Preface to Volume II

For well over a decade, econometrics has been one of the major routes into finance. I took this route myself several years ago. Starting an academic career as an algebraist, I then had a brief encounter with game theory before discovering that the skills of an econometrician were in greater demand. I would have found econometrics much more boring than algebra or game theory had it not been for the inspiration of some great teachers at the London School of Economics, and of Professor Robert Engle who introduced me to GARCH models some twenty years ago.

At that time finance was one of the newest areas of applied econometrics and it was relatively easy to find interesting problems that were also useful to practitioners. And this was how my reputation grew, such as it is. I was building GARCH models for banks well before they became standard procedures in statistical packages, applying cointegration to construct arbitrage strategies for fund managers and introducing models for forecasting very large covariance matrices. In the end the appreciation of this work was much greater than the appreciation I received as an academic so I moved, briefly, to the City. Then, almost a decade ago, I returned to academic life as a professor of financial risk management. In fact, I believe I was the first professor to have this title in the UK, financial risk management being such a new profession at that time. It was the late 1990s, and by then numerous econometricians were taking the same route into finance that I had. Some of the top finance journals were populating many of their pages with applied financial econometrics, and theoretical econometric journals were becoming increasing focused on financial problems. Of course I wanted to read and learn all about this so that I could publish the academic papers that are so important to our profession. But I was disappointed and a little dismayed by what I read. Too few of the papers were written by authors who seemed to have a proper grasp of the important practical problems in finance. And too much journal space was devoted to topics that are at best marginal and at worst completely irrelevant to financial practitioners.

Econometrics has now become a veritable motorway into finance where, for many, prospects are presently more lucrative than those for standard macro- or micro-economists. The industry has enormous demand for properly trained financial econometricians, and this demand will increase. But few econometricians enter the industry with an adequate knowledge of how their skills can be employed to the best advantage of their firm and its clients, and many financial econometricians would benefit from improving their understanding of what constitutes an important problem.

AIMS AND SCOPE

This book introduces the econometric techniques that are commonly applied to finance, and particularly to resolve problems in market risk analysis. It aims to fill a gap in the market by offering a critical text on econometrics that discuss what is and what is not important to financial practitioners. The book covers material for a one-semester graduate course in applied financial econometrics in a very pedagogical fashion. Each time a concept is introduced, an empirical example is given, and whenever possible this is illustrated with an Excel spreadsheet.

In comparison with Greene (2007), which has become a standard graduate econometrics text and which contains more than enough material for a one-year course, I have been very selective in the topics covered. The main focus is on models that use time series data, and relatively few formal proofs are given. However, every chapter has numerous empirical examples that are implemented in Excel spreadsheets, many of which are interactive. And when the practical illustration of the model requires a more detailed exposition, case studies are included. More details are given in the section about the CD-ROM below.

Econometrics is a broad discipline that draws on basic techniques in calculus, linear algebra, probability, statistics and numerical methods. Readers should also have a rudimentary knowledge of regression analysis and the first chapter, which is on factor models, refers to the capital asset pricing models and other models derived from the theory of asset pricing. All the prerequisite material is covered *Market Risk Analysis* Volume I: *Quantitative Methods in Finance*. However, there is only one chapter on basic regression in Volume I. A very comprehensive introductory text, written at a more elementary level than this but also aimed towards the finance student market, is Brooks (2008). For many years Professor Chris Brooks has been a close colleague at the ICMA Centre.

The other volumes in *Market Risk Analysis* are Volume III: *Pricing, Hedging and Trading Financial Instruments* and Volume IV: *Value at Risk Models*. Although the four volumes of *Market Risk Analysis* are very much interlinked, each book is self-contained. This book could easily be adopted as a stand-alone course text in applied financial econometrics, leaving students to follow up cross-references to other volumes only if they wish.

OUTLINE OF VOLUME II

Chapter 1, *Factor Models*, describes the models that are applied by portfolio managers to analyse the potential returns on a portfolio of risky assets, to determine the allocation of their funds to different assets and to measure portfolio risk. The chapter deals with models having fundamental factors and which are normally estimated by regression. We focus on the Barra model, giving a detailed description of its construction, and emphasizing the dangers of using tracking error as a risk metric for actively managed portfolios.

Chapter 2, *Principal Component Analysis*, covers statistical factor models, which are also used for portfolio management and risk management, but they are most successful when applied to a highly correlated system such as a term structure of interest rates, of futures prices or of volatility. Since it is not easy to find a complete treatment of principal component analysis in a finance-oriented text, we provide full details of the mathematics but, as usual, we focus on the applications. Empirical examples include bond portfolio immunization, asset–liability management and portfolio risk assessment.

Chapter 3, *Classical Models of Volatility and Correlation*, provides a critical review of the time series models that became popular in the industry during the 1990s, making readers aware of the pitfalls of using simple moving averages for estimating and forecasting portfolio risk. These are based on the assumption that returns are independent and identically distributed so the volatility and correlation forecasts from these models are equal to the current estimates. The sample estimates vary over time, but this is only due to sampling error. There is nothing in the model to capture the volatility and correlation clustering that is commonly observed in financial asset returns.

