-sectionally, expected returns deviate from the CAPM even if investors attempt to hold mean-variance efficient portfolios, and these deviations will be predictable based on past dividends, prices, and returns. In short, we argue that estimation risk is likely to be important for characterizing an efficient market.

Loretan, Mico & Peter Phillips (1994), “Testing the Covariance Stationarity of Heavy-Tailed Time Series: An Overview of the Theory with Applications to Several Financial Datasets”, *Journal of Empirical Finance*, vol. 1, pp. 211-248, reprinted as Yale University, *Cowles Foundation Paper*, no. 866

We investigate methods of testing the proposition that the unconditional variance of a time series is constant over time. Motivated by the observation that many financial datasets are “heavy-tailed”, we focus on the properties of statistical tests of covariance stationarity when unconditional fourth and second moments of the data are not finite. We find that sample split prediction tests and cusum of

squares tests have nonstandard limiting distributions when fourth unconditional moments are infinite. These tests are consistent provided that variances are finite. However, the rate of divergence under the alternative hypothesis and hence the power of these tests is sensitive to the index of tail thickness in the data. We estimate the maximal moment exponent (which measures tail thickness) for a number of stock market return and exchange rate return series, and conclude that fourth unconditional moments of these series do not appear to be finite. In our formal tests of covariance stationarity, we reject the null hypothesis of constancy of the unconditional variance of these series. This raises questions about the nature of the observed volatility in economic time series, and about appropriate methods of statistically modeling this volatility.

Los, Cornelis (1998), “Nonparametric Testing of the High-Frequency Efficiency of the 1997 Asian Foreign Exchange Markets”, Nanyang Technological University, Singapore, *Centre for Research in Financial Services Working Paper*, no. 98-03 (1 August)

For the first time, non-parametric statistical tests, originally developed by Sherry (1992) to test the efficiency of information processing in nervous systems, are used to ascertain if the Asian FX rates followed random walks. The stationarity and serial independence of the price changes are tested on minute-by-minute data for nine currencies for the period from January 1, 1997 to December 30, 1997. Tested were the Thai baht, Indonesian rupiah, Malaysian ringgit, Philippines’ peso, Singapore dollar, Taiwan dollar and the Hong Kong dollar, with the Japanese Yen and German Deutschmark as benchmarks (The U.S. Dollar is the base currency). The efficiency of these FX markets before and after the onset of the Asian currency turmoil (i.e., January 1 – June 30, 1997 and July 1 – December 30, 1997) are compared. The Thai baht, Malaysian ringgit, Indonesian rupiah and Singapore dollar exhibited non-stationary behavior during the entire year, and gave evidence of a trading regime break, while the Philippines’ peso, Taiwan dollar, Yen and Deutschmark remained stationary (The Hong Kong dollar was pegged). However, each half-year regime showed stationarity by itself, indicating stable and nonchaotic trading regimes for all currencies, despite the high volatilities, except the Malaysian ringgit, which exhibited non-stationarity in the second half of 1997. The Thai baht traded non-stationarity in the first half of 1997, but stationarily in the second half, while the Taiwan dollar reversed that trading pattern. Regarding Sherry’s four serial independence tests of differential spectrum, relative price changes, temporal trading windows of at least 20 minutes long and price change category transitions: none of the currencies exhibited complete independence. Thus no Asian currency market – including the Yen – exhibited complete efficiency in 1997 regarding both stationarity and independence, in particular when compared with the highly efficient Deutschmark. But, remarkably, the Philippines’ peso remained as efficient as the Japanese Yen throughout 1997.

Low, Aaron & Jayaram Muthuswamy (1996), “Information Flows in High Frequency Exchange Rates”, Chapter 1 in Christian Dunis, ed. (1996), *Forecasting Financial Markets: Exchange Rates, Interest Rates and Asset Management*, John Wiley & Sons, Chichester, England, pp. 3-32; revised version of paper in *Proceedings of the First International Conference on High Frequency Data in Finance, Zürich, 29-31 March 1995*, vol. 3

In this study, we analyze the informational content of high frequency exchange rate data. Finance theory, e.g. Admati and Pfleiderer (1988) suggests that more information might be generated in markets with high trading volume. Relevant studies that examine prices, e.g. French and Roll (1986), Ross (1989), argue that information will be reflected in returns volatility. One such implication is that exchange rates that are heavily traded will tend to lead rates that trade with less liquidity via cross-currency arbitrage.

Using a unique high frequency database, we are able to exploit directly observable news and study its effects on price and spread dynamics. We find strong evidence of the effects of public information on quote returns volatility and spread changes. As expected, news activity directly increases conditional volatility in both spreads and returns as expected. There are consistent daily cyclical patterns in

the frequency of news releases and quote arrivals across all trading days and across different markets. However, sharp increases in trading activity at the beginning and end of each market trading day do not seem to coincide with the level of news activity. We also find that more heavily traded exchange rates like the Japanese Yen/US Dollar and US Dollar/Deutsche Mark tend to lead the less frequently traded Japanese Yen/Deutsche Mark. The intensity of news announcements is also found to increase the conditional volatility of returns and spread changes as predicted by theory. We also find, after allowing for conditional heteroskedasticity, that spreads tends to increase when more news announcements hit the financial markets.

Lyons, Richard (1996c), “Optimal Transparency in a Dealer Market with Application to Foreign Exchange”, *Journal of Financial Intermediation*, vol. 5, no. 3 (July), pp. 225-254; revised version of “Optimal Transparency in a Dealership Market with an Application to Foreign Exchange”, *NBER Working Paper*, no. 4467 (September 1993)

This paper addresses a fundamental tradeoff in the design of multiple-dealer markets. Namely, though greater transparency can accelerate revelation of information in price, it can also impede dealer risk management. Recognizing this, we examine the following question: If dealers could choose the transparency regime ex-ante, which regime would they choose? We show that dealers do prefer incomplete transparency (where here, incomplete means that marketwide order-flow is observed with noise). The reason is that slower price adjustment provides time for non-dealers to trade, thereby sharing risk otherwise borne by dealers. At some point, however, further reduction in transparency impedes risk sharing. This is because too noisy a public signal provides non-dealers too little information to induce them to trade.

Lyons, Richard (1997a), “A Simultaneous Trade Model of the Foreign Exchange Hot Potato”, *Journal of International Economics*, vol. 42, no.s 3-4 (May), pp. 275-298; revised version of “Information Externalities in the Microstructure of the Foreign Exchange Market”, *NBER Working Paper*, no. 3889 (October 1991)

[Description] The foreign exchange market is distinctive at the microstructural level. The three most striking features relative to other markets are: (1) trading volume is enormous, (2) the share of interdealer trading is very high, and (3) the transparency of order flow is very low. This paper introduces a model designed to capture these three features. The model includes multiple dealers who trade with customers and among themselves. In contrast to the sequential move framework of the canonical dealer trading game, here we introduce a simultaneous move trading game (with multiple periods). The model produces hot potato trading among dealers – a term that refers to repeated passing of inventory imbalances. This type of trading appears to account for much of the enormous volume in foreign exchange, and squares with the fact that the share of interdealer trading is very high. We show, however, that hot potato passing of inventories is not innocuous: because the passing of inventories dilutes the information content of order flow, this hampers information aggregation, making price less informative.

Lyons, Richard (1998a), “Profits and Position Control: A Week of FX Dealing”, *Journal of International Money and Finance*, vol. 17, no. 1 (February), pp. 97-115

[Description] This paper extends earlier work on FX microstructure by answering a number of key quantity-dependent questions. Earlier work was unable to address these questions because direct measures of quantity (order flow) were not available. For example, how profitable is dealing in FX? And how rapidly do FX dealers dispose of risky inventory compared to, say, NYSE equity specialists? Other questions are less straightforward, requiring some methodological progress. For example, what share of dealer profits come from speculation versus intermediation? To answer this question one needs a method for measuring dealer speculation over time. This paper introduces a method for doing this.

Our answers to these questions are striking. First consider dealer profits: the dealer we track averages \$100,000 profit per day (on volume of \$1 billion per day). By comparison, equity dealers

average about \$10,000 profit per day (on volume of roughly \$10 million per day). Further, we find that these profits derive primarily from intermediation rather than speculation. We also find intense inventory management: the half-life of non-zero positions is only 10 minutes. This is remarkably short relative to half-lives for equity specialists of one week. Inventory theory is clearly essential to understanding trading in this market. Though striking, these results also present a challenge: Why do equity and FX markets look so different in these dimensions?

