协整理论与波动模型

金融时间序列分析及应用

清华大学出版社

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内 容 简 介

本书论述了时间序列的协整理论和金融时间序列波动性模型的原理、方法和实际应用。在时间序列的协整理论方面，包括单位根过程的极限分布和检验，单方程和系统方程协整关系的估计和检验，讨论了非线性、长记忆协整关系的建模和检验问题，协整系统的贝叶斯分析及变结构协整的理论、方法等。在金融时间序列波动模型方面，全面地讨论了自回归条件异方差模型(ARCH 模型)的各类一维和多维模型体系及各类随机波动(SV)模型，讨论了它们的性质、模型参数估计和检验问题，讨论了变结构波动模型的建模及其应用等。对各类模型和方法均针对我国资本市场进行了实证研究。金融波动性问题是当今金融分析中的重要课题，本书探讨了金融波动及其持续性的市场机制，建立了在金融波动持续性基础上的资本资产定价模型等。书中对金融时间序列进一步需要研究的几个新课题进行了分析。

本书可作为数量经济学研究人员、有关教师、经济和金融工作者的参考书，亦可作为相关领域研究生的教学参考书。

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前言 PREFACE

本书是我们研究集体近十多年来在协整理论和时间序列波动性分析两个领域的研究成果。这项研究工作得到国家自然科学基金项目——“多变量时间序列波动持续性及其在金融系统上的应用”(No. 70171001)和教育部博士点基金项目——“社会经济系统中协整建模方法研究”(No. 9505621)的资助。结合这两项基金的研究工作,在协整理论、方法和金融时间序列波动性分析两个方面都获得了一系列创造性的成果。

在协整理论和方法方面,Engle 和 Granger 所建立的协整理论反映了非平稳时间序列之间的长期线性均衡关系,所以是线性协整。但在经济系统中,许多经济变量具有长期记忆的特点,而且这些序列本身及它们之间的关系往往是非线性的。为了揭示非线性与长记忆时间序列之间的长期均衡关系,我们全面地研究了非线性协整的理论、方法,以及非线性协整关系的拟合和检验问题;研究了长记忆向量分整序列的线性协整和非线性协整问题,并利用吸引子的概念解释了长记忆向量非线性时间序列之间的协整关系,这样就将协整理论在 Engle 和 Granger 工作的基础上作了全面提升。为了拓宽线性协整理论和方法的应用,我们提出并研究了非协整系统中分量序列的非线性变换问题,这样就使得一些看似不存在协整关系的序列经过变换后,可以利用协整方法来处理。对于协整系统(包括季节性协整)的检验问题,我们发展了贝叶斯检验,并进行了实证研究。利用协整技术来提高经济预测精度是协整技术的重要应用领域,通过系统的实证研究指出,协整方法对于预测精度的提高在中长期预测时表现得最为明显,对短期预测同样也可以提高其预测精度,但与其他方法相比改善不大,因此协整技术在经济预测中的作用主要应是提高中长期预测精度。

在时间序列波动性模型研究方面,自从 Engle(1982)首创

ARCH 模型以来，国际上迄今已有十多种各类扩展的 ARCH 类模型用以描述不同特点的 ARCH 效应，这对 ARCH 类模型的应用、检验、参数估计和变结构研究既方便又有不足。为了统一现有的各种 ARCH 类模型，我们提出了分整增广 GARCH-M 模型，该模型除包容了国际上目前所发展的 11 种 ARCH 类模型外，还提出了 21 种新的长、短记忆的 ARCH 类模型，这些新模型都具有明确的经济含义，因此，分整增广 GARCH-M 模型在 ARCH 模型族的设定检验中具有重要作用。为了解决这一复杂模型的参数估计问题，我们提出了禁忌-递阶遗传算法并用之进行分整增广 GARCH-M 模型的参数估计问题。此外，对于向量 ARCH 类模型以及另一类波动性模型——SV 模型的估计问题，我们也采用了禁忌-递阶遗传算法。实证表明，采用禁忌-递阶遗传算法解决复杂模型的参数估计问题，比一些常规方法，如 BHHH 算法，具有明显的优势。

波动持续性问题是金融波动性研究中的重要问题，Engle 和 Bollerslev 等在这一领域作出了重要贡献。对于多变量时间序列的波动持续性问题，Bollerslev 和 Engle(1993)提出了波动协同持续这一概念，即通过对多个变量的线性组合来消除波动的持续性，这一问题对于资产组合理论以及金融风险防范问题无疑具有重要意义，但是，此后国外文献中很少有进一步的研究。我们深入研究并发展了国外相关的研究成果，证明了波动持续性与波动非协方差平稳性之间的等价关系，给出了市场组合意义下波动协同持续性存在与否的条件，同时建立了时间序列协同持续性与线性协整之间的关系。另一方面，从单整的角度，我们也提出了波动持续性和协同持续性的定义，并在此基础上讨论了向量 GARCH 过程和向量 SV 过程的持续性和协同持续性问题。进一步，我们将协同持续概念扩展为非线性协同持续，提出非线性协同持续的概念及其算法。线性协同持续与非线性协同持续概念与方法的提出，为从动态角度研究金融风险的持续性及其规避策略提供了理论基础。基于金融波动持续性和协同持续性分析，我们系统地研究了金融动态风险的影响问题以及资产组合中的风险规避策略和途经。研究了存在方差持续性条件下资本资产定价模型和套利定价模型的性质，为证券投资分析提供一种新的方法和手段。

