Chapter One

Introduction

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1.1 EXTREMES

When I started to study extreme events in finance just after the stock market crash of October 1987, academic studies considered such events as outliers. It meant that the data associated with extreme events in financial markets were considered as abnormal and were discarded in empirical works. A few decades later, I am more than happy to edit a collective book about extreme events in finance.

Over the past decades, extreme value theory (EVT) has shown that we are gaining a better understanding of the statistical behavior of extreme movements of financial asset prices. Moreover, the understanding of the behavior of the market during extreme events is also useful for understanding the whole behavior of the market, both under ordinary and extraordinary conditions. In other words, it is a mistake to separate extreme events from other events. In fact, this could be a universal truth touching many aspects of society including business, politics, and religion.

This book is a *collective* work: it gathers 25 chapters written by more than 40 contributors from all over the world. This book is *diverse* in terms of contributors: it includes academics and practitioners from banks, fund management firms, insurance companies, and central banks. This book is also *open minded* in terms of areas: while most of the chapters deal with EVT and its applications in finance and insurance, it also includes professional expressions, reflection on modeling issues, and time.

This book is about extreme events in finance with an emphasis on EVT. It gives all the necessary information (theoretical results and estimation methods) to apply the techniques to financial problems. It also provides useful information about financial problems where extremes matter from different points of view: academics who applied EVT in finance (mainly risk management and portfolio

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management) and also practitioners who experienced extreme events in their working life. The objective of this book is to offer a comprehensive overview in terms of both methods and problems.

I would also like to mention the website that has been created to support this book: http://extreme-events-finance.net/ where you will find additional resources: information about events such as workshops and conferences, an interactive blog, a community open to academics, practitioners, and investors.

The book is organized as follows: history, EVT, statistical estimation of extremes, applications in finance, practitioners' points of view, and a broader view on modeling.

1.2 HISTORY

The book starts with two chapters about history.

Ross Leadbetter (University of North Carolina at Chapel Hill) in his chapter "Extremes Under Dependence: Historical Development and Parallels with Central Limit Theory," looks back at the theoretical developments of EVT, beyond well-known results for the independent identically distributed case. Ross shares with us the secrets of the development of all these results that are so useful today in applications of EVT in finance. Very interestingly, you will learn the relation of EVT with another fundamental field in statistics: central limit theory (CLT).

Christian Walter (Ethics and Finance Chair at Fondation Maison des Sciences de l'Homme) will, in the third chapter, "The Extreme Value Problem in Finance: Comparing the Pragmatic Program with the Mandelbrot Program," bring you back to the history of financial modeling. Should we use a diffusion process, a jump process, or a mixed diffusion process to describe the behavior of financial asset prices?

1.3 EXTREME VALUE THEORY

After these historical developments in statistics and financial modeling, Isabel Fraga Alves (CEAUL & University of Lisbon) and Cláudia Neves (University of Reading), in their chapter "Extreme Value Theory: An Introductory Overview," lay down in a very clear and well-illustrated way the fundamental results of EVT, both in the univariate case and the multivariate case. They start from the first results found in the middle of the twentieth century by Gumbel, Fréchet, Weibull, Gnedenko, and others, and finish with references for further reading about the most recent research in the field.

1.4 STATISTICAL ESTIMATION OF EXTREMES

From the theoretical results presented in the chapter by Isabel Fraga Alves and Claudia Neves, we learned that the behavior of extremes is well known and can be modeled by the extreme value distribution. The key parameter of this distribution is the tail index, also called the extreme value index. Jan Beirlant, K. Herrmann and Jozef Teugels (KU Leuven), in their chapter "The Estimation of the Extreme Value Index" address the statistical estimation techniques for the tail index. This is a "must read" if you want to apply EVT to data.

Following this general presentation of the statistical issues in estimating the central parameter of the extreme value distribution (the tail index), Ivette Gomes (Universidade de Lisboa, FCUL, DEIO, and CEAUL), Frederico Caeiro (Universidade Nova de Lisboa, FCT and CMA), Lígia Henriques-Rodrigues (Instituto Politecnico de Tomar and CEAUL), and B.G. Manjunath (Universidade de Lisboa and CEAUL) present, in their chapter "Bootstrap Methods in Statistics of Extremes," the promising bootstrap approach. In particular, they address the critical issue of bias in the estimator with small samples.