Madhavan, Ananth (1995), “Consolidation, Fragmentation, and the Disclosure of Trading Information”, *Review of Financial Studies*, vol. 8, no. 3

It is commonly believed that fragmented security markets have a natural tendency to consolidate. This paper examines this belief, focusing on the effect of disclosing trading information to market participants. We show that large traders who place multiple trades can benefit from the absence of trade disclosure in a fragmented market, as can dealers who face less price competition than in a unified market. Consequently, a fragmented market need not coalesce into a single market unless trade disclosure is mandatory. We also compare and contrast fragmented and consolidated markets. Fragmentation results in higher price volatility and violations of price efficiency.

Madhavan, Ananth, Matthew Richardson & Mark Roomans (1997), “Why do Security Prices Fluctuate? A Transaction-Level Analysis of NYSE Stocks”, *Review of Financial Studies*, vol. 10, no. 4 (Winter), pp. 1035-1064; revised version of “Why Do Security Prices Change? A Transaction-Level Analysis of NYSE Stocks”, *Proceedings of the First International Conference on High Frequency Data in Finance, 29-31 March 1995*, Olsen & Associates, Zürich, vol. 4

This paper develops a structural model of intraday price formation that embodies both public information shocks and microstructure effects. Due to its structural nature, the model’s underlying parameters provide summary measures to assess trading costs, the sources of short-run price volatility, and the speed of price discovery in an internally consistent, unified setting. We estimate the model using transaction level data for a cross-section of NYSE stocks. We find, for example, that the parameter estimates jointly explain the observed U-shaped pattern in bid-ask spreads and in price volatility, the magnitude of transaction price volatility due to market frictions, and the autocorrelation patterns of transaction returns and quote revisions. Further, in contrast to bid-ask spread patterns, we find that execution costs of a trade are much smaller than the spread and increase monotonically over the course of the day. This may provide an explanation for why there is concentration in trade at the open.

Mandelbrot, Benoît, Adlai Fisher & Laurent Calvet (1997), “A Multifractal Model of Asset Returns”, Yale University, *Cowles Foundation Discussion Paper*, no. 1164 (15 September)

This paper presents the multifractal model of asset returns (“MMAR”), based upon the pioneering research into multifractal measures by Mandelbrot (1972, 1974). The multifractal model incorporates two elements of Mandelbrot’s past research that are now well-known in finance. First, the MMAR contains long-tails, as in Mandelbrot (1963), which focused on Levy-stable distributions. In contrast to Mandelbrot (1963), this model does not necessarily imply infinite variance. Second, the model contains long- dependence, the characteristic feature of fractional Brownian Motion (FBM), introduced by Mandelbrot and van Ness (1968). In contrast to FBM, the multifractal model displays long dependence in the absolute value of price increments, while price increments themselves can be uncorrelated. As such, the MMAR is an alternative to ARCH-type representations that have been the focus of empirical research on the distribution of prices for the past fifteen years. The distinguishing feature of the multifractal model is multi-scaling of the return distribution’s moments under time-re-scaling. We define multi-scaling, show how to generate processes with this property, and discuss how these processes differ from the standard processes of continuous-time finance. The multifractal model implies certain empirical regularities, which are investigated in a companion paper.



Mann, Steven, Cynthia McDonald & Pradipkumar Ramanlal (1996), "The Bid-Ask Spread's Cost Components: Theory and Evidence", Louisiana State University, Finance Department, working paper, September

We develop and test a model that provides improved estimates of the bid-ask spread's cost components: order processing, adverse selection, and inventory control. The model incorporates three unique features: (1) a dealer's response to inventory imbalances is not static but depends on the size of the imbalance and the dealer's aversion to inventory risk; (2) active inventory management by a dealer will result in a stationary stochastic process for inventory; and (3) inventory management will influence the adverse selection cost component. We estimate the spread's components using intraday data for NYSE/AMEX and NASDAQ stocks. We also examine the impact of our model's features on the cost estimates. The results suggest inventory costs are higher and order processing costs are lower than previously reported.

Martens, Martin, Yuanchen Chang & Stephen Taylor (1998), "Intraday Volatility Forecasts Using Different Seasonal Adjustment Methods", *Proceedings of the Second International Conference on High Frequency Data in Finance, 1-3 April*, Olsen & Associates, Zürich, vol. 1

This study compares volatility forecasts over a thirty-minute horizon for the DEM/USD spot exchange rate. We find that taking into account the intraday seasonal pattern improves the out-of-sample forecasting performance. We compare different methods to take into account the seasonal pattern. It is found that a seasonal estimated from the log of squared returns improves upon the use of simple squared returns, and that the Fast Fourier Form (FFF) is an efficient way of determining the seasonal. It performs marginally better than a Periodic GARCH model that includes the FFF, although PGARCH is a 1-step estimation method in contrast to the 2-step approach that first estimates the seasonal and then the parameters of the GARCH model for the de-seasonalized returns.

Milevsky, Moshe-Arye (1995), "An Empirical Examination of the Geometric Brownian Motion Hypothesis via the Space-Time Duality of a Stochastic Process", York University, North York, Ontario, Faculty of Administrative Studies, working paper

In this paper we will propose an alternative methodology for testing the Geometric Brownian Motion/Random Walk Hypothesis. This methodology focuses on the duality that exists between time and space for any given stochastic process. We will use a concept known as the First Passage Time, which is the amount of time required by a stochastic process to travel a pre-specified distance. In particular we will demonstrate that testing the hypothesis that (logarithmic) investment returns are independent and normally distributed is equivalent to testing the hypothesis that the First Passage Time is Inverse Gaussian distributed. We will demonstrate this methodology by empirically examining the SP500 Index for the period 1975-1988. This type of approach is of particular relevance when attempting to price options on deeply in/out of the money options. In addition, we discuss extensions of this methodology to other functional forms of stochastic process. Our preliminary results confirm the hypothesis that (logarithmic) equity index returns are severely non-normal.

Moody, John & Lizhong Wu (1995), "Statistical Analysis and Forecasting of High Frequency Foreign Exchange Rates", *Proceedings of the First International Conference on High Frequency Data in Finance, Zürich, 29-31 March*, vol. 4

Three investigations of tick-by-tick interbank foreign exchange rates are presented in this paper. The first is on the behavior of price returns. The time scales observed vary from one or two ticks to thousands of ticks. We find evidence for mean-reverting price behavior in the probability distributions of Bid and Ask returns, in the autocorrelation coefficients in short-run windows and in the zero-crossing times of the price changes. The mean-reverting behavior is further revealed by underlying symmetric feature patterns and their transition probability matrix. Comparing rescaled range analysis and computations of Hurst exponents for the original price returns series, scrambled returns data, a synthetic

Gaussian process and a synthetic Gauss-Markov process, we find that the original price returns series is qualitatively different from the scrambled data and Gaussian series, and is more similar to a Gauss-Markov process with negative coefficient. This again confirms the mean-reversion in the market returns. We then show that the mean-reverting behavior could be due to the inventory effects. We demonstrate how the price movements shift from mean-reverting to mean-averting behavior when short-run oscillations (possibly caused by the inventory effects) are smoothed. The second investigation is on prediction of price changes. We present the forecasting performance of recursive linear AR models. We demonstrate the existence of forecastable structure on a time scale of less than 16 ticks. The third investigation is on the relation of Bid/Ask spreads, volatility and forecastability. We find highly significant correlations between Bid/Ask spreads, volatility and forecastability in the data. These interactions show that higher volatility results in higher forecast error and increased risk for market makers, and that to compensate for this in risk, market makers increase their Bid/Ask spreads.

Müller, Ulrich (1993), “Statistics of Variables Observed Over Overlapping Intervals”, Olsen & Associates, Zürich, working paper, 30 November

This working paper discusses the problem of overlapping intervals when computing statistical quantities for time series. For the simple case of the normal distribution, it is shown that the use of overlapping intervals does not improve the precision of the mean, or for that matter of any linear statistical estimator but provides a significant improvement of the precision of the variance or any non-linear statistical quantity. The improvement of significance is computed in the case of the variance of a normal distribution. The error variance is shown to be reduced by 25% by using an overlap of 2 and at maximum by 33% for an infinite overlap. A formula for the effective number of observations as a function of the number of overlaps is derived from this computation. From this study of the “ideal case” of a normal distribution, recommendations are given for the use of overlapping intervals in empirical studies.

