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Mathematische Stochastik
(Finance and Statistics)

07.03.-13.03.1999

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7.3. - 13.3. 1999

This meeting was organized by H. Dette (Bochum), D.C. Heath (Carnegie-Mellon, Pittsburgh) and M. Schweizer (TU Berlin). It was attended by 43 participants from all over the world.

The talks covered a very broad spectrum, ranging from stochastic analysis over applied problems to asymptotic theory in mathematical statistics.

During the course of the week, the following three topics emerged as important areas of present and future research:

- modelling of financial asset price processes
- parametric and nonparametric estimation problems for stochastic processes arising in finance
- management of risks by developing new methods in extreme value theory

The question of appropriate models for the price evolution of financial assets was discussed from several viewpoints. These included looking at the microstructure of prices by analyzing trade-by-trade data, studying links to turbulence, and detecting and describing long range dependence and heavy-tailedness properties. Questions raised by finance applications also turned out to be a rich source of new statistical problems. One major direction discussed in this context concerned the estimation of parameters in partially observed diffusion models and its links to hidden Markov models. Other aspects included model checking for time series and nonparametric estimation of curves generated by financial data. A special evening session was devoted to very recent developments in computer-based methods for statistical analysis.

Most of the talks were very well attended. The schedule deliberately allowed for fewer but longer presentations and this prompted many lively and stimulating discussions. A lot of new scientific contacts were formed, initiating quite a number of collaborations. All the participants agreed that the initial goal of bringing together researchers from finance and statistics to enhance future interaction has been successfully achieved.

Abstracts of given talks

Finance and Turbulence

O. E. Barndorff-Nielsen, Aarhus University

First a discussion was given of similarities and differences between main stylized facts concerning observational series from finance and turbulence. This was followed by an overview of some recent and ongoing work aimed at constructing models that capture the stylized features. The models in question build on background driving Lévy processes and generalized hyperbolic laws. (work joint partly with N. Shephard, partly with P. Blæsild.)

The Generalized Hyperbolic Model: Lévy Processes in Finance

E. Eberlein, University of Freiburg

Statistical analysis of data from the financial markets shows that generalized hyperbolic (GH) distributions allow a more realistic description of asset returns than the classical normal distribution. GH distributions contain as subclasses hyperbolic as well as normal inverse Gaussian (NIG) distributions, which have recently been proposed as basic ingredients to model price processes. We introduce a model driven by a Lévy process, which is generated by the GH distribution. An option pricing formula is derived and the resulting prices are compared to Black-Scholes prices. We examine the consistency of our model assumptions with the empirically observed price processes from various points of view. We also discuss modelling of interest rates based on driving Lévy processes.

Extreme Value Theory as a Risk Management Tool

P. Embrechts, ETH Zürich

Consider the following problems:

i) the estimation of an attachment point in an excess-of-loss reinsurance treaty; i.e. $u_t = F^{\leftarrow}(1-1/t)$ for a t-year event and loss distribution function F;

ii) the estimation of a t-day Value-at-Risk at level α for a financial portfolio ($\mathrm{VaR}_\alpha(t)$) and the conditional VaR measure $E(X|X > \mathrm{VaR}_\alpha(t))$.

Both problems can be analyzed using extreme value theory. Under specific data assumptions (i.i.d. in case i), AR(1) and GARCH(1,1) for ii)) this will be exemplified. A summary of the underlying mathematical (in some cases open) problems will be given.