迄今，ARCH 类模型和 SV 类模型是广泛应用于金融时间序列波动性分析的两类重要模型。我们从建模理论以及模型对于金融时间序列实际刻画能力两个角度研究了两类模型各自的特点以及二者之间的联系，从而为金融波动性分析和实际应用提供基础。

本书利用分形理论探讨了金融波动特性的市场机制，指出波动的持续性

反映了市场的分形和非线性特性，分析了传统有效市场理论的缺陷和不足，指出在金融分析中引入分形市场理论的必要性。分形和多重分形理论可以作为金融风险分析与管理的理论基础，在这方面特别研究了分形市场中的资本资产定价问题。

变结构建模是社会经济系统建模中的一个重要问题，可以说模型结构变化是社会经济系统中模型的基本特征。在20世纪80年代初，我们系统地建立了变结构经济计量模型的建模理论和方法。在协整模型的变结构分析中，对于线性协整模型，通常的结构突变和结构渐变问题可以沿用一般的变结构分析方法来处理，而对非线性向量时间序列而言，系统内部动态均衡结构的变化不仅体现在空间结构上，而且具有一定的时间结构特性。为此，提出了一种新的变结构分析理论，即无模型的非线性系统变结构分析思想，给出与模型无关的系统变结构的定义，并利用非参数的神经网络技术和基于递归遗传规划的智能化变结构分析方法，解决了非线性复杂系统的变结构分析问题。

对于ARCH类模型的变结构问题，国外目前的一些研究是基于ARCH类模型中的某一种模型形式进行的，但这未能解决包含许多模型形式的ARCH类模型族的变结构问题。正因为此，我们充分发挥所提出的分整增广GARCH-M模型的包容性，利用分整增广GARCH-M模型进行ARCH类模型的变结构分析，这就是我们解决ARCH类模型变结构问题的基本途经。

本书主要是以我们的研究成果为中心展开讨论的。为使本书体系完整，也提到国外相关的工作，但这些内容只起到进一步说明我们工作的作用。

在本书定稿之际，得知协整理论以及ARCH模型的原创者美国经济学家Engle和英国经济学家Granger荣膺2003年度诺贝尔经济学奖，我们也受到鼓舞。本书内容正是在他们工作的基础之上，提出新的研究课题，获得的一些新成果。

在这里我特别感谢十多年来和我一道从事这项研究的我的博士生和硕士生们。他们在协整理论、方法以及时间序列波动性分析两个领域进行了大量的研究工作，本书所反映的只是他们的部分工作(在参考文献中列出)，还有相当多的成果不可能包括在一本书中。而且我们的研究集体目前还在继续从事着这项研究工作，就该领域的一些国际前沿问题进行探讨。尽管一些研究是与国际同步进行的，但具有自己的特色。

樊智同志和我一道完成本书的编写工作，书中第5章和第8章的稿子是

由他完成的(第5章我也参加了部分内容的编写)。在该书写作中,韦艳华、徐梅、许启发和徐正国同志也给予了帮助。全书由我统纂定稿。本书在出版过程中得到清华大学出版社的大力支持,刘昱、龙海峰同志给予了许多帮助。在此谨向有关同志致以衷心的感谢。

张世英

于天津大学

2003年11月13日

Preface

This book is the fruit of over ten years' research on cointegration theory and volatility of time series of our research team. The research was sponsored by National Science Foundation of China—"Persistence in Volatility of Multivariate Time Series and its Applications in Financial System(No. 70171001)", and Doctoral Foundation of Ministry of Education—"Research on Cointegration Modeling in Social Economic System(No. 9505621)". Integrating the research work of these two foundations, we have achieved a series of creative results in cointegration theory and analysis of volatility in financial time series.

In the research of cointegration, the cointegration theory established by Engle and Granger indicated long term linear equilibrium relationship among non-stationary time series, and it could be defined as linear cointegration. While in the economic system, many variables have long memory. The univariate time series and the relationship among them are usually nonlinear. To disclose the long term equilibrium relationship among nonlinear and long memory time series, we did a thorough research on the theory and methodology, as well as fitting and testing of nonlinear cointegration. We studied the linear and nonlinear cointegration of long memory fractional time series, and demonstrated the mechanism of cointegration by introducing the conception of attractor, thus enhanced the cointegration theory based on the work of Engle and Granger to a new level. To broaden the applications of linear cointegration theory, we raised and studied the issue of nonlinear transformation of time series in non-cointegrated system, and made it possible to apply cointegration analysis to these time series. As for testing of cointegrated system, including seasonally cointegrated system, we developed Bayesian testing method and carried out empirical studies. One important application of cointegration

analysis is to improve the forecasting precision. Empirical studies in this book have shown prominent improvement in mid and long term forecasting by using cointegration technique, while no such evident improvement in short term forecasting compared with other forecasting methods, although it does help to some extent. Therefore, the main aim of cointegration technique is to improve mid and long term forecasting precision.