Müller, Ulrich, Michel Dacorogna, Richard Olsen, Olivier Pictet, Matthias Schwarz & Claude Morgengegg (1990), “Statistical Study of Foreign Exchange Rates, Empirical Evidence of a Price Scaling Law, and Intraday Analysis”, *Journal of Banking and Finance*, vol. 14, no. 6 (December), pp. 1189-1208

In this paper we present a statistical analysis of four foreign exchange spot rates against the U.S. Dollar with several million intra-day prices over 3 years. The analysis also includes gold prices and samples of daily foreign exchange prices over 15 years. The mean absolute changes of logarithmic prices are found to follow a scaling law against the time interval on which they are measured. This empirical law holds although the distributions of the price changes strongly differ for different interval sizes.

Systematic variations of the volatility are found even during business hours by an intra-day analysis of price changes. Seasonal heteroskedasticity is observed with a period of one day as well as one week as the result of an analogous intra-week analysis; taking this into account is necessary for any future study of intra-day price change distributions and their generating process. The same type of analysis is also made of the bid-ask spreads.

Müller, Ulrich, Michel Dacorogna, Rakhil Davé, Olivier Pictet, Richard Olsen & Robert Ward (1994), “Fractals and Intrinsic Time – A Challenge to Econometricians”, in B. Lüthje, ed., *Erfolgreiche Zinsprognose*, Verband öffentlicher Banken, Bonn

A fractal approach is used to analyze financial time series, applying different degrees of time resolution, and the results are interrelated. Some fractal properties of foreign exchange (FX) data are found. In particular, the mean size of the absolute values of price changes follows a “fractal” scaling law (a power law) as a function of the analysis time interval ranging from a few minutes up to a year. In an autocorrelation study of intra-day data, the absolute values of price changes are seen to behave like the fractional noise of Mandelbrot and Van Ness rather than those of a GARCH process.

Intra-day FX data exhibit strong seasonal and autoregressive heteroskedasticity. This can be modeled with the help of new time scales, one of which is termed intrinsic time. These time scales are

successfully applied to a forecasting model with a “fractal” structure for FX as well as interbank interest rates, the latter presenting market structures similar to the Foreign Exchange.

The goal of this paper is to demonstrate how the analysis of high-frequency data and the finding of fractal properties lead to the hypothesis of a heterogeneous market where different market participants analyze past events and news with different time horizons. This hypothesis is further supported by the success of trading models with different dealing frequencies and risk profiles. Intrinsic time is proposed for modeling the frame of reference of each component of a heterogeneous market.

Müller, Ulrich, Michel Dacorogna & Olivier Pictet (1995), “The Error of Statistical Volatility of Intra-Daily Quoted Price Changes Observed Over a Time Interval”, Olsen & Associates, Zürich, working paper, 8 August

For a proper computation of the scaling law exponent from intra-daily quoted prices, it is essential to discuss and estimate the different type of errors present when computing the volatility.

We present here the derivation of the error of a statistical average of an absolute or squared price change observed over a certain time interval. The sources of error are of two types: the conventional statistical error due to the number of observations and a measurement error due to the definition of the middle price which contains a fundamental uncertainty caused by the spread.

Müller, Ulrich, Michel Dacorogna & Olivier Pictet (1996b), “Heavy Tails in High-Frequency Financial Data”, Olsen & Associates, Zürich, working paper, 11 December

We perform a tail index estimation of financial asset returns in two markets: the foreign exchange market and the interbank market of cash interest rates. Thanks to the high-frequency of the data, we obtain good estimates of the tail indices and we are able to analyze their stability with time aggregation.

Our analysis confirms that the variance of the return is finite but points to the non-convergence of the kurtosis. Both financial markets present similar tail behavior of the returns. A study of the extreme risks reveals the need to depart from the Gaussian assumption by taking the fat tails fully into account. A study of tails under temporal aggregation, also investigating data from theoretical price formation processes, shows that ARCH-type processes represent the true behavior better than unconditional distribution models.

Müller, Ulrich, Michel Dacorogna, Rakhil Davé, Richard Olsen, Olivier Pictet & Jakob von Weizsäcker (1997), “Volatilities of Different Time Resolutions: Analyzing the Dynamics of Market Components”, *Journal of Empirical Finance*, vol. 4, no.s 2-3 (June), pp. 213-239; revised version of paper in *Proceedings of the First International Conference on High Frequency Data in Finance, 29-31 March 1995*, Olsen & Associates, Zürich, vol. 1

The heterogeneous market states that the diversity of actors causes different behaviors of volatilities of different time resolutions. A lagged correlation study reveals that statistical volatility defined over a coarse time grid significantly predicts volatility defined over a fine grid. This empirical fact is not explained by conventional theories and models.

We propose a new model class that takes into account squared price changes from time intervals of different size. This model is shown to reproduce the same empirical properties that have been found for FX intra-day data: long memory, fat-tailed distribution, and predictability of finely defined volatility by coarsely defined volatility.

Naik, Narayan, Anthony Neuberger & S. Viswanathan (1994), “Disclosure Regulation in Competitive Dealership Markets: Analysis of the London Stock Exchange”, London Business School, *IFA Working Paper*, no. 193 (July)

This paper presents a two stage trading model of a competitive dealership market. In the first stage, one among a group of risk averse market makers executes a public trade which contains some information. Details of this trade are not publicly disclosed. In the second stage, an inter-dealer market allows the market maker to offset her inventory position and exploit the information contained in the public order by trading with the other market makers. We show that the price of a trade in such a market depends in a nonlinear way on the informativeness and the size of the trade. We also show that public disclosure of trades in the first stage reveals the information contained in the trade and thus radically alters the structure of the market. We use our model to compare the competitive dealership market (with and without public disclosure) with the standard auction type market and to address some of the issues raised in the continuing public disclosure controversy at the London Stock Exchange.

Neal, Robert & Simon Wheatley (1995), “How Reliable Are Adverse Selection Models of the Bid-Ask Spread?”, *Research Division, Federal Reserve Bank of Kansas City, Research Working Paper*, no. 95-02 (March)

Theoretical models of the adverse selection component of bid-asked spreads predict the component arises from asymmetric information about a firm’s fundamental value. We test this prediction using two well known models [Glosten and Harris (1988) and George, Kaul, and Nimalendran (1991)] to estimate the adverse selection component for closed-end funds. Closed-end funds hold diversified portfolios and report their net asset values on a weekly basis. Thus, there should be little uncertainty about their fundamental values and their adverse selection components should be minimal. Estimates of the component from the two models, however, average 19 and 52 percent of the spread. These estimates, while smaller than corresponding estimates from common stocks, are large enough to raise doubts about the reliability of these models.

Neely, Christopher & Paul Weller (1997a), “Technical Analysis and Central Bank Intervention”, *Federal Reserve Bank of St. Louis, Research Division Working Papers*, no. 97-002A (23 January)

This paper extends the genetic programming techniques developed in Neely, Weller and Dittmar (1996) to show that technical trading rules can make use of information about intervention by the Federal Reserve to improve their out-of-sample profitability. A considerable part of the improvement in performance results from more efficient use of the information in the past exchange rate series. We show that much of the profitability of the rules is accounted for by returns from  $t - 1$  to  $t$ , when intervention takes place at date  $t$ . This supports the view that intervention is intended to check or reverse strong and predictable trends in the market. However, the rules interpret intervention as a signal that an existing trend will continue, rather than undergo a reversal.

Neely, Christopher & Paul Weller (1997b), “Technical Trading Rules in the European Monetary System”, *Federal Reserve Bank of St. Louis, Research Division Working Papers*, no. 97-015A (11 June)

Using the genetic programming methodology developed in Neely, Weller and Dittmar (1997), we find ex ante trading rules which generate significant excess returns for three of four EMS exchange rates over the out-of-sample period 1986-1996. Permitting the rules to use information about the interest rate differential proved to be important. The reduction in volatility resulting from the imposition of a narrower band may reduce trading rule profitability. The currency for which there was least evidence of significant excess returns was the Dutch guilder, which was also the only currency which remained within a band of  $\pm 2.25\%$  throughout our sample period. Our results cannot be duplicated by the moving average or filter rules commonly used by technical analysts or by two trading rules designed specifically

to exploit known features of target zone exchange rates. Nor can the observed excess returns be explained as compensation for bearing systematic risk.