Nonparametric Stochastic Volatility Models

J. Franke, University of Kaiserslautern

We consider nonparametric approaches to describe stochastic volatility in financial time series. Two of the main goals we have in mind are the development of exploratory statistical methods which allow for selecting appropriate parametric stochastic volatility models and the construction of tests for parametric hypotheses against general nonparametric alternatives. One of the models we study in detail is a nonlinear heteroskedastic autoregression $X_{t+1} = m(X_t) + \sigma(X_t)\ \varepsilon_{t+1}$. We derive a bootstrap approximation for kernel estimates of m and, in particular, of the volatility function σ which holds uniformly. As an immediate consequence, uniform confidence bands for m, σ and tests of parametric hypotheses (e.g. $m \equiv 0,\ \sigma^2(x) = \alpha_0 + \alpha_1 x$, i.e. X_t is ARCH(1)) based on supremum-type statistics may be constructed using the bootstrap. As a second model, we discuss a stochastic volatility model which may be reduced by a simple transformation to $X_t = \xi_{t-1} + \eta_t$, $\xi_t = m(\xi_{t-1}) + \varepsilon_t$, where $\xi_t = \log \sigma_t$ is the log-volatility process. This model includes various parametric stochastic volatility models from the literature. We construct a deconvolution kernel estimate for m and prove its consistency. The talk is based on joint work with W. Härdle, J.-P. Kreiss and E. Mammen.

A Nonlinear Filtering Approach to Volatility Estimation in Discretely Observed Volatility Models

R. Frey, ETH Zürich

We consider models for asset price fluctuations where asset price changes occur only at discrete, random points in time (the jump-times of a conditional Poisson process). Both jump size and jump intensity depend on an underlying unobservable Markov process. In economic terms this state-variable process can be interpreted as the rate at which new information is absorbed by the market.

We consider the problem of determining recursively the conditional distribution of the state-variable process given past price information; this leads to some new results in the filtering of marked point processes. A simulation study is carried out in order to obtain information about the performance of the method. (Joint work with W. Runggaldier)

Web Based Statistics

W. Härdle, Humboldt University, Berlin

Statistics is considered to be a difficult science since it requires a variety of skills including handling of quantitative data, graphical insights as well as mathematical ability. Yet ever increasing special knowledge of statistics is demanded since data of increasing complexity and size need to be understood and analyzed. Although this changing demand on educated statisticians is visible, our methods of teaching statistics follow essentially the ideas developed by our grandfathers in the fifties. An attractive and powerful new way of incorporating today's and future demands is via tools based on an intra- or the internet. In this talk we suggest a set of criteria for effective web based teaching and propose the first web based approach to meet these criteria.

Minimal Description Risky Asset Models with Heavy Tails and Strong Dependence

C. Heyde, Australian National University and Columbia University

This talk was concerned with the search for the simplest variant on the geometric Brownian motion model for the price of a risky asset which incorporates the features necessitated by the recently obtained statistical evidence. These include leptokurtic tails, heteroskedastic conditional variances, long range dependence of absolute values and squares of the log returns but not of the log returns process itself, and aggregational Gaussianity. The proposed model, which incorporates these features, can be thought of as geometric Brownian motion with a fractal activity time replacing the usual clock time.

Branching Particle Systems: Nonparametric Estimation of the Branching Rate

R. Höpfner, University of Paderborn

We consider finite systems of particles travelling on diffusion paths and branching at a position-dependent rate according to a position-dependent reproduction law. We define a local time for the process of particle configurations and specify its asymptotics with the help of a Tanaka formula. Under assumptions on the concentration of an invariant measure we deduce from this the asymptotics of kernel estimates for the spatially dependent branching rate.

On Equivalent Martingale Measures and Classical Asymptotic Statistics for Generalized Hyperbolic Distributions

F. Hubalek, Vienna University of Technology

The first part of the talk deals with the situation that the asset return process is under the given probability measure a generalized hyperbolic (GH) Lévy process. Whereas in discrete time any combination of parameters is possible, there is less freedom for continuous time. In particular, the GH option prices do not cover the maximal interval in the sense of Eberlein and Jacod (1997).

In the second part I want to discuss finite samples and asymptotic properties of some estimators for the GH distribution and summarize (hopefully with the help of the participants) the existing literature on this subject.