In finance, the modeling of asset prices in continuous time has provided plenty of models. A critical choice is whether to model the path of an asset price as continuous or to introduce jumps. Olivier Le Courtois (EM Lyon Business School) and Christian Walter (Ethics and Finance Chair at Fondation Maison des Sciences de l'Homme) make the link, in their chapter "Lévy Processes and Extreme Value Theory," between Lévy processes and EVT. Some models proposed in the finance literature will belong to the domain of attraction of the Gumbel distribution (thin and semiheavy-tailed distributions), while other models will belong to the domain of attraction of the Fréchet distribution (fat-tailed distributions).

Patrice Bertail (modal X, Université Paris Ouest Nanterre La Défense et CREST), Stéphan Clémençon (Telecom ParisTech), and Charles Tillier (Université Paris Ouest Nanterre La Défense), in their chapter "Extreme Values Statistics for Markov Chains with Applications to Finance and Insurance," are interested in extremes for dependent processes. Such processes are important in finance because it is well known that volatility of financial asset prices is changing over time. The dependence in extremes (clustering) is modeled by an additional parameter called the extremal index.

Miguel de Carvalho (Pontificia Universidad Católica de Chile), in his chapter "Statistics of Extremes: Challenges and Opportunities," provides a personal overview of some recent concepts and methods for the statistics of extremes. Measure-dependent measures are presented as a natural probabilistic concept for modeling bivariate extreme values, and predictor-dependent spectral measures are introduced as a natural concept for modeling extremal dependence structures that vary according to a covariate. Families of g-tilted measures are presented as a unifying device connecting some recently proposed approaches. En passant, Miguel discusses a new estimator for the so-called scedasis density function.

Serguei Novak (Middlesex University, London), overviews available measures of financial risk in his chapter "Dynamic Measure of Financial Risk," and investigates a new risk measure. Traditional risk measures such as value-at-risk (VaR) and expected shortfall are rather static as they change slowly over time and do not necessarily take into account current market conditions. Using concepts related to technical analysis, Dr Novak proposes a dynamic risk measure that takes into account current market conditions.

Marie Kratz (ESSEC Business School, CREAR), in her chapter "On the Estimation of the Distribution of Aggregated Heavy Tailed Risks," proposes a sharp approximation of the entire distribution of independent aggregate risks. It is obtained by distinguishing two parts: a trimmed sum (taking away a small number of extremes) modeled by a normal distribution, and a Pareto distribution for the sum of extremes. When working on financial or insurance data under the presence of fat tails, it allows one to obtain the most accurate evaluations of risk measures, whatever the aggregation size. A direct application is for the sum of returns of different assets of a portfolio, when moving from daily to yearly returns.

Saralees Nadarajah and Stephen Chan (University of Manchester) provide a comprehensive review of estimation methods for VaR, in their chapter "Estimation Methods for Value at Risk." The properties of this well-used risk measure in finance are presented in detail: ordering properties, upper comonotonicity, aggregation of risks, risk concentration, and various inequalities. Furthermore, the authors provide an impressive list of useful references about VaR.

1.5 APPLICATIONS IN FINANCE

Wesley Phoa (Capital Group), in his chapter "Extreme Value Theory and Credit Spreads," gives a practical introduction to the use of EVT in modeling and managing credit portfolios. Using both univariate and multivariate EVT, Wesley computes VaR for credit portfolios using CDS.

Kam Fong Chan (The University of Queensland Business School) and Philip Gray (Monash University), in their chapter "Extreme Value Theory and Risk Management in Electricity Markets," emphasize the importance of risk management in financial markets and especially for nontraditional securities such as electricity markets. Such markets present episodes of extreme volatility rarely observed in equity markets, which make trading and hedging challenging issues. The authors show that EVT can then be a very useful tool in risk management.

Stefan Straetmans (Maastricht University) and Thanh Thi Huyen Dinh (Group de Lage Landen), in their chapter "Comparing Tail Risk and Systemic Risk Profiles for Different Types of US Financial Institutions," use EVT to propose innovative ways to measure risk in the banking sector. While risk is usually measured by variance or covariance, Stefan and Thanh use tail VaR to measure individual bank risk and a measure of extreme systematic risk (tail β) to capture systemic risk. Their approach allows one to answer various relevant questions: which institutions are the most sensitive to tail risk or systemic risk – deposit banks, broker-dealers, or insurance companies? Is there a relation between extreme risks and institutional size?