Neely, Christopher & Paul Weller (1997c), “Predictability in International Asset Returns: A Reexamination”, *Federal Reserve Bank of St. Louis, Research Division Working Papers*, no. 97-010B (12 August)

This paper reexamines the findings of Bekaert and Hodrick (1992), who found predictability in international equity and foreign exchange markets using the VAR methodology for a variety of countries over the period 1981-1989. In out-of-sample forecasts, the VAR projections are badly biased and conclusively outperformed by a random walk model at horizons up to six months. Examination of structural break statistics in the three VARs suggests that factors such as the downturn in Japanese equities, the pound's withdrawal from the ERM and German reunification may have contributed to the observed instability in the VARs. Our results illustrate the limitations of the VAR-based approach to forecasting and provide another cautionary tale on the dangers of instability in estimated relationships and the importance of long spans of data with which to test the robustness of those relationships.

Neely, Christopher, Paul Weller & Robert Dittmar (1997), “Is Technical Analysis in the Foreign Exchange Market Profitable? A Genetic Programming Approach”, *Journal of Financial and Quantitative Analysis*, vol. 32, no. 4 (December), pp. 405-426; revised version of *Federal Reserve Bank of St. Louis, Research Division Working Papers*, no. 96-006B (June 1996)

We use genetic programming techniques to identify optimal technical trading rules, and find strong evidence of economically significant out-of-sample excess returns to the rules for each of six exchange rates (\$/DM, \$/£, \$/SF, \$/¥, DM/¥, SF/£), over the period 1981-1995. Further, when the \$/DM rules were allowed to determine trades in the other markets, there was a significant improvement in performance in all cases except the DM/¥. Some of the rules have a structure similar to those used by technical analysts. Betas calculated for the returns according to various benchmark portfolios provide no evidence that the returns to these rules are compensation for bearing systematic risk. Bootstrapping results for the \$/DM indicate that the trading rules are detecting patterns in the data that are not captured by standard statistical models.

Neuberger, Anthony & Oliver Hansch (1996), “Strategic Trading by Market Makers on the London Stock Exchange”, London Business School, *IFA Working Paper*, no. 224-1996 (January)

In this paper we address the question whether dealers on the London Stock Exchange act strategically. While a large part of the microstructure literature assumes that dealers are constrained to make zero expected profits on each trade we argue that, if dealers can learn valuable information from the order flow, one might expect them to trade strategically in order to make money on their own account and avoid revealing their knowledge through their price setting. We test for evidence of this behavior by examining profit margins for synthetic order-balancing and position taking trading strategies. Using transaction data for a sample of 30 FTSE-100 stocks during the period 1991/92, we find large differences in dealer profit margins for order-balancing and position-taking trades, which cannot be explained by risk premia, irrationality, or benefits outside the market making business, but are consistent with strategic behavior for information and/or reputation related reasons.

Nielsen, Erland Hejn (1995), “The Dynamics of Speculative Trade Places: High Frequency Data Generated from a Structural Continuous Dynamic Model”, *Proceedings of the First International Conference on High Frequency Data in Finance, Zürich, 29-31 March*, vol. 3

This paper discusses the high frequency behavior of a generic speculative trade model. Based on a fundamental description of the behavior of groups of noise traders and informed traders in deterministic dynamic terms, it is showed that some of the more characteristic patterns found in high frequency stock prices, might very well be the result of simple dynamic interaction, that is in essence a function of the agents speed of change of opinion.

Odean, Terrance (1998), “Volume, Volatility, Price and Profit When All Traders Are Above Average”, *Journal of Finance*, vol. 53, no. 6 (December), pp. 1887-1934; revised version of University of California, Davis, Graduate School of Management, working paper, April; in turn revised version of University of California at Berkeley, working paper, November 1994

People are overconfident. Overconfidence affects financial markets. How depends on who in the market is overconfident and on how information is distributed. This paper examines markets in which price-taking traders, a strategic-trading insider, and risk-averse market-makers are overconfident. Overconfidence increases expected trading volume, increases market depth, and decreases the expected utility of overconfident traders. Its effect on volatility and price quality depend on who is overconfident. Overconfident traders can cause markets to underreact to the information of rational traders. Markets also underreact to abstract, statistical, and highly relevant information, while they overreact to salient, anecdotal, and less relevant information.

Olsen, Richard, Michel Dacorogna, Ulrich Müller & Olivier Pictet (1992), “*Going Back to the Basics – Rethinking Market Efficiency*”, Olsen & Associates, Zürich, working paper, 2 December

[Introduction] The real-life experience of our customers shows that we successfully forecast foreign exchange (FX) price movements for short to medium-term time horizons. This is substantiated by a positive forecast quality and high trading model returns (Dacorogna et al., 1992; Pictet et al., 1992).

We have to ask ourselves why O&A is able to forecast. Are we successful in capturing the inefficiencies of the FX market? Since this market is widely held to be the most efficient of the financial markets, we should ask a more pertinent question: Does our success not conflict with the theory of efficient markets, which precludes the ability to forecast and denies the existence of profitable trading models?

The present discussion paper explains why, in contrast to the statement of the efficient market theory, we have been able to develop successful forecasting and profitable trading models. We believe that there are a number of reasons, which are all associated with market dynamics. We emphasize that such explanations are highly tentative. In particular, we think that many years of hard investigation will be needed to prove scientifically that the claims made here are actually valid. To facilitate this research, we suggest some ideas for a new definition of market efficiency at the end of the paper.

Osler, Carol (1998), “Short-Term Speculators and the Puzzling Behavior of Exchange Rates”, *Journal of International Economics*, vol. 45, no. 1 (June), pp. 37-57; apparently revised version of “Short-Term Speculators and the Origins of Near-Random-Walk Exchange Rate Behavior”, *Federal Reserve Bank of New York Staff Reports*, no. 3 (July 1995)

This paper suggests that normal speculative activity could be a source of random-walk exchange rate behavior. Using a noise trader model to analyze very short-term exchange rate behavior, it shows that rational, risk-averse speculators will smooth the impact of shocks to exchange rate fundamentals. With

sufficient speculative activity, an exchange rate could become statistically indistinguishable from a random walk, regardless of the generating processes of its fundamental determinants.

This result may help resolve the apparent inconsistency between the observed behavior of floating exchange rates and the behavior predicted by existing theoretical models given the actual behavior of exchange rate fundamentals. The result also suggests that heavy speculative activity could cause exchange rates to be forecast better via random-walk than via structural models—even when structural forces are correctly identified. Finally, the paper provides an explanation for the observed extended response of exchange rates to sterilized intervention.

Osler, Carol & Kevin Chang (1995), “Head and Shoulders: Not Just a Flaky Pattern”, *Federal Reserve Bank of New York Staff Reports*, no. 4 (August)

Much empirical research suggests that exchange-rate forecasts are not rational. This paper identifies a commonly used technical trading signal, the head-and-shoulders pattern, as a potential source of that irrationality. We use an objective, computer-implemented algorithm to identify head-and-shoulders patterns in daily dollar exchange rates during the floating rate period. The resulting profits, replicable in real time, are then evaluated statistically using the bootstrap technique.

We impose two conditions for trading-rule rationality: a rule must be profitable and it must not be dominated by other trading rules. We find that head-and-shoulders trading generates statistically significant profits, and thus satisfies the first condition. However, the trading rule is dominated by simple filter rules, so it does not satisfy the second condition.

Pai, Jeffrey & Wolfgang Polasek (1995), “Irregularly Spaced AR and ARCH (ISAR-ARCH) Models”, *Proceedings of the First International Conference on High Frequency Data in Finance, Zürich, 29-31 March*, vol. 1

Many time series in finance and in other applied analyses are often measured at unequally or irregularly spaced time intervals. We suggest these models by an AR-response surfaces where the AR coefficients are declining functions in continuous lag time. The irregularly spaced AR-ARCH (ISAR-ARCH) models contain the usual AR-ARCH models as special case in equal space. The Markov chain Monte Carlo approach is performed by using a Metropolis-Rao-Blackwellization method.