Particular emphasis is given to three subfamilies of the GH distribution proposed recently in finance, namely the hyperbolic, the normal inverse Gaussian, and the (asymmetric) variance gamma distribution.

Martingale Representation: Explicit Form and Robustness

J. Jacod, University of Paris VI

The aim of this work is to give conditions on a sequence of martingales X^n and of random variables U^n which can be written as $U^n = \alpha_n + \int_0^1 \xi^n_s dX^n_s + N^n_1$ (where ξ^n is predictable and N^n is a martingale orthogonal to X^n), so that $\xi^n \to \xi$ when $U = \alpha + \int_0^1 \xi_s dX_s + N_1$.

There are two kinds of results: "strong" results when $X^n \to X$ and $U^n \to U$ in the L^2 sense, and then $\xi^n \to \xi$ in measure w.r.t. a suitable measure.

Then we have "weak" results, in which the assumptions are that $X^n \to X$ in law and $U^n = F(X^n)$, $U = F(X)$ where F is a function on the path space, with some smoothness (at least continuity) assumptions.

This is joint work with S. Méléard and P. Protter.

Statistical Problems for the Geometric Brownian Motion

A. Janssen, University of Düsseldorf

The extended geometric Brownian motion

$$\exp\left(\int_0^t h\ dB - \frac{1}{2}\|h\ \mathbf{1}_{[0,t]}\|_2^2\right), \quad 0 \leq t \leq 1,$$

is a basic model as well in mathematical finance as in asymptotic statistics. The present talk summarizes some recent developments for this statistical model from the point of view given by testing statistical hypotheses. The model is the limit model for nonparametric survival models and testing goodness of fit problems. It is shown that every level α test prefers a finite number of orthonormal directions. Turning to level points we have a similar result which holds uniformly w.r.t. the sample size n. As special examples Kolmogorov-Smirnov type tests are discussed and their main preference direction is approximated.

The Risk in Credit Spreads

R. Kiesel, Birkbeck College, University of London

In this talk we investigate the empirical behaviour of credit spreads for different rating categories of corporate bonds. In particular we are interested to investigate the volatility of time-lagged differences to obtain a term-structure of volatility of credit spreads (which is taken to be flat in the usual modelling approaches). Using a variance-ratio type estimator we estimate a volatility profile, which shows that volatility varies in time as well as over rating strategies. We then use the improved volatility estimate to improve risk estimates for corporate bond portfolios.

Managing Financial Risk: Value-at-Risk etc.

C. Klüppelberg, Technical University, München

Financial risk is concerned about losses, i.e. it can be measured by so-called lower partial moments of the profit-loss distribution of a portfolio. Thus stochastic quantities of interest are quantiles (leading to the benchmark measure Value-at-Risk = mean-quantile), expected shortfall or semivariance. We investigate various questions w.r.t. such modern risk measures:

Extreme value methods are applied to estimate such risk measures from data. These are standard methods for i.i.d. data, for more complex financial models such as diffusions or ARCH-like models new results on the extremal behaviour are needed. We derive such results. We also solve a continuous-time portfolio selection problem that consists of maximizing expected terminal wealth under the constraint of an upper bound for the Value-at-Risk. In a Black-Scholes model we obtain an explicit solution, which can be compared to the classical Markowitz mean-variance problem.

This is joint work with M. Borkovec (TU München) and R. Korn (Mainz).

Value Preserving Portfolio Strategies

R. Korn, University of Mainz

We present a new framework for portfolio optimization when stock prices are given by general semimartingales. Instead of maximizing the expected utility of consumption and/or terminal wealth the aim is to look for "good" choices of the portfolio value process and the portfolio return process. For the special choice of the requirement of a constant portfolio value process, we give existence and uniqueness results for so-called value preserving portfolio strategies. Especially, their explicit forms are given in detail.

