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A Study on the Application of Chaos Theory to
Economics

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内容摘要

混沌是一种由确定性方程产生的貌似随机的非线性动力学系统，它具有对初始条件的敏感依赖性。混沌吸引子是动态系统行为的最终归宿，并具有分形结构。混沌理论的魅力在于它揭示了隐匿在貌似随机的经济现象背后的有序结构和规律性，提供了一种方法把复杂事物理解为自身内部某种有结构、有目的的行为，而不是外来的、偶然的行爲。

近十年来，我国学者开始研究混沌理论在经济领域中的应用。但总体来看，无论是深度还是广度，都存在着明显不足。基于这种情况，本文拟冲破经典经济学的思维方式，利用混沌理论拓宽人们对现实经济问题研究的视野，探讨多种随机经济现象背后的运行规律；把混沌与其它联系密切的非线性模型作出比较，分析它们的异同点，同时探讨宏观经济数据的动力学特征，对经济的运行作出预测和控制。

本文由七章组成。第一章介绍了选题背景、本文的研究内容及创新之处；第二章评介了混沌理论的基本思想、混沌的识别、混沌与分形的关系以及国内外关于混沌理论在经济领域应用的现状；第三章对股票和期货价格行为特征进行研究，利用三种常用的非线性模型即 ARCH、ARFIMA 和混沌模型，根据中国证券市场的数据资料，对三种模型进行实证分析；第四章在以上实证结论的基础上，探析资产定价理论的起源，指出了传统资产定价理论的不足，进而建立了具有混沌特征的资产定价模型；第五章研究混沌理论在宏观经济学中的应用，通过三次样条插值扩展季度 GDP 和年度 GDP 样本数据，并将其用于实证分析，同时应用混沌理论从内生角度解释经济增长和经济周期理论；第六章将混沌理论和神经网络理论相结合，探讨了混沌经济系统的预测；第七章对全文作出总结，并对未来进一步的研究做了展望。

本文的创新之处主要有：1. 在国内首次全面系统地研究混沌理论在经济领域中的应用，拓宽了人们的视野，为发展具有新范式的经济理论作出自己的绵薄贡献。2. 将 BDS 检验与 ARCH、ARFIMA 以及混沌三种非线性模型结合使用，比较了三种非线性模型在中国证券市场的适用性和有效性，在此基础上，分析了证券价格具有混沌动力学特征的原因，并指出了实证结论的理论意义和现实意义。3. 指出了传统资产定价理论的缺陷，在国内首次展示了具有混沌特征的资产定价模型。4. 首次使用样条插值、递归图方法和基于神经网络的李雅普诺夫指数算法对中国的宏观经济数据作出实证分析。5. 基于混沌模型比较了 BP 神经网络和 RBF 神经网络在混沌经济系统预测中的效果，并将 RBF 神经网络应用于实际预测。

关键词：混沌；非线性；神经网络

Abstract

Chaos theory describes the seemingly random behaviors of nonlinear deterministic systems. A chaotic series is called a nonlinear, dynamic, and deterministic process. The observed dynamics looks like random processes and conventional econometric methods tend to conclude they are random walks. However, they are the products of deterministic systems. Chaos exhibits extreme sensitivity to initial conditions (SDIC), which means that an infinitesimal difference in starting points rapidly results in completely divergent trajectories. The dynamic systems converge chaotic attractor, which is a fractal structure. The chaotic characteristics of the dynamic system are captured by the largest Lyapunov exponent (LE) and correlation dimension (CD). The first (LE) is a measure of stability, where positive values indicate the presence of chaos, and the second (CD) is a geometric measure of the space with which the dynamic systems moves. The attraction of chaos theory lies in the fact that it opens the rules out behind seemingly random economic phenomena, and provides a method of regarding complex things as inherently structural and purposeful behaviors, rather than external and incidental.

In recent ten years, Chinese scholars take up the studies on the application of chaos theory to economics. On the whole, the studies have some limitations in depth and extent. Therefore, the dissertation aims to break through the thinking pattern of classical economics, expands people's horizon of studying practical economic phenomena, and discusses the rules behind some random economic phenomena. Meanwhile, the paper compares chaos theory with closely related nonlinear models, analyzes their characteristics, studies the dynamics characteristics of macroeconomic data, and forecasts and controls economic fluctuations.

The paper comprises seven chapters. Chapter One introduces the background, contents and innovations. Chapter Two appraises and introduces chaos theory, the identification of chaos, and the relations between chaos and

fractal. Chapter Three studies the stock and futures price behaviors, and empirically analyses ARCH, ARFIMA, and chaos model based on data in Chinese securities markets. Chapter Four, based on the foregoing evidence, explores asset pricing theories, indicates the limitations of traditional asset pricing theories, and constitutes a asset pricing model with chaotic characteristic. Chapter Five studies the application of chaos to macroeconomics, which expand quarterly Gross Domestic Product and annual Gross Domestic Product sample data by means of cubic spline interpolation and positively analyzes them, and interprets economic growth and business cycle theories from an endogenous viewpoint. Chapter Six, uniting chaos theory with neural network theory, probes into Chaotic economic systems prediction. Chapter Seven summarizes the whole paper and points out future research directions.

The first contributions of the study consist of five aspects. First of all, the paper, for the first time, gives a complete and systematical study on the application of chaos theory to economics in China, expands people's horizon, and contributes to the development of a new pattern of economic theory; Secondly, the paper combines BDS test with ARCH, ARFIMA, and chaos, studies applicability and validity of three nonlinear models in Chinese securities markets, then analyzes the chaotic characteristics of securities prices, and indicates theoretical and practical significance; Thirdly, the paper points out the limitations of traditional asset pricing theory and first displays an asset pricing model with chaotic characteristics in China; Fourthly, the study first makes use of recurrence plots and an algorithm for n Lyapunov exponents with multivariate feedforward network to empirically analyze Chinese macroeconomic data, and investigates business cycles and economic growth from an endogenous viewpoint; Finally, the paper compares BP neural network with RBF neural network based on chaotic model, and applies RBF neural network to Shanghai Securities Exchange Composite prediction.

Key Words: Chaos; Nonlinear; Neural Network

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