Paul, Jonathan (1995), “Information Aggregation without Exogenous Liquidity Trading”, Kellogg Graduate School of Management, Northwestern University, working paper, March

Information aggregation models invariably rely on the presence of liquidity traders who submit price-independent demands. (See Grossman-Stiglitz (1980), Hellwig (1980), Kyle (1985), and the resulting literature.) This paper shows that price-independent liquidity demands cannot arise from any rational motive for trade, and, in fact, implicitly assume an extreme form of irrationality. This paper removes the price-independent liquidity demands found in these models and replaces them with investors who have a hedging motive for trade. The paper provides closed-form solutions that require no additional assumptions beyond those already assumed in this literature and which handles the full range of parameters in the original Hellwig model as the most general model to-date that has a closed-form solution.

Endogenizing the liquidity trading allows us to examine trading volume and welfare implications: two important issues which could not be addressed in previous models of information aggregation. The paper also allows for investors who have private information about the liquidity (or endowment) shock. The paper shows that private information about the liquidity shock is not a peripheral feature of the model: any large economy information aggregation model with endogenous liquidity trading must contain investors who have private information about the liquidity shock.

Payne, Richard (1996), “Announcement Effects and Seasonality in the Intra-Day Foreign Exchange Market”, *LSE Financial Markets Group Discussion Paper*, no. 238 (March)

This paper examines two aspects of spot FX volatility. Using intra-daily quotation data on the Deutsche Mark/Dollar we simultaneously estimate the deterministic intra-daily seasonal pattern inherent in volatility and the effects of U.S. macroeconomic announcements. The empirical specification and estimation technique is based on the Stochastic Volatility methodology contained in Harvey, Ruiz, and Shephard (1994). Results conform with previous work, in that “news” effects are strong and persistent, being felt for over one hour after the initial release time. Inclusion of an explicit seasonal is shown to be essential for the accurate estimation of other volatility components. Further estimations allow us to examine which particular pieces of U.S. data move the markets. These results show that the most important statistics are those associated with the Employment and Mercantile Trade reports.

Peiers, Bettina (1997), “Informed Traders, Intervention and Price Leadership: A Deeper View of the Microstructure of the Foreign Exchange Market”, *Journal of Finance*, vol. 52, no. 4 (September), pp. 1589-1614; revised version of paper in *Proceedings of the First International Conference on High Frequency Data in Finance, 29-31 March 1995*, Olsen & Associates, Zürich, vol. 3

This paper identifies price leadership patterns in foreign exchange trading, with a focus on central bank intervention as an informational trigger for leadership positioning. Granger causality tests applied to DM/US\$ spot rate quotes reveal Deutsche Bank as a price leader up to 60 minutes prior to Bundesbank interventionary reports. By the minus 25-minute mark, interbank quote adjustments become two-way Granger-causal. These results suggest that central bank activity is revealed in stages: first to the price leader, then to competitors and lastly to the general public.

Pictet, Olivier, Michel Dacorogna, Ulrich Müller, Richard Olsen & Robert Ward (1992), “Real-Time Trading Models for Foreign Exchange Rates”, *Neural Network World*, vol. 2, no. 6, pp. 713-744

A set of real-time trading models offering analysis of foreign exchange (FX) rate movements and providing explicit trading recommendations is presented. These models are based on the continuous collection and treatment of FX quotes from market makers operating around the clock. These data are processed by a distributed system of computers performing tasks of data collection, data validation, indicator computation, rule-based analysis, communication and display generation. The out-of-sample performance of these models is typically close to 18% return per year with unleveraged positions and excluding any interest gains. Diversifying the exposure through a portfolio of currencies reduces the risk of using such models for real trading. With a portfolio of three equally weighted FX rates the maximum drawdown is reduced from an average of 9% to 5% for a single trading model while keeping the annual return practically unchanged.

Pictet, Olivier, Michel Dacorogna, Bastien Chopard, Mouloud Oudsaidene, Roberto Schirru & Marco Tomassini (1995), “Using Genetic Algorithm for Robust Optimization in Financial Applications”, *Neural Network World*, vol. 5, no. 4, pp. 573-587; revised version of Pictet, Dacorogna, Rakhil Davé, Chopard, Schirru & Tomassini, “Genetic Algorithms with Collective Sharing for Robust Optimization in Financial Applications”, Olsen & Associates, Zürich, working paper

In this study, optimal indicators and strategies for foreign exchange trading models are investigated in the framework of genetic algorithms. We first explain how the relevant quantities of our application can be encoded in “genes” so as to fit the requirements of the genetic evolutionary optimization technique. In financial problems, sharp peaks of high fitness are usually not representative of a general solution but, rather, indicative of some accidental fluctuations. Such fluctuations may arise out of inherent noise



in the time series or due to threshold effects in the trading model performance. Peaks in such a discontinuous, noisy and multimodal fitness space generally correspond to trading models which will not perform well in out-of-sample tests. In this paper we show that standard genetic algorithms will be quickly attracted to one of the accidental peaks of the fitness space whereas genetic algorithms for multimodal functions employing clustering and a specially designed fitness sharing scheme will find optimal parameters which correspond to broad regions where the fitness function is higher on average. The optimization and the quality tests have been performed over eight years of high frequency data of the main foreign exchange rates.

Pictet, Olivier, Michel Dacorogna & Ulrich Müller (1996), “Hill, Bootstrap and Jackknife Estimators for Heavy Tails”, Olsen & Associates, Zürich, working paper, 11 December

We perform an analysis of tail index estimation through Monte-Carlo simulations of synthetic data, in order to evaluate several tail estimators proposed in the literature. We derive and discuss the error of the Hill estimator under a general tail expansion of the distribution function. The analysis is extended to study the behavior of tail estimation under aggregation.

A detailed description is given of an algorithm designed to reduce the bias of the Hill estimator. This algorithm is based on a sub-sample bootstrap combined with the jackknife method. We show through simulations that this algorithm gives reasonable estimations of the tail index provided the number of observations is sufficiently large. The bias of the Hill estimator is successfully reduced. We also show that the estimation gives a constant tail index under aggregation up to an aggregation factor of 12. We recommend this method as a standard for tail estimation of empirical data.

Ramsey, James & Camille Lampart (1997), “The Decomposition of Economic Relationships by Time Scale Using Wavelets”, *Economic Research Report*, C.V. Starr Center for Applied Economics, New York University, no. 97-08 (January)

Economists have long known that time scale matters in that the structure of decisions as to the relevant time horizon, degree of time aggregation, strength of relationship, and even the relevant variables differ by time scale. Unfortunately, until recently it was difficult to decompose economic time series into orthogonal time scale components except for short and long run in which the former is dominated by noise. This paper uses wavelets to produce an orthogonal decomposition of some economic variables by time scale over six different time scales. The relationships of interest are the permanent income hypothesis and velocity. We confirm that time scale decomposition is very important for analyzing economic relationships and that a number of anomalies previously noted in the literature are explained by these means. The analysis also indicates the importance of recognizing variations in phase between variables when investigating the relationships between them and throws considerable light on the conflicting results that have been obtained in the literature using Granger causality tests.

Ramsey, James & Zhifeng Zhang (1997), “The Analysis of Foreign Exchange Data Using Waveform Dictionaries”, *Journal of Empirical Finance*, vol. 4, no. 4 (December), pp. 341-372; revised version of New York University, C.V. Starr Center for Applied Economics, *Economic Research Report*, no. 95-03 (January 1995); also in *Proceedings of the First International Conference on High Frequency Data in Finance, 29-31 March 1995*, Olsen & Associates, Zürich, vol. 1

This paper uses waveform dictionaries to decompose the signals contained within three foreign exchange rates using tick-by-tick observations obtained world wide. The three exchange rates examined are the Japanese Yen and the German Deutsche Mark against the U.S. dollar and the Deutsche Mark against the Yen. The data were provided by Olsen & Associates.

A waveform dictionary is a class of transforms that generalizes both windowed Fourier transforms and wavelets. Each wave form is parameterized by location, frequency, and scale. Such transforms can analyze signals that have highly localized structures in either time or frequency space

as well as broad structures; that is, waveforms can, in principle, detect everything from shocks represented by Dirac Delta functions, to “chirps”, short bursts of energy within a narrow band of frequencies, to the presence of frequencies that occur sporadically, and finally to the presence of frequencies that hold over the entire observed period. Waveform dictionaries are most useful in analyzing data that are not stationary and non-stationarity up to second order is well recognized in the context of foreign exchange rates.