Stochastic Differential Delay Equations: Modelling and Statistical Aspects

U. Küchler, Humboldt University, Berlin

Stochastic differential delay equations have almost never explicit solutions. They are complicated to treat, but they have many practical applications: many phenomena in nature and economics include time delays which cannot be ignored. Linearizations around equilibrium points lead to so-called affine or linear differential equations with time delay. For affine equations ("Ornstein-Uhlenbeck processes with memory") a general method of treatment is presented. It is based on the Laplace transform of the fundamental solution and known from the theory of deterministic delay equations. The application to the stochastic case leads to new results concerning the existence of stationary solutions, the asymptotic behaviour of maximum likelihood estimators of the coefficients and the length of the memory.

The results presented in the talk are based on common work with A. Gushchin (Moscow) and Y. Kutoyants (Le Mans).

Nonparametric Estimation by Observations of Ergodic Diffusion Processes

Y. Kutoyants, University of Le Mans

The model of observations is a diffusion process $dX_t = S(X_t)dt + \sigma(X_t)dW_t$, where $\sigma(.)$ is a known positive function, $S(.)$ is unknown and both coefficients are such that there exists an invariant measure. We consider the problem of invariant distribution function and density estimation. In these problems we propose lower minimax bounds on the risk function of any estimator and then show that in the first problem the empirical distribution function is an asymptotically efficient estimator. In the second problem we propose several asymptotically efficient estimators. The first one is a local-time estimator, others are a wide class of unbiased estimators and kernel-type estimators. For the local-time estimator we have weak convergence (as a process) to the limit Gaussian process as well. The integral-type bound is constructed and the asymptotic efficiency of this estimator is established. Some parametrical problems of the density estimation are also treated.

Statistical Inference for Discretely Observed Stochastic Volatility Models

C. Larédo, INRA, Jouy-en-Josas

We consider a two-dimensional diffusion process (Y_t, V_t) where only (Y_t) is observed at n discrete times with regular sampling interval Δ. The unobserved coordinate (V_t) is ergodic and rules the diffusion coefficient (volatility) of (Y_t). In previous works (Genon-Catalot, Jeantheau and Larédo, Bernoulli 98, 99), we have investigated the problem of estimating unknown parameters in the drift and diffusion coefficients of (V_t) in the asymptotic framework $\Delta \to 0$.

We are concerned now with the case of a fixed sampling interval. This approach is complementary to the former one and enables to relate the role of Δ in the estimation procedures. We first study the ergodicity and mixing properties of $(Y_{i\Delta})$. For this, we prove that our observations can be viewed as a hidden Markov model, and that they inherit the mixing properties of (V_t). Therefore, we present a thorough review of these properties for one-dimensional diffusion processes and give some simple and explicit conditions on the drift and diffusion coefficients of (V_t) which characterize these properties. We then study empirical estimators and prove limit theorems for functions of $(Y_{i\Delta}, ..., Y_{(i+k)\Delta})$. This leads to consistent and asymptotically normal estimators of all the parameters in the (V_t)-model at rate $\sqrt{n}$. Examples coming from finance are fully treated. We focus on the asymptotic variances and establish the links with the case of a small sampling interval studied in previous works.

Estimating Yield Curves by Kernel Smoothing Methods

E. Mammen, University of Heidelberg

We introduce a new method for the estimation of discount functions, yield curves and forward curves from government issued coupon bonds. Our approach is nonparametric and does not assume a particular functional form for the discount function although we do show how to impose various restrictions in the estimation. Our method is based on kernel smoothing and is defined as the minimum of some localized population moment condition. The solution to the sample problem is not explicit and our estimation procedure is iterative, rather like the backfitting method of estimating additive nonparametric models. We establish the asymptotic normality of our methods using the asymptotic representation of our estimator as an infinite series with declining coefficients. The rate of convergence is standard for one-dimensional nonparametric regression. The talk reports on joint work with O. Linton, J.P. Nielsen and C. Tanggaard.

