
Time-Series Analysis and Forecasting



December 2019

Acknowledgements

NABE extends a special thank you to the members of the Working Group whose support and guidance shaped this course.

Gregory Daco, Chief US Economist, Oxford Economics USA

Jim Diffley, CBE, Senior Director, IHS Markit

Charles Steindel, CBE, Resident Scholar; Editor, Business Economics, Ramapo College of NJ

Luis B. Torres, CBE, Research Economist, Real Estate Center at Texas A&M

Chris P. Varvares, CBE, VP and Co-head US Economics, Macroeconomic Advisers LLC

About the Author

Robert McNown is responsible for the development of this Guide and related materials for the NABE course in Time Series Analysis and Forecasting. Dr. McNown is Professor Emeritus in Economics at the University of Colorado, Boulder. He received his BA in Economics from UCLA and his PhD in Economics from UC San Diego. His primary areas of research and teaching interest are Econometrics, Time Series Analysis, Demography, and International Economics. Dr. McNown has held visiting faculty positions at Tribhuvan University (Kathmandu, Nepal) as a Fulbright Lecturer, People's University (Beijing) under World Bank sponsorship, Semester at Sea, the Department of Econometrics at Sydney University (Australia), and at the National Economics University in Hanoi, Vietnam as a Fulbright Scholar.

Dr. McNown has conducted training sessions in applied econometrics and time series econometrics at the Bank of Kenya (2007), the National Bank of Croatia (2007, 2008), Haver Analytics in New York (2013-2015), the International Monetary Fund (2013-2017), and the Bank of Korea (2014). He has been teaching Applied Econometrics in the NABE Certified Business Economist program since 2015. He has also been involved in the development and application of macro-econometric models for forecasting state and local district tax revenues for the Colorado Governor's Office, the Regional Transportation District of the Denver metropolitan area, and the University of Colorado's Department of Finance.

This Guide was prepared with the assistance of Michelle Thrun. Michelle earned her BA in Economics with a Quantitative Emphasis Certificate and a Mathematics Minor from the University of Colorado Boulder (2016). She is currently Private Client Coordinator in the Denver office of Alliance-Bernstein. Michelle contributed to the development of similar course materials in Applied Econometrics as a Research Assistant for JTC Econometrics LLC (2016). Her contributions to the development of the materials for Time Series Analysis and Forecasting included writing assistance, implementing and checking exercises, developing the PowerPoint slides, and drafting some of the chapters.

Time-Series Analysis and Forecasting, developed for the National Association for Business Economics.



The Certified Business Economist® (CBE) is the Certification in Applied Economics and Data Analytics.

The CBE designation is a symbol of distinction that business economists and analysts earn by meeting a prescribed level of achievement. It documents your professional accomplishments, experience, and abilities.

The Curriculum:

Applied Econometrics

This program covers cutting-edge developments in econometric methodologies and quantitative analysis, emphasizing business applications of statistical techniques.

Business Applications of Statistics and Data Analytics

This program in statistics and quantitative methods focuses on practical, applied problems and covering topics as hypothesis testing, tools for working with big data, basic regression methods, and diagnostics.

Economics of Strategy and Managerial Decision Making

This program covers the integration of microeconomic theory with real-world business scenarios to facilitate decision making, problem solving, and planning.

Economic Measurement Seminar

Instructed by leading data users and data providers, this program provides an overview of the sources and characteristics of the most vital economic statistics.

Communication and Presentation Skills for Business Economists and Analysts

A prerequisite for the CBE designation, this program offers the skills needed for effective verbal communication and best practice presentation tools and techniques.

Writing Skills for Business Economists and Analysts

A prerequisite for the CBE designation, this program provides useful tips for effective written communication and identifies common pitfalls experienced by writers in communicating technical information to clients and end users of varying levels of sophistication.

The CBE Examination:

Today's business economists and analysts are expected to master a wide array of disciplines. The CBE examination is based on an advanced body of knowledge, developed and reviewed by leading business economists to ensure that it reflects the most relevant information and core competencies sought by today's top employers.