Rau, Raghavendra (1995), “*Efficient Markets in the Presence of an Irrational Investor: The Case of the INSEAD Ball Ticket Market*”, INSEAD, Fontainebleau, working paper, 23 July

An efficient market is supposed to aggregate all available and relevant information into prices. All the investors in this market are assumed to be rational. In fact, a basic assumption among many of the standard analyses of such markets is usually that it is common knowledge among all investors that all the investors in the financial market are rational, where rationality means that the individual behaves as though he is maximizing his utility. In the aggregate, such individually rational behavior is usually supposed to yield good predictions for the behavior of the market as a whole. Several studies have shown that this is not always the case: rationality is not always selected for. However, these studies usually assume that all individuals in the economy have similar preference rules. This paper examines a case at a business school in Europe where individually rational behavior in a market does not lead to an “obvious” outcome. The paper further hypothesizes that this is because the market becomes aware of the possibility (though in actual fact, it may not be true) that some investors in the market have different utility functions to the others. At this stage, it is no longer common knowledge that all market participants are rational, and the market breaks down. The phenomenon emphasizes how critical is the usually unstated assumption of the common knowledge of rationality of the participants and suggests that the traditional analyses of “irrational” “noise” trader risk may not capture all the effects of irrationality.

Ready, Mark (1997), “Profits from Technical Trading Rules”, University of Wisconsin-Madison, Department of Finance, working paper, 5 February

I examine technical trading rules developed by Allen and Karjalainen (1993) and moving average rules studied by Brock, Lakonishok, and LeBaron (1992). Using intraday data, I find that profits reported in these studies may not have been achievable due to price slippage between when trading signals are measured and when trades could actually be executed. I also find that the 0.1% one-way transaction cost assumed by Allen and Karjalainen appears too low. I find that the ability of all of the rules to distinguish between days of high and low returns has declined dramatically over the last six to eight years, suggesting that factors causing return predictability may change over time.

I test modified rules that account for higher transaction costs and potential price slippage and are based on more recent data. These new rules do considerably better, but they still are unable to beat a buy and hold strategy.

Russell, Jeffrey & Robert Engle (1998), “Econometric Analysis of Discrete-Valued, Irregularly-Spaced Financial Transactions Data Using a New Autoregressive Conditional Multinomial Model”, University of Chicago, Graduate School of Business, *Center for Research in Security Prices Working Paper*, no. 470 (April); also *University of California, San Diego, Department of Economics, Discussion Paper*, no. 98-10 (April); also in *Proceedings of the Second International Conference on High Frequency Data in Finance, 1-3 April*, Olsen & Associates, Zürich

This paper proposes a new approach to modeling financial transactions data. A model for discrete valued time series is introduced in the context of generalized linear models. Since the model specifies probabilities of return outcomes conditional on both the previous state and the historic distribution, we call it the Autoregressive Conditional Multinomial (ACM) model. Recognizing that prices are observed

only at transactions, the process is interpreted as a marked point process. The ACD model proposed in Engle and Russell (1998) allows for joint modeling of the price transition probabilities and the arrival times of the transactions. The transition probabilities are formulated to allow general types of duration dependence. Estimation and testing are based on Maximum Likelihood methods. The data are IBM transactions from the TORQ dataset. Variations of the model allow for volume and spreads to impact the conditional distribution of price changes. Impulse response studies show the long run price impact of a transaction can be very sensitive to volume but is less sensitive to the spread and transaction rate.

Samorodnitsky, Gennady (1995), "A Class of Shot Noise Models for Financial Applications", *Proceedings of the First International Conference on High Frequency Data in Finance, Zürich, 29-31 March*, vol. 3

We describe a class of non-Markov shot noise processes that can be used as models for rates of return on securities, exchange rate processes and other processes in finance. These are continuous time processes that can exhibit heavy tails that become lighter when sampling interval increases, clustering and long memory.

Sanders, Dwight, Scott Irwin & Raymond Leuthold (1997), "Noise Traders, Market Sentiment, and Futures Price Behavior", Ohio State University & University of Illinois at Urbana-Champaign, Departments of Agricultural Economics, working paper, May

The noise trader sentiment model of De Long, Shleifer, Summers, and Waldmann (1990a) is applied to futures markets. The theoretical results predict that overly optimistic (pessimistic) noise traders result in market prices that are greater (less) than fundamental value. Thus, returns can be predicted using the level of noise trader sentiment. The null rational expectations hypothesis is tested against the noise trader alternative using a commercial market sentiment index as a proxy for noise trader sentiment. Fama-MacBeth cross-sectional regressions test if noise traders create a systematic bias in futures prices. The time-series predictability of futures returns using known sentiment levels is tested in a Cumby-Modest market timing framework and a more general causality specification. The empirical results lead to the following conclusions. First, there is no evidence that noise trader sentiment creates a systematic bias in futures prices. Second, predictable market returns using noise trader sentiment is not characteristic of futures markets in general. Third, futures market returns at weekly intervals are characterized by low-order positive autocorrelation with relatively small autoregressive parameters. In those instances where there is evidence of noise trader effects, it is at best limited to isolated markets and particular specifications.

Schnidrig, Remo & Diethelm Würtz (1995), "Investigation of the Volatility and Autocorrelation Function of the USD-DEM Exchange Rate on Operational Time Scales", *Proceedings of the First International Conference on High Frequency Data in Finance, Zürich, 29-31 March*, vol. 3

The investigation of high frequency data in finance is one of the most actual research topics in the field of empirical finance. The number of papers on econometric models for thight frequency data, especially for the foreign exchange market, and on the investigation of trading mechanisms in theory and practice have increased continuously during the last few years. It is thus a natural consequence that the first international conference on this topic will be held this year. The organizing committee of this conference has provided a standard set of high frequency data with the intention of stimulating research for presentation at the conference.

In this paper we are investigating one of the provided data sets, the US Dollar/German Mark foreign exchange rate. It is well known that the stochastic process generating the returns of currency exchange rates deviates significantly from a simple random walk. Changes in the mean and variance of these kind of financial time series characterizing a non-gaussian and non-linear behavior, a scaling

power law for the volatilities on different time horizons, and long memory effects in the autocorrelation function are the major aspects which we like to discuss in this paper.

Scheinkman, José & Blake LeBaron (1989), “Nonlinear Dynamics and Stock Returns”, *Journal of Business*, vol. 62, no. 3 (July), pp. 311-337

Simple deterministic systems are capable of generating chaotic output that “mimics” the output of stochastic systems. For this reason, algorithms have been developed to distinguish between these two alternatives. These algorithms and related statistical tests are also useful in detecting the presence of nonlinear dependence in time series. In this article we apply these procedures to stock returns and find evidence that indicates the presence of nonlinear dependence on weekly returns from the Center for Research in Security Prices (CRSP) value-weighted index.

Sjöö, Boo & Richard Sweeney (1994), “Do Central Banks Beat the Foreign Exchange Market? Evidence from Sweden”, *Gothenburg Studies in Financial Economics*, working paper no. 1994:10 (revised 26 February 1995)

Previous evidence on profitability of central bank intervention is mixed. No previous study has presented evidence on risk-adjusted profits, or for the Swedish central bank (Riksbanken), as this study does. Because the outside observer cannot tell which part of intervention is undertaken to pursue central bank goals beyond profits. The test is phrased in terms of the risk-adjusted profits a private speculator could make if s/he had knowledge of intervention and took positions based on this knowledge; various ways of filtering raw intervention data to extract buy-sell signals are tried. The results, on daily data, support the view that an investor responding (directly) proportionately to Swedish central bank intervention at the least did not make losses over the period 1986-1990.

Smith, Anthony Jr., Fallaw Sowell & Stanley Zin (1997), “Fractional Integration with Drift: Estimation in Small Samples”, *Empirical Economics*, vol. 22, no. 1, pp. 103-116

We examine the finite-sample behavior of estimators of the order of integration in a fractionally integrated time-series model. In particular, we compare exact time-domain likelihood estimation to frequency-domain approximate likelihood estimation. We show that over-differencing is of critical importance for time-domain maximum-likelihood estimation in finite samples. Over-differencing moves the differencing parameter (in the over-differenced model) away from the boundary of the parameter space, while at the same time obviating the need to estimate the drift parameter. The two estimators that we compare are asymptotically equivalent. In small samples, however, the time-domain estimator has smaller mean squared error than the frequency-domain estimator. Although the frequency-domain estimator has larger bias than the time-domain estimator for some regions of the parameter bias, it can also have smaller bias. We use a simulation procedure which exploits the approximate linearity of the bias function to reduce the bias in the time-domain estimator.