Asymptotic Equivalence of Statistical Experiments: Recent Developments

M. Nussbaum, Weierstrass Institute, Berlin

We introduce the notion of asymptotic equivalence of statistical experiments, starting from the concept of sufficiency. When the law of the sufficient statistic can be approximated in total variation, this gives rise to a concept of asymptotic equivalence. The idea can be formalized by introducing Markov kernel randomizations of families of laws, leading directly to the definition of Δ-distance (deficiency distance) by Le Cam. In the case of discrete laws of sufficient statistics converging weakly to a Gaussian limit, we discuss appropriate Markov kernels which amount to smoothing operations. The LAN-paradigm or Le Cam theory is briefly discussed in this context, which uses the likelihood process methodology to obtain local limits of experiments in Δ-distance. The subject proper of this survey talk are nonparametric models like density estimation from i.i.d. data and nonparametric regression. We discuss asymptotic equivalence of these models to signal estimation in Gaussian white noise, furthermore discretization of SDE models with small noise, Gaussian stationary sequences with unknown spectral density and ergodic nonparametric autoregression. For the i.i.d. density model, the equivalence to signal-in-white-noise can be realized in a constructive way. A finance related example is presented (discretely observed geometric Brownian motion with unknown volatility function).

Modelling Financial Markets

E. Platen, University of Technology, Sydney

Despite many attempts, the consistent and global modelling of financial markets remains an open problem. In particular it remains a challenge to find a simple and tractable economic and probabilistic approach to market modelling. The talk attempted to highlight fundamental properties that a market model should have. Assuming these properties, which include the relativity principle and the principle of market risk minimization, it is possible to establish a corresponding interactive stochastic market dynamics that involves a minimal number of factors. Several interesting properties related to stochastic volatility, market index and interest rate dynamics can be derived. Empirical evidence that supports the Minimal Market Model (MMM) has been given for market indices, discounted stock prices and drift and diffusion coefficient functions of these. The well-known leverage effect for market indices appears as a natural feature of the MMM.

The Client/Server System XGPL/Xtremes: With a View Towards Financial Data

R.-D. Reiss, University of Siegen

A demo of a statistical computing environment is given in the form of a case study. The data to be analyzed are the Yen/US Dollar exchange rates from Dec. 78 to Jan. 91. We demonstrate and apply the POT (peaks-over-threshold) method which concerns the local fitting of a parametric distribution to the lower/upper part of data, to the log returns of the exchange rates. The parametric approach enables the extrapolation of the empirical insight beyond the range of the data. An important application is the estimation of very low quantiles which entails an estimation of the VaR (value-at-risk). The performances of the Dekker et al. moment estimator and that of the Hill estimator of the shape parameter within the GP (generalized Pareto) model are compared by using a graphical program within the XGPL environment. The conclusion is that the Hill estimator should not be used in applications.

XGPL is scheduled as a general graphical programming language in statistics whereby nodes for extreme value procedures are provided by Xtremes. This project is joint work with M. Thomas (Siegen).

Robust Hedging of Derivatives

L.C.G. Rogers, University of Bath

Let S_t be the price of some share at time t, $\bar{S}_t \equiv \sup_{w \leq t} S_w$, and $C(K) \equiv E(S_1 - K)^+$ the price of a call of strike K, expiry 1. We assume throughout that interest rates are zero. In keeping with other recent work, we regard the price of all calls as given, in that the market prices them. We then ask what bounds can be established for the price of a derivative, assuming *only* that $E(S_1 - K)^+ = C(K)$, so S may be *any* martingale with this property. It turns out that upper and lower bounds may be calculated for various options, including barriers, and that the derivation leads to non-trivial quasi-static super- and sub-replicating strategies. These bounds can be quite good in parts of the range of the parameters. The method is to identify the problem as a suitable linear programming problem. (Joint work with D. Hobson and H. Brown, Bath)

Dynamics of Trade-by-Trade Price Movements: Decomposition and Models

N. Shephard, Nuffield College, Oxford

In this paper we introduce a decomposition of the joint distribution of price changes of assets recorded trade-by-trade. Our decomposition means that we can model the dynamics of price changes using quite simple and interpretable models which are easily extended in a great number of directions, including using durations and volume as explanatory variables. Thus we provide an econometric basis for empirical work on micro market structure using time series of transactions data.