Chapter 4, *Introduction to GARCH Models*, provides a complete and up-to-date treatment of the generalized autoregressive conditional heteroscedasticity models that were introduced by Engle (1982) and Bollerslev (1986). We explain how to: estimate the model parameters by maximizing a likelihood function; use the model to forecast term structures for volatility and correlation; target the long term volatility or correlation and use the GARCH model to forecast volatility and correlation over the short and medium term; and extend the model to capture non-normal conditional returns distributions and regime-switching volatility behaviour. There are so many approaches to modelling multivariate distributions with time varying volatility and correlation that I have been very prescriptive in my treatment of multivariate GARCH models, recommending specific approaches for different financial problems. Throughout this long chapter we illustrate the GARCH model optimization with simple Excel spreadsheets, employing the Excel Solver whenever possible. Excel parameter estimates for GARCH are not recommended, so the estimates are compared with those obtained using GARCH procedures in the Matlab and EViews software. The section on simulation is enlightening, since it demonstrates that only regime-switching GARCH models can properly capture the observed behaviour of financial asset returns. The final section covers the numerous applications of GARCH models to finance, including option pricing, risk measurement and portfolio optimization.

Chapter 5 is on *Time Series Models and Cointegration*. Building on the introduction to stochastic processes given in Chapter I.3, this begins with a mathematical introduction to stationary and integrated processes, multivariate vector autoregressions and unit root tests. Then we provide an intuitive definition of cointegration and review the huge literature on applications of cointegration in financial markets. A case study focuses on the benchmark tracking and statistical arbitrage applications that I developed more than a decade ago, and which are now used by major fund managers. The final section provides a didactic approach to modelling short term dynamics using error correction models, focusing on the response of cointegrated asset prices to market shocks and the time taken for a spread to mean-revert. Another case study examines pairs trading volatility indices.

Chapter 6, *Introduction to Copulas*, took much longer to write than the other chapters. I was less familiar with copulas than with the other topics in this book, and found the available literature a little obscure and off-putting. However, copulas are of crucial importance to the development of our subject and no reputable financial econometrician can afford to ignore them. So it became quite a challenge to present this material in the pedagogical style of the rest of the book. I have programmed several copulas, including the normal, normal mixture, Student's t, Clayton and Gumbel copulas, in interactive Excel spreadsheets, so that you can see how the shape of the copula alters on changing its parameters. The quantile curves of conditional copulas play a crucial role in financial applications – for instance, in quantile regression – so these have been derived mathematically and also encoded into Excel. Many other applications such as value-at-risk measurement, portfolio optimization

and risk aggregation, which are discussed in the last section of the chapter, are based on simulation with copulas. Two simulation algorithms are described and spreadsheets generate simulations based on different copulas.

Chapter 7 covers the *Advanced Econometric Models* that have important applications to finance. A significant portion of this chapter provides a tutorial on quantile regression, and contains two case studies in Excel. The first implements linear and non-linear quantile regressions to examine the relationship between an equity index and its volatility, and the second demonstrates how non-linear quantile regression using copulas can be applied to hedge a portfolio with futures. A relatively brief treatment of other non-linear models is restricted to polynomial regression and discrete choice models, the latter being illustrated with an application to credit scoring models. What I hope is an accessible specification of Markov switching models is followed with a short review of their applications and the software that can be used for estimation, and the chapter concludes by describing the main high frequency data sets and two of the most important financial problems in high frequency data analysis. First, for capturing the clustering of the times between trades we describe the autoregressive conditional duration model. Then we review the large and growing literature on using high frequency data to forecast realized variance and covariance, this being important for pricing the variance swaps and covariance swaps that are actively traded in over-the-counter markets.

The last chapter, Chapter 8 on *Forecasting and Model Evaluation*, describes how to select the best model when several models are available. The model specification and evaluation criteria and tests described here include goodness-of-fit criteria and tests, which measure the success of a model to capture the empirical characteristics of the estimation sample, and post-sample prediction criteria and tests, which judge the ability of the model to provide accurate forecasts. Models for the conditional expectation, volatility and correlation of financial asset returns that were introduced in earlier chapters are considered here, and we explain how to apply both statistical and operational criteria and tests to these models. Amongst the statistical tests, we emphasize the Kolmogorov–Smirnoff and related tests for the proximity of two distributions and the coverage tests that are applied to evaluate models for predicting quantiles of conditional distributions. We also explain how to simulate the critical values of non-standard test statistics. A long section on operational evaluation first outlines the model backtesting procedure in general terms, and then explains how backtests are applied in specific contexts, including tests of: factor models used in portfolio management; covariance matrices used for portfolio optimization and value-at-risk estimation; and models that are used for short term hedging with futures, trading implied volatility, trading variance swaps and hedging options

ABOUT THE CD-ROM

Whenever possible the econometric models, tests and criteria that are introduced in this book are illustrated in an Excel spreadsheet. The Excel workbooks for each chapter may be found on the accompanying CD-ROM. Many of the spreadsheets are interactive, so readers may change any parameters of the problem (the parameters are indicated in *red*) and see the new solution (the output is indicated in *blue*). Rather than using VBA code, which will be

obscure to many readers, I have encoded the formulae directly into the spreadsheet. Thus the reader need only click on a cell to read the formula. Whenever a data analysis tool such as regression or a numerical tool such as Solver is used, clear instructions are given in the text, and/or using comments and screenshots in the spreadsheet. Hence, the spreadsheets are designed to offer tutors the possibility to set, as exercises for their courses, an unlimited number of variations on the examples in the text.

Excel is not always an adequate program for estimating econometric models, and I have been particularly emphatic on this point for the spreadsheets that estimate GARCH model parameters. Excel has its limits in other respects, too, and so references to and recommendations of proper econometric programs are given where necessary. For instance, the CD-ROM includes the EViews code for Markov switching models that was written by my PhD student Andreas Kaeck.

Several case studies, based on complete and up-to-date financial data, and all graphs and tables in the text are also contained in the Excel workbooks on the CD-ROM. The case study data can be used by tutors or researchers since they were obtained from free internet sources, and references for updating the data are provided. Also the graphs and tables can be modified if required, and copied and pasted as enhanced metafiles into lectures notes based on this book.

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