Stout, Lynn (1997), “How Efficient Markets Undervalue Stocks: CAPM and ECMH Under Conditions of Uncertainty and Disagreement”, *Georgetown University Law Center Business, Economics, and Regulatory Law Working Paper Series*, no. 97-2

Taken together, the Efficient Capital Markets Hypothesis (ECMH) and the Capital Asset Pricing Model (CAPM) appear to predict that the market price of a security in an efficient market should reflect the best possible estimate of its fundamental value. Although this notion once exercised great influence among both finance theorists and legal scholars, closer inspection reveals it to be tautological: because the CAPM rests on an assumption that all investors make identical estimates of securities' future risks and returns, it naturally predicts that market prices reflect that consensus. More recent work in finance examines what happens to securities prices when investors hold disagreeing expectations for the future. This “heterogeneous expectations” literature offers to resolve a number of the mysteries that have plagued scholars who rely on the conventional ECMH/CAPM.

In illustration, this paper presents a simple heterogeneous expectations pricing model premised on investor disagreement, risk aversion, and short sales restrictions. The model explains at least the following market puzzles: (1) why many investors don't diversify; (2) why target shareholders receive large premiums in corporate takeovers while bidding firms' share prices remain relatively unchanged; (3) why certain anomalous classes of securities, including neglected stocks, low P/E stocks, and low-beta stocks, offer superior risk-adjusted returns relative to the market; (4) why stock buyback programs and dividend payments support stock prices while stock issues depress market prices; and (5) how certain actively managed investment funds, Berkshire Hathaway chief among them, can consistently beat the market over long periods.

Sullivan, Ryan, Allan Timmermann & Halbert White (1999), "Data-Snooping, Technical Trading Rule Performance, and the Bootstrap", *Journal of Finance*, forthcoming in some no. after April; revised version of *University of California, San Diego, Department of Economics, Discussion Paper*, no. 97-31 (8 December 1997)

Numerous studies in the finance literature have investigated technical analysis to determine its validity as an investment tool. Several of these studies conclude that technical analysis does have merit, however, it is noted that the effects of data-snooping are not fully accounted for. In this paper we utilize White's Reality Check bootstrap methodology (White (1997)) to evaluate simple technical trading rules while quantifying the data-snooping bias and fully adjusting for its effect in the context of the full universe from which the trading rules were drawn. Hence, for the first time, the paper presents a means of calculating a comprehensive test of performance across all trading rules. In particular, we consider the study of Brock, Lakonishok, and LeBaron (1992), expand their universe of 26 trading rules, apply the rules to 100 years of daily data on the Dow Jones Industrial Average, and determine the effects of data-snooping. During the sample period inspected by Brock, Lakonishok and LeBaron, we find that the best technical trading rule is capable of generating superior performance even after accounting for data-snooping. However, we also find that the best technical trading rule does not provide superior performance when used to trade in the subsequent 10-year post-sample period. We also perform a similar analysis, applying technical trading rules to the Standard and Poor's 500 futures contract. Here, too, we find no evidence that the best technical rule outperforms, once account is taken of data-snooping effects.

Taylor, Stephen (1998a), "Stock Index and Price Dynamics in the U.K. and the U.S.: New Evidence from a Trading Rule and Statistical Analysis", University of Lancaster, Department of Accounting and Finance, working paper

The predictability of long time series of stock index levels and stock prices is investigated using both statistical and trading rule methodologies. The trading rule analysis uses a double moving-average rule and the methods of Brock, Lakonishok and LeBaron (1992). Results are obtained for the FTA, FTSE-100, DJIA and S&P-500 indices, prices for twelve U.K. stocks and indices derived from these stock prices. Statistical analysis shows that the index and price series are not random walks. The trading rule analysis generally confirms this conclusion. However, small transaction costs would eliminate the profitability of the moving-average rule. Standard ARMA-ARCH models are estimated for time series of returns and bootstrap methods are used to decide if the models can explain the observed trading statistics. The models provide a reasonable description but there is evidence from the trading rule methodology that standard models sometimes fail to describe the dynamics of the indices and prices. Several comparisons are made: between an index and the stock prices that define the index, between spot levels and futures prices for indices, and between U.K. and U.S. indices.

Taylor, Stephen (1998b), "Markov Processes and the Distribution of Volatility: A Comparison of Discrete and Continuous Specifications", University of Lancaster, Department of Accounting and Finance, working paper

Two mixtures of Normal distributions, created by persistent changes in volatility, are compared as models for asset returns. A Markov chain with two states for volatility is contrasted with an autoregressive Gaussian process for the logarithm of volatility. The conditional variances of asset returns are

shown to have a bimodal distribution for the former process when volatility is persistent, that contrasts with a unimodal distribution for the latter process. A test procedure based upon this contrast shows that a log-normal distribution for Sterling/Dollar volatility is far more credible than only two volatility states.

Taylor, Stephen & Xinzhong Xu (1997), "The Incremental Volatility Information in One Million Foreign Exchange Quotations", *Journal of Empirical Finance*, vol. 4, no. 4 (December), pp. 317-340; also forthcoming in Lequeux (1999); revised version of Lancaster University, *Working Papers in Accounting and Finance*, no. 95/008 (June 1995); revised version of first draft in *Proceedings of the First International Conference on High Frequency Data in Finance, 29-31 March 1995*, Olsen & Associates, Zürich, vol. 4

The volatility information contained in high-frequency exchange rate quotations and in implied volatilities calculated from options prices is compared by estimating ARCH models for hourly and daily DM/\$ returns. The results are based on the year of Reuters quotations supplied by Olsen & Associates. These quotations are used to calculate five-minute returns and hence hourly and daily estimates of realised volatility that can be included in equations for the conditional variances of hourly and daily returns. The ARCH results show that there is a significant amount of information in five-minute returns that is incremental to the options information when estimating hourly variances. The same conclusion is obtained by an out-of-sample comparison of forecasts of hourly realised volatility.

Teräsvirta, Timo (1996), "Two Stylized Facts and the GARCH (1,1) Model", *Stockholm School of Economics, Working Paper Series in Economics and Finance*, no. 96 (November)

Many high frequency economic or financial time series display two empirical characteristics: high kurtosis and positive autocorrelation in the centred and squared observations. The first-order autocorrelation is typically low, and the autocorrelation function decays slowly. These series are often modelled with a GARCH (1,1) model. In this paper it is shown why such a model with normal errors cannot adequately characterize these stylised facts. The same seems true for the IGARCH (1,1) model with normal errors. It is also shown why one can improve the situation by replacing the normal error distribution by a leptokurtic one, although this may not provide a complete remedy, and what kind of effects temporal aggregation may have on reproducing the stylized facts.

Toulson, Sabine (1995), "A Comparative Study for Forecasting Intra-Daily Exchange Rate Data", *Proceedings of the First International Conference on High Frequency Data in Finance, Zürich, 29-31 March*, vol. 3

For the last few years neural nets have been applied to economic and financial forecasting where they have shown to be increasingly successful. This paper compares the performance of a two hidden layer multi-layer perceptron (MLP) with conventional statistical techniques. The statistical techniques used here consist of the basic structural model (BSM) and the stochastic volatility model (SV). After reviewing each of the three models a comparison between the MLP and the BSM is made investigating the predictive power of both models for a one-step ahead forecast of the Dollar-Deutschmark exchange rate. Reasons are given for why the MLP is expected to perform better than a conventional model in this case. A further study gives results on the performance of an MLP and a SV model in predicting the volatility of the Dollar-Deutschmark exchange rate and a combination of both models is proposed to decrease the forecasting error.