Since ARCH model was presented by Engle in 1982, more than ten kinds of extended ARCH class models have been used to describe different ARCH effects. The complication of these ARCH models has brought conveniences, as well as difficulties, to their applications, tests, parameters estimation and study of structure change. To consolidate the current ARCH class models, we presented fractionally integrated augment GARCH-M model. It included not only 11 existing ARCH class models, but also 21 new kinds of long and short memory ARCH models which have explicit economic meanings, and this new model played an important role in specification of ARCH class models. In order to estimate the parameters in the complicated models, we proposed tabu-hierarchy genetic algorithm (THGA) and applied it to parameter estimation of fractionally integrated augment GARCH-M model. Furthermore, THGA was used in parameter estimation of vector ARCH class models and another type of volatility models—SV models. Empirical studies indicated that THGA had more advantages than regular algorithm does, e. g. BHHH algorithm.

Persistence in volatility is an important problem in financial volatility study, to which Engle and Bollerslev have made great contributions. In multivariate time series analysis, Engle and Bollerslev proposed the conception of co-persistence in variance, i. e. to reduce the volatility persistence by linear combination of assets. This proposition had significant influences on assets portfolio theory and financial risk management, but little further research on this topic has been carried out since then. Based on thorough studying and developing of relevant research work of foreign researchers, we proved the equivalence of

persistence in variance and non-stationarity of covariance for volatility, and introduced the conditions for existence of co-persistence in assets portfolio. Meanwhile, we established the relationship between cointegration and co-persistence. We also proposed the definitions of persistence and co-persistence in variance from integration point of view, and discussed persistence and co-persistence in vector GARCH process and vector SV process. Furthermore, we extended the conception of co-persistence into nonlinear co-persistence and proposed the algorithm for it. These work constituted the theoretical foundations for the research on persistence in financial risk and the dynamically avoiding strategies. Based upon this analysis, we systematically studied the dynamics of financial risk and the avoidance strategies in portfolio. Considering the persistence in variance, we investigated the characteristics of CAPM and APT, which would provide a new way for portfolio allocation.

So far, ARCH models and SV models are two kinds of important models used in financial volatility analysis. We studied the characteristics and relations of these two models from two aspects—modeling theory and the ability to simulate financial time series, which provided the basis for financial volatility analysis and applications.

This book discussed the market mechanism of financial volatility by utilizing the fractal theory, and showed that persistence in variance reflected the fractal and nonlinear characteristics of the financial market. We analyzed the insufficiency of efficient market theory and pointed out the necessity of introducing fractal market theory into financial analysis. Fractal and multifractal theories can be taken as the theoretical basis for financial risk analysis and management. We particularly set up capital assets pricing model in fractal market.

Structure change is an important issue in social economic system modeling, and structure change can be considered as the basic characteristic of social economic system. In the early 1980's, we systematically set up the modeling theory and methodology for econometric models with structure changes. For cointegration models

with structure changes, the breaks or gradual changess of the models can be analyzed by using regular structure change analytical methods. However, for the nonlinear vector time series, structure changes of models are reflected not only in space structure, but also in time series structure. We gave the definition of model-free structure change of nonlinear system as a new structure change theory, and put forward structure change analysis of nonlinear complicated system through non-parameter neural network technique and intelligent structure change analysis, based upon recursive genetic programming.

For structure change analysis of ARCH class models, current research is based on a certain type of ARCH model, but this can not includes structure changes of all ARCH class models. For this, we made full use of the fractionally integrated augment GARCH-M model and applied it to structure change analysis of ARCH class models, which was our way to study the structure changes of ARCH class models.

The contents of the book are centered on the research achievements of our research team. To ensure the integrity of the book, we also refer to the related works abroad, which just help to demonstrate our research.

Before the finalization of the book, we were excited to learn that American economist Engle and English economist Granger, the founders of cointegration theory and ARCH models, were awarded the Nobel Prize for Economics in 2003. The main contents of this book are new research topics and achievements based upon their works.

I would like to thank my Ph. D. and Master students who carried out the research together with me. They did plenty of work in cointegration theory and time series volatility analysis. This book just represents part of their works (listed in the references), and quite a lot can not be covered here. Our research work is continuing, focusing on some forefront issues in this field. Although our research work is in phase with those of the counterparts abroad, we have our own specialties.

Fan Zhi and I wrote this book together, in which, chapter 5 and 8 were written by him (part of chapter 5 was written by me). Wei Yanhua, Xu Mei, Xu Qifa, and Xu Zhengguo gave their help in writing of the book. I was responsible for the compilation and finalization of the whole book. The publication of the book was greatly supported by Tsinghua University Press, with originalities from Liu Yu and a lot of assistance from Long Haifeng. Here I sincerely express my gratitude to those who gave their support for this book.

Zhang Shiying
in Tianjin University
Nov. 13, 2003

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