Managing Uncertainty Short Programme

23 July to 10 August 2001

Report from the Organisers: P Embrechts (ETH, Zurich), DJ Goodman (The Foundation for Science and Technology, London), WJ Fitzgerald (Engineering, Cambridge), RL Smith (University of North Carolina, Chapel Hill)

Scientific Background

Corporations and governments are making risk decisions based on perceptions of extreme values. Frequently these decisions are taken with an inadequate framework for handling low probability, high severity events drawn from non-stationary time series. These problems are very diverse and range from analysis of the stability of the UK economy, corporate governance issues, to the reinsurance purchase decision of a major insurer. Forecasts of future events must take into account possible changes in the structure of the underlying time series, including the possible impact of global changes in the environment.

This Short Programme brought together mathematicians, statisticians, economists and environmental scientists who specialise in the analysis of financial and environmental data. Particular attention was paid to mathematical models and statistical prediction tools for extreme events, and for handling nonstationarity. Specific problems include the calculation of Value at Risk in non-stationary time series, the development of alternative "measures of risk", incorporation of model uncertainty into statistical calculations, and the extensions to multivariate time series.

A series of open one-day workshops, concentrating on new techniques and their applications, provided interactions with the wider academic, financial, insurance and government communities. This Short Programme was a follow-up to two workshops on extreme events held during the Nonlinear and Nonstationary Signal Processing Programme held at the Newton Institute from July to December 1998.

A dinner/discussion was held with The Foundation for Science and Technology on 2nd August, 2001 with over 100 participants on the theme of managing uncertainty in the corporate context. The three speakers were Professor Myron Scholes (Stanford), Sir Ian Prosser (Chairman, Six Continents plc) and Dr David Allen (Executive Vice-President, BP plc).

Core Programme

The nineteen core-programme participants (and three student s) collaborated informally on a variety of aspects of extreme value and non-stationary time series analysis methods but also met together for formal seminars. Topics discussed in the seminars were:
Multivariate high risk scenarios
Volatility estimation in very high dimensions
Extreme value theory and internet auctions
Global asset liability management
Recent advances in the application of copulae to non -linear Value-at-Risk
Managing uncertainty and corporate governance
Market equilibrium with coherent measures of risk
General state space modelling and its applications to analysis of financial and economic time series
Real option games with incomplete information and learning spillovers
A characterization of multivariate regular variation
Nonparametric implied volatility: A single number based on no arbitrage.
Maximum likelihood estimation of non-Gaussian state space models including stochastic volatility models
Max-stable processes and value at risk
Nonstationarities in stock returns
Modelling financial data as a max-stable process

Workshops

Four one-day workshops were held on the estimation of risk, particularly for low probability, high severity events in insurance, finance, economics and environmental problems. One workshop was organised to discuss corporate governance issues at which executive and non-executive directors met with the core programme participants to discuss how companies and government organisations tackled risky decisions. Around fifteen extra participants joined the core group for each of the workshops.

Core participants presented at the workshops on a range of analysis methods and workshop participants presented case studies for which these methods might be applied. The case studies ranged very widely from electricity pricing, windstorm loss data, step jumps in the economy, tree ring analysis to signals passed at danger (SPADs) from the railway safety authority.

Outcome and Achievements

All the participants valued the special atmosphere of the Newton Institute and, because of the excellent facilities, the ability to work together during the programme on new problems. Three weeks is, however, only sufficient time to develop ideas rather than complete a study.