We use maximum likelihood estimation and testing methods to assess the fit of the model to a year of IBM stock data taken from the New York Stock Exchange.

Estimating Functions for Stochastic Volatility Models

M. Sørensen, University of Copenhagen

A generalization of martingale estimating functions was presented that is useful when there is no natural or easily calculated class of martingales which can be used to construct a family of estimating functions. This is the case for stochastic volatility models. Other model types for which the new estimating functions can be used are sums of Ornstein-Uhlenbeck processes or diffusion compartment models. It was demonstrated that the new type of estimating functions, called prediction-based estimating functions, has most of the nice properties of the martingale estimating functions. Particular attention was given to prediction-based estimating functions given by a finite-dimensional space of predictors. For this case a simple expression was found for the optimal estimating function, and conditions ensuring consistency and asymptotic normality of the estimators were given.

Goodness-of-Fit Tests in ARCH Models

W. Stute, University of Giessen

ARCH models are often used to incorporate heteroskedastic effects in financial time series. Much work has been devoted to the statistical analysis of the parameter estimators. In this talk we focus on the nonparametric component, namely the distribution of the multiplicative innovations. As an application of our main result, we study a nonparametric test of symmetry.

Stock Market Indices and Long-Range Dependence

M. S. Taqqu, Boston University

Using daily stock return data, we revisit the question of whether or not actual stock market prices exhibit long-range dependence. The study is based on the modified R/S statistic proposed by Lo, as a test for long-range dependence with good robustness properties under "extra" short-range dependence. The main conclusion is that because the modified R/S statistic shows a strong preference for accepting the null hypothesis of no long-range dependence, irrespective of whether it is present in the data or not, Lo's acceptance of the hypothesis that the stock return data he looked at had no long-range dependence is less conclusive than is usually regarded in the econometrics literature. In fact, upon further analysis of the data, we find empirical evidence of long-range dependence, but because its degree is typically very low (H-values around 0.60), the evidence is not absolutely conclusive.

Nonparametric Specification Procedures for Time Series

Dag Tjøstheim, University of Bergen

A brief overview was given over recent work in linearity testing, independence testing and additivity testing. The emphasis was on presenting the unifying principles. I also mentioned some new work on nonparametric estimation in a nonstationary environment, an essential ingredient being Markov theory of null recurrent chains, and in particular use of the split chain technique.

Efficient Estimation in Autoregressive Models

W. Wefelmeyer, University of Siegen

We consider the nonlinear heteroskedastic autoregressive model

$$X_i = m_\vartheta(X_{i-1}) + v_\vartheta(X_{i-1})^{1/2}\, \varepsilon_i,$$

with two types of innovations ε_i : (1) independent and identically distributed, and (2) Markovian martingale increments. We construct efficient estimators for (1) the parameter ϑ, and for (2) expectations $\pi f = \int \pi(dx) f(x)$ of functions f under the invariant distribution π of X_i. In the model with i.i.d. innovations, the efficient estimators are one-step improvements of appropriate initial estimators. The model with martingale increment innovations is close to nonparametric, and efficient estimators are simpler. For ϑ, a weighted least squares estimator

$$\sum \Big[\hat{w}_m (X_i - m_\vartheta(X_{i-1})) + \hat{w}_v ((X_i - m_\vartheta(X_{i-1}))^2 - v_\vartheta(X_{i-1})) \Big] = 0$$

is efficient; for πf, a correction of the empirical estimator of the form

$$\frac{1}{n} \sum f(X_i) - W_n$$

is efficient.

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