Vigfusson, Robert (1996), "Switching Between Chartists and Fundamentalists: A Markov Regime-Switching Approach", *Bank of Canada Working Paper*, no. 96-1 (January)

Since the early 1980s, models based on economic fundamentals have been poor at explaining the movements in the exchange rate (Messe 1990). In response to this problem, Frankel and Froot (1988) developed a model that uses two approaches to forecast the exchange rate: the fundamentalist approach, which bases the forecast on economic fundamentals, and the chartist approach, which bases the forecast on the past behaviour of the exchange rate. This was an innovation, as only the fundamentalist approach had been used before. A feature of the chartist-and-fundamentalist (c&f) model is that these two approaches' relative importance varies over time. Because this weighting is unobserved, the c&f model can not be estimated or tested using standard techniques. To overcome these difficulties and to test the model, the author uses Markov regime-switching techniques. He defines the two groups' different methods of forecasting as regimes and rewrites the c&f model as a regime-switching model. The model is then used to test for c&f behaviour in the Canada-U.S. daily exchange rate between 1983 and 1992. The author finds favourable though inconclusive evidence for the c&f model and accordingly makes suggestions for further research.

Wei, Jason (1996), "A Nonparametric Test of Monthly Seasonality for International Stock Markets", University of Saskatchewan, College of Commerce, working paper, January

The objective/contribution of this study is five-fold: 1) to propose a well-known nonparametric test which has not been widely used in the seasonality literature before, namely, the Friedman's test; 2) to test for seasonality for major international indexes; 3) to find out if dividend yields cause/exhibit seasonalities; 4) to determine if seasonality is "transferable" through currency translations; and 5) to uncover seasonalities for the "world market" by using the world stock index.

Using the Morgan Stanley Capital International indexes for 19 local markets plus the world index, the study performs various tests for monthly seasonality. The major findings include: 1) general seasonalities exist in some of the international markets, and dividend yields do not exhibit/cause seasonalities; 2) seasonalities in local markets tend to disappear when measured in U.S. dollars because of exchange rate fluctuations, and stable exchange rates (e.g. Hong Kong dollar vis-à-vis the U.S. dollar) do preserve seasonality (if any); 3) most markets have significant higher returns in January and December and significantly lower returns in September; for the world market, May also has a lower return, which leads to what I call a "trapezoid effect"; and 4) the tax-loss-selling hypothesis is rejected for all markets.

Wei, Jason (1996b), "*Seasonality in Holding Period Returns*", University of Saskatchewan, working paper, July

The focus of the extant stock market seasonality literature has been on the natural calendar intervals, such as day of the week or month of the year, and a month is the longest holding period that has been looked at. Using monthly indexes for ten local markets and the world market, this paper uncovers seasonalities of a different form. Specifically, it finds that seasonalities also exist for holding periods longer than a month. Indeed, seasonalities are detected for holding periods ranging from one month to eleven months. For example, for a six-month holding period, December or November are the best times to start the investment, while May or June are the worst times. The average difference (across the ten local markets) in annualized returns between the two investment periods is 23.8%! Moreover, the following intra-year pattern is found: January and December have the biggest one month growth; most of the growth within a year occurs between January and August; and the markets either are sluggish or decline between August and November.

Womack, Kent (1996), “Do Brokerage Analysts’ Recommendations Have Investment Value?”, *Journal of Finance*, vol. 51, no. 1 (March), pp. 137-167

An analysis of new buy and sell recommendations of stocks by security analysts at major U.S. brokerage firms shows significant, systematic discrepancies between pre-recommendation prices and eventual values. The initial return at the time of the recommendations is large, even though few recommendations coincide with new public news or provide previously unavailable facts. However, these initial price reactions are incomplete. For buy recommendations, the mean post-event drift is modest (+2.4%) and short-lived, but for sell recommendations, the drift is larger (-9.1%) and extends for six months. Analysts appear to have market timing and stock picking abilities.

Youssefmir, Michael, Bernardo Huberman & Tad Hogg (1998), “Bubbles and Market Crashes”, *Computational Economics*, vol. 12, no. 2 (October), pp. 97-114

We present a dynamical theory of asset price bubbles that exhibits the appearance of bubbles and their subsequent crashes. We show that when speculative trends dominate over fundamental beliefs, bubbles form, leading to the growth of asset prices away from their fundamental value. This growth makes the system increasingly susceptible to any shock, thus eventually precipitating a crash. We also present computer experiments which in their aggregate behavior confirm the predictions of the theory.

Zaffaroni, Paolo (1995), “A Nonlinear Model of ‘Persistence’ in Volatility”, *Proceedings of the First International Conference on High Frequency Data in Finance, Zürich, 29-31 March*, vol. 3

It has long been suspected that variances and covariances for speculative prices change over time, in particular showing serial “strong dependence”. This mirrors the fact that, in the levels, price changes appear to be uncorrelated (i.e. the “efficient market-martingale” hypothesis). The need to build in these two features together compel the use of an econometric model which is nonlinear, to express the second feature, with “strong dependence”, to represent the first feature. In explaining nonlinear financial time series ARCH models (Engle 1982) have proved popular in part due to their tractability relative to many other nonlinear time series models. Unfortunately, the degree of serial dependence decays too fast or, in other words they exhibit no “long memory”. This gap has been filled by ARCH-type models capable of displaying long-memory in the “squared” process (Robinson 1991; Baillie, Bollerslev & Mikkelsen 1993). Rigorous derivation of the asymptotical properties of its estimators (based on maximum likelihood framework) appear very difficult, even for the simplest cases, where one such model is nonstationary.

Here we propose a different kind of nonlinear model, characterized by the ability to display “long memory” in the squares, yet uncorrelatedness in the levels together with stationarity. The asymptotic analysis is developed in the frequency domain, based on a pseudo-maximum likelihood framework. We show the consistency and asymptotic distribution for the pseudo-maximum likelihood estimator. An application to foreign exchange rate data is considered.

Zhou, Bin (1996b), “Forecasting Foreign Exchange Rates Subject to De-Volatilization”, Chapter 3 in Christian Dunis, ed. (1996), “*Forecasting Financial Markets: Exchange Rates, Interest Rates and Asset Management*”, John Wiley & Sons, Chichester, England, pp. 51-67; revised version of paper in *Proceedings of the First International Conference on High Frequency Data in Finance, Zürich, 29-31 March 1995*, vol. 4

There is considerable literature analyzing the behavior of exchange rates. However, the modeling and forecasting of exchange rates has not been very successful. One of the obstacles to effective modeling of financial time series is heteroscedasticity. The recent availability of high frequency data, such as tick-by-tick data, provides us with extra information about the market. However, even with today’s computer power, analyzing data with order of gigabits is extremely expensive and time consuming. This article



proposes to analyze a homoscedastic subsequence of such data. The procedure of obtaining such a homoscedastic subsequence is called de-volatilization. The empirical evidence suggests that de-volatilization can help us to detect trends of the market quickly. Empirical results indicated that there are many short term trends in exchange market.

Zhou, Chunsheng (1996), "Forecasting Long- and Short-Horizon Stock Returns in a Unified Framework", *Board of Governors of the Federal Reserve System, Finance and Economics Discussion Series*, no. 96-4 (January)

If stock prices do not follow random walks, what processes do they follow? This question is important not only for forecasting purposes, but also for theoretical analyses and derivative pricing where a tractable model of the movement of underlying stock prices is needed. Although several models have been proposed to capture the predictability of stock returns, their empirical performances have not been evaluated. This paper evaluates some popular models using a Kalman Filter technique and finds that they have serious flaws. The paper then proposes an alternative parsimonious state-space model in which state variables characterize the stochastic movements of stock returns. Using equal-weighted CRSP monthly index, the paper shows that (1) this model fits the autocorrelations of returns well over both short and longer horizons and (2) although the forecasts obtained with the state-space model are based solely on past returns, they subsume the information in other potential predictor variables such as dividend yields.

Zumbach, Gilles (1998), "Considering Time as the Random Variable: The First Hitting Time", Olsen & Associates, Zürich, working paper, 15 January

The usual point of view when analyzing time series is to consider quantities for a given fixed time interval. Yet, one can adopt the opposite point of view, namely that the quantity is fixed and the time interval is the random variable of interest. This reverted point of view leads us to study the first hitting time and the first exit time. We are studying the probability density  $P(t|r)$ , that a given return  $r$  is reached for the first time after an elapsed time  $t$ . This probability density is being computed for the FX market, for a GARCH(1,1) process and for a Gaussian random walk. In particular, this study is showing the region in which the probability density does not scale and exemplify the large event region.