For many years, it has been widely recognised that financial time series display a number of characteristic properties, widely known as "stylised facts", which distinguish them from other kinds of time series:

· *They tend to be long -tailed, i.e. there is a higher frequency of very extreme events than would be expected with say normally distributed data;*

· *They tend to show long-range dependence, e.g. the autocorrelation function of the absolute log returns or squared log returns decays to zero at a much slower rates than conventional time series models such as ARMA;*
· *They exhibit volatility, i.e. the apparent variance of the log returns is not a constant but tends to fluctuate irregularly.*
The same phenomena tend to be observed in other contexts as well, e.g. insurance data, internet traffic data (not a theme of the Managing Uncertainty Programme, but containing many similar mathematical ideas). Earlier research has developed a number of tools for handling each of these properties on their own, e.g. extreme value theory and threshold methods for long-tailed data; Hurst coefficient and fractional ARIMA models for long-range dependence; GARCH and stochastic volatility models to handle variable volatility. However, the interplay among these different themes is only very imperfectly understood.
New research during the Managing Uncertainty programme helped shed insight on a number of aspects of the links among these three characteristic themes. Themes of study were:
· New mathematical techniques, based on the theory of stochastic recurrence equations, are being developed for analysing the asymptotic extreme value behaviour of GARCH and related models for volatile time series. These show, for example, that many of the apparent long-tailed properties of GARCH processes are a natural consequence of the structure of the process;
· Multivariate regular variation is being developed as a broad general tool for understanding dependence in long-tailed time series. It is also relevant in developing a theory of "high-risk scenarios", i.e. what we can say about the values of a multivariate random variable conditional on the information that it lies in an extreme subset. The mathematical analysis of multivariate regularly varying functions continues to develop, and has proved to be a valuable tool in developing statistical models for multivariate extremes.
· New research has shown that apparent "long-range dependence" can arise in time series displaying a standard volatility structure (such as GARCH) but with an additional assumption of "regime changes", which are linked to nons tationarity. This is relevant to the applied themes of the programme because although long-range dependence is widely observed as an empirical phenomenon, there is no satisfactory economic theory to explain it. In contrast, both volatility and the notion of a long-term instability in the basic parameters of the process are phenomena that are widely observed (and which recent research has confirmed, for example in analysis of the S&P 500 Index data) and therefore much easier to explain;
· Alternative models involving multivariate extreme value theory are being developed and are proving successful for explaining the dependence among tail values offinancial time series;
· Within the theme of nonstationary time series, further work (since the 1998 Newton Institute programme on "nonlinear and nonstationary signal processing") has led to a number of new developments, including much new work on the "particle filters" approach and refinement of Markov Chain Monte Carlo (MCMC) methods. For example, particle filter methods have been applied to the problem of earthquake forecasting in Japan;
· Another way to combine the themes of long-tailed distributions and nonstationarity is through "generalised additive modelling for extremes", which allows for a random process to behave locally (in any short time interval) like a stationary extreme value process, but for the parameters of that process to change over time. New methods for fitting these models were presented and discussed during the programme.
Although the programme was only of three weeks duration and therefore too short for many new papers to be written during the programme, it is likely that over the next 2-3 years,

numerous papers will appear which were in some way influenced by the programme. As a specific example, three of the core participants (Mikosch, Smith and Embrechts) subsequently participated in the "SEMSTAT" (European statistics research group) meeting on extreme values that took place in Gothenburg during December 2001. The proceedings of that meeting are being published as a monograph in the Chapman and Hall statistics series. At least a dozen other research papers were in some way stimulated by discussion during the programme and are likely to acknowledge the Newton Institute.

Conclusion

The gap between theory and application is wide. Many workshop participants found it difficult to see how the theories presented by the core group could be applied in the real world. Nevertheless real progress was made in developing theoretical aspects of extreme value theory and nonstationary time series analysis. Many new papers were stimulated by the programme. The workshop participants were stimulated to find out more about the methods discussed – one success was the adoption by Railway Safety of a new method for analysing Signals Passed at Danger (SPADs).

For further details of the programme please contact Dr Dougal Goodman. The support of the British Antarctic Survey, an NERC Research Institute, the staff of the Newton Institute and the following for financial support – BP, Benfield Greig, Faraday, McKinsey & Co., the Newton Institute, Royal & SunAlliance, Schlumberger and TXU Europe Trading – is gratefully acknowledged.

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