John Cotter (University College Dublin School of Business) and Kevin Dowd (Durham University Business School) explain in their chapter "Margin Setting and Extreme Value Theory" that extreme price movements are central to the setting of margins in futures markets and that EVT can play a very important role in setting margins at the appropriate level. Margin setting by the clearinghouse for each counterparty is one of the mechanisms to mitigate default risk. How should margin levels be set in practice? From a quantitative view, the margin level can be interpreted as a quantile of the distribution of price movements in futures contracts. The authors emphasize that the use of a normal distribution would lead to an underestimation of margin levels but that the use of the extreme value distribution would adequately estimate margin levels.

Geoffrey Booth (Eli Broad Graduate School of Management at Michigan State University) and John Paul Broussard (School of Business at Camden Rutgers, The State University of New Jersey) use EVT in their chapter "The Sortino Ratio and Extreme Value Theory: An Application to Asset Allocation," to improve the measure of performance of financial assets portfolios. They focus especially on the Sortino ratio, which considers the downside risk of portfolios.

Philippe Bertrand (University of Aix-en-Provence and Kedge Business School) and Jean-Luc Prigent (University of Cergy-Pontoise) propose, in their chapter "Portfolio Insurance: The Extreme Value Approach Applied to the CPPI Method," a straight-forward application of EVT to a well-known asset allocation method: portfolio insurance. Such a method allows one to provide a capital-guarantee for portfolios. When market prices are assumed to follow a continuous path and returns are normally distributed, portfolio insurance techniques work fine; the fund management firm that manages this product will succeed in delivering the guarantee. But in real markets characterized by jumps and fat-tailed distributions, portfolio insurance techniques may fail as the fund value may be below the guarantee level because of a market crash. Using the EVT allows a better risk management of such financial portfolios.

François Longin (ESSEC Business School), in his chapter "The Choice of the Distribution of Asset Returns: How Extreme Value Theory Can Help?" explains that one of the issues of risk management is the choice of the distribution of asset returns. Academics and practitioners have assumed for a long time that the distribution of asset returns is a Gaussian distribution. Such an assumption has been used in many fields of finance: building optimal portfolio, pricing and hedging derivatives, and managing risks. However, real financial data tend to exhibit extreme price changes such as stock market crashes that seem incompatible with the assumption of normality. This chapter shows how EVT can be useful to know more precisely the characteristics of the distribution of asset returns and finally help to choose a better model by focusing on the tails of the distribution. An empirical analysis using equity data of the US market is provided to illustrate this point.

Jean-Marie Choffray (ESSEC Business School and University of Liège) and Charles Pahud de Mortanges (University of Liège), in their chapter "Protecting Assets Under Nonparametric Market Conditions," share their experience as both academics and individual investors. They propose a concise set of heuristics aimed at conceptualizing response to the unknown, at connecting proven facts, and at identifying profitable investment opportunities when market states and events are not generated by continuous models – or probabilistic processes – that would render them amenable to mathematical analysis.

1.6 PRACTITIONERS' POINTS OF VIEW

Jean-François Boulier (Aviva) shares his experience in his chapter "EVT Seen by a Vet: A Practitioner's Experience on Extreme Value Theory," of applying statistical models to financial data: the Gaussian distribution, ARCH processes, and EVT. Jean-François situates the development of quantitative finance with the development of financial regulation and internal risk management in financial institutions. Related to extreme events, he discusses the concept of "stress scenarios," which complements the VaR measure. He argues that while models based on normality do their job of computing the VaR (associated with market shocks appearing every four years on average), EVT adds value for designing "stress scenarios" (associated with extreme market shocks appearing every 20 or 50 years on average). Finally, Jean-François asks the question: what could EVT additionally bring to the party?

Hubert Rodarie (SMA), in his chapter "The Robotization of Financial Activities: A Cybernetic Perspective," shares his thoughts about the trend toward the use of robots in finance (a trend that seems to apply to every sector, and finance is no exception). The author uses the framework of cybernetics to analyze the finance machine. Is automation going in the right direction? What is its impact on financial markets in terms of volatility and extreme events? What can be done to improve the financial sector?

Jacques Ninet (La Française) addresses an important issue in finance, liquidity, in his chapter "Two Tales of Liquidity Stress." Jacques shares his long experience as an asset manager. He explains in detail the forex exchange crisis of 1992–1993 and the recent financial crisis of 2007–2008. Such episodes, lived "from the inside," remind us that "those who cannot remember the past are condemned to repeat it." What is the meaning of an extreme situation in financial markets? What can we learn from historical extreme events?

Maxime Laot (European Central bank), in his chapter "Managing Operational Risk in the Banking Business: An Internal Auditor Point of View," shares his thoughts and experience of operational risk, which has only recently been studied and considered by financial regulation (as compared with market risk and credit risk). Maxime details the types of operational risk and the different approaches to measure operational risk and provides data on bank losses due to the realization of operational risk.

