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Introduction

The period since the late 1990s has been marked by financial crises—the Asian crisis of 1997, the Russian debt crisis of 1998, the bursting of the dot-com bubble in 2000, the crises following the attack on the World Trade Center in 2001 and the invasion of Iraq in 2003, the sub-prime mortgage crisis of 2007, and European sovereign debt crisis since 2009 being the most prominent. All of these crises had a tremendous impact on the financial markets, in particular an upsurge in observed volatility and massive destruction of financial wealth. During most of these episodes the stability of the financial system was in jeopardy and the major central banks were more or less obliged to take countermeasures, as were the governments of the relevant countries. Of course, this is not to say that the time prior to the late 1990s was tranquil—in this context we may mention the European Currency Unit crisis in 1992–1993 and the crash on Wall Street in 1987, known as Black Monday. However, it is fair to say that the frequency of occurrence of crises has increased during the last 15 years.

Given this rise in the frequency of crises, the modelling and measurement of financial market risk have gained tremendously in importance and the focus of portfolio allocation has shifted from the μ side of the (μ, σ) coin to the σ side. Hence, it has become necessary to devise and employ methods and techniques that are better able to cope with the empirically observed extreme fluctuations in the financial markets. The hitherto fundamental assumption of independent and identically normally distributed financial market returns is no longer sacrosanct, having been challenged by statistical models and concepts that take the occurrence of extreme events more adequately into account than the Gaussian model assumption does. As will be shown in the following chapters, the more recently proposed methods of and approaches to wealth allocation are not of a revolutionary kind, but can be seen as an evolutionary development: a recombination and application of already existing statistical concepts to solve finance-related problems. Sixty years after Markowitz's seminal paper "Modern

Portfolio Theory,” the key (μ, σ) paradigm must still be considered as the anchor for portfolio optimization. What has been changed by the more recently advocated approaches, however, is how the riskiness of an asset is assessed and how portfolio diversification, that is, the dependencies between financial instruments, is measured, and the definition of the portfolio’s objective per se.

The purpose of this book is to acquaint the reader with some of these recently proposed approaches. Given the length of the book this synopsis must be selective, but the topics chosen are intended to cover a broad spectrum. In order to foster the reader’s understanding of these advances, all the concepts introduced are elucidated by practical examples. This is accomplished by means of the R language, a free statistical computing environment (see R Core Team 2016). Therefore, almost regardless of the reader’s computer facilities in terms of hardware and operating system, all the code examples can be replicated at the reader’s desk and s/he is encouraged not only to do so, but also to adapt the code examples to her/his own needs. This book is aimed at the quantitatively inclined reader with a background in finance, statistics, and mathematics at upper undergraduate/graduate level. The text can also be used as an accompanying source in a computer lab class, where the modelling of financial risks and/or portfolio optimization are of interest.

The book is divided into three parts. The chapters of this first part are primarily intended to provide an overview of the topics covered in later chapters and serve as motivation for applying techniques beyond those commonly encountered in assessing financial market risks and/or portfolio optimization. Chapter 2 provides a brief course in the R language and presents the **FRAPO** package that accompanies the book. For the reader completely unacquainted with R, this chapter cannot replace a more dedicated course of study of the language itself, but it is rather intended to provide a broad overview of R and how to obtain help. Because in the book’s examples quite a few R packages will be presented and utilized, a section on the existing classes and methods is included that will ease the reader’s comprehension of these two frameworks. In Chapter 3, stylized facts of univariate and multivariate financial market data are presented. The exposition of these empirical characteristics serves as motivation for the methods and models presented in Part II. Definitions used in the measurement of financial market risks at the single-asset and portfolio level are the topic of the Chapter 4. In the final chapter of Part I (Chapter 5), the Markowitz portfolio framework is described and empirical artifacts of the accordingly optimized portfolios are presented. The latter serve as motivation for the alternative portfolio optimization techniques presented in Part III.

In Part II, alternatives to the normal distribution assumption for modelling and measuring financial market risks are presented. This part commences with an exposition of the generalized hyperbolic and generalized lambda distributions for modelling returns of financial instruments. In Chapter 7, the extreme value theory is introduced as a means of modelling and capturing severe financial losses. Here, the block-maxima and peaks-over-threshold approaches are described and applied to stock losses. Both Chapters 6 and 7 have the unconditional modelling of financial losses in common. The conditional modelling and measurement of financial market risks is presented in the form of GARCH models—defined in the broader sense—in

Chapter 8. Part II concludes with a chapter on copulae as a means of modelling the dependencies between assets.

Part III commences by introducing robust portfolio optimization techniques as a remedy to the outlier sensitivity encountered by plain Markowitz optimization. In Chapter 10 it is shown how robust estimators for the first and second moments can be used as well as portfolio optimization methods that directly facilitate the inclusion of parameter uncertainty. In Chapter 11 the concept of portfolio diversification is re-considered. In this chapter the portfolio concepts of the most diversified, equal risk contributed and minimum tail-dependent portfolios are described. In Chapter 12 the focus shifts to downside-related risk measures, such as the conditional value at risk and the draw-down of a portfolio. Chapter 13 is devoted to tactical asset allocation (TAA). Aside from the original Black–Litterman approach, the concept of copula opinion pooling and the construction of a wealth protection strategy are described. The latter is a synthesis between the topics presented in Part II and TAA-related portfolio optimization.

In Appendix A all the R packages cited and used are listed by name and topic. Due to alternative means of handling longitudinal data in R, a separate chapter (Appendix B) is dedicated to the presentation of the available classes and methods. Appendix C shows how R can be invoked and employed on a regular basis for producing back-tests, utilized for generating or updating reports, and/or embedded in an existing IT infrastructure for risk assessment/portfolio rebalancing. Because all of these topics are highly application-specific, only pointers to the R facilities are provided. A section on the technicalities concludes the book.

The chapters in Parts II and III adhere to a common structure. First, the methods and/or models are presented from a theoretical viewpoint only. The following section is reserved for the presentation of R packages, and the last section in each chapter contains applications of the concepts and methods previously presented. The R code examples provided are written at an intermediate language level and are intended to be digestible and easy to follow. Each code example could certainly be improved in terms of profiling and the accomplishment of certain computations, but at the risk of too cryptic a code design. It is left to the reader as an exercise to adapt and/or improve the examples to her/his own needs and preferences.

All in all, the aim of this book is to enable the reader to go beyond the ordinarily encountered standard tools and techniques and provide some guidance on when to choose among them. Each quantitative model certainly has its strengths and drawbacks and it is still a subjective matter whether the former outweigh the latter when it comes to employing the model in managing financial market risks and/or allocating wealth at hand. That said, it is better to have a larger set of tools available than to be forced to rely on a more restricted set of methods.

Reference

R Core Team 2016 *R: A Language and Environment for Statistical Computing* R Foundation for Statistical Computing Vienna, Austria.