1.7 A BROADER VIEW ON MODELING EXTREMES

Henri Bourguinat (University of Bordeaux) and Eric Briys (Cyberlibris) offer a critical view of modern finance in their chapter "Credo Ut Intelligam," characterized by the extensive use of models with the hypothesis of normality for asset prices and the hypothesis of an average individual (*homo economicus*) driven by rationality. What is the role of models? Should the world of finance deviate from traditional assumptions? Do we believe in models to understand them or do we try to understand models to believe them?

Laurent Bibard (ESSEC Business School), in his chapter "Bounded Rationality, Routines, and Practical as well as Theoretical Blindness: On the Discrepancy between Markets and Corporations," discusses the behavior of individuals, firms, and markets. The consideration of time (short-term vs long-term) is especially important.

1.8 FINAL WORDS

The French mathematician, physicist, and philosopher Henri Poincaré (1854–1912) once noted that "All the world believes it (the normal distribution) firmly, because the mathematicians imagine that it is a fact of observation and the observers that it is a theorem of mathematics." It seems that more than a century later, the world, especially in finance, has not changed much as the Laplace–Gauss distribution is still considered as *normal*. While the normal distribution tends to underestimate the weight of extreme events in finance, and therefore risk, an objective of this book is to show that EVT with its strong theoretical results, extensive empirical evidence, and new applications in risk management can be an alternative to the current paradigm of the normal distribution.

The German mathematician Emil Gumbel (1891–1966), who was a pioneer in the application of EVT to engineering problems, in particular to hydrological phenomena such as annual flood flows, once wrote: "It seems that the rivers know the theory. It *only* remains to convince engineers of the validity of this analysis." Considering the world of finance, we can paraphrase Gumbel words by saying:

> *It seems that financial markets know the theory.*
>
> *It only remains to convince traders, investors, financial engineers, risk managers, asset managers, bankers, central bankers, regulators, and professors of the validity of this analysis.*

Together with the contributors to this handbook, I hope that this collective work will help to open up wider consideration of this direction.

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References

Alves Fraga I., Neves C. Extreme value theory: an introductory overview. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Beirlant J., Herrmann K., Teugels J.L. Estimation of the extreme value index. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Bertail P., S. Clémençon and C. Tiller Extreme values statistics for Markov chains with applications to finance and insurance published in *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. edited by F. Longin, Wiley; 2017.

Bertrand P., Prigent J.-L. Portfolio insurance: the extreme value approach applied to the CPPI method. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Bibard L. Bounded rationalities, routines, and practical as well theoretical blindness: on the discrepancy between markets and corporations. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Booth G.G., Broussard J.-P. The Sortino ratio and the generalized Pareto distribution: an application to asset allocation. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Boulier J.-F. EVT seen by a vet: a practitioner's experience of extreme value theory. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Bourguinat H., Bryis E. Credo Ut Intelligam. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Chan K.F., Gray P. Extreme value theory and risk management in electricity markets. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Choffray J.-M., Pahud de Mortanges C. Protecting assets under non-parametric market conditions. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Cotter J., Dowd K. Margin setting and extreme value theory. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

de Carvalho M. Statistics of extremes: challenges and opportunities. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Gomes M.I., Caeiro F., Henriques-Rodrigues L., Manjunath B.G. Bootstrap methods in statistics of extremes. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Kratz M. On the estimation of the distribution of aggregated heavy tailed risk. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Laot M. Managing operational risk in the banking business – an internal auditor point of view. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Leadbetter R. Extremes under dependence: historical development and parallels with central limit theory. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Le Courtois O., Walter C. Lévy processes and extreme value theory. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Longin F. The choice of the distribution of asset returns: how extreme value theory can help? In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Nadarajah S., Chan S. Estimation methods for value at risk. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Ninet J. Two tales of liquidity stress. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Novak S.Y. Measures of financial risk. In: Longin F, editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Phoa W. Extreme value theory and credit spreads. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Rodarie H. The robotisation of financial activities: a cybernetic perspective. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Straetmans S., Huyen Dinh T.T. Comparing tail risk and systematic risk profiles for different types of US financial institutions. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Wiley; 2017.

Walter C. In: Longin F., editor. *Extreme Events in Finance: A Handbook of Extreme Value Theory and Its Applications*. Vol. The extreme value problem in finance: comparing the pragmatic programme with the Mandelbrot programme. Wiley; 2017.