The CBE Exam is designed to be a comprehensive multiple-choice assessment, testing a candidate's practical and applied knowledge in the following areas:

- Applied Econometrics
- Business Applications of Statistics and Data Analytics
- Economic Measurement
- Economics of Strategy and Managerial Decision Making
- Macroeconomics and Microeconomics

Candidates may choose prepare independently or enroll in NABE's courses if guided learning is preferred. Detailed content outlines will be posted for each subject area and sample test questions will be available.

The Certified Business Economist Requirements*:

- Examination - candidates must pass a comprehensive practical examination.
 - Membership - candidates must be a member in good standing with NABE.
 - Experience - candidates must have two years of work experience in applied business economics or in a related field.
 - Education - candidates must attain at least a four-year degree.
 - Curriculum Requirements - candidates must complete NABE's Communication and Presentation Skills for Business Economists and Writing Skills for Business Economists certificate courses or courses deemed equivalent by NABE.
 - Ethics - candidates must sign and adhere to the NABE Code of Ethics.
- Continuing Education/renewal - designees are required to earn 30 hours of continuing education every two years to renew the certification. A renewal fee applies.

About NABE

The National Association for Business Economics is the premier professional association for business economists and others who use economics in the workplace. Since 1959, NABE has attracted the most prominent figures in economics, business, and academia to its membership with highly-regarded conferences, educational and career development offerings, industry surveys, and its unrivaled networking opportunities. Past presidents of NABE include former Chairman of the Board of Governors for the Federal Reserve System, Alan Greenspan, several former Federal Reserve Governors, and other senior business leaders.

NABE's mission is to provide leadership in the use and understanding of economics.

Time-Series Analysis and Forecasting

Table of Contents

Introduction – Time Series Analysis and Forecasting	9
Forecasting	12
References	14
Chapter 1 – EViews Basics and Time Series Regressions	15
Introduction	15
Some EViews Basics	15
Naming conventions in EViews	17
The Equation Object – Gasoline Demand	17
Exercise 1: Lagged Dependent Variable Model	27
Newey-West Robust Standard Errors	28
Exercise 2: Spurious Regressions and Dangers of Not Testing for Autocorrelation	29
Exercise 3: Aggregate Production Function for the U.S.	29
The FRED Database	30
Conclusion	32
References	32
Chapter 2 – Univariate Time Series Analysis.....	35
Introduction	35
White Noise	36
Simulation and Diagnostics	36
AR, MA, and ARMA Processes	39
Seasonality	40
Nonstationary Processes	40
Simulating Time Series Processes	40
Box-Jenkins Approach to Univariate Modeling	43
Identification	43
Estimation	44
Diagnostic Testing of Residuals	44
An ARIMA Modeling Example: Inflation	45
Forecasts and Forecast Evaluation	53
Exercise 3 – ARIMA Modeling and Forecasting	57
References	59

Chapter 3 – Non-Stationary Time Series, Unit Roots: Concepts, Significance, and Testing	61
Introduction and Terminology	61
Difference Stationary vs. Trend Stationary Processes.....	63
Testing for Unit Roots	64
Implementation of the Dickey-Fuller Test	66
A More Powerful Unit Root Test – the DF-GLS Test.....	69
Technical Details of DF-GLS Test.....	70
Exercise: Application of DF-GLS Test to L_OUTPUT_PER_HOUR	71
References	74
Chapter 4 – Multivariate Models I: Autoregressive Distributed Lag (ADL) Models, Granger Causality, and Conditional Forecasts	75
Introduction	75
Autoregressive Distributed Lag (ADL) Models	76
Exercise 1: Interest Rate Spreads as Leading Indicators	79
Granger Causality	88
Exercise 1 (continued): Granger Causality Tests	89
Conditional Forecasts	94
Exercise 2: Evidence of Recession	96
Exercise 3 Build and Analyze an ADL Model	97
References	98
Chapter 5 – Vector Autoregression Models (VARs)	99
Background and Motivation	99
VAR Model Specification and Estimation	100
Selection of Variables	101
Transformation of Variables	101
Deterministic Factors	102
Number of Lags on Each Variable	103
EViews Implementation: VAR Model Specification and Estimation (A Phillips Curve Example).....	103
VAR Interpretation and Analysis	115
The Autoregressive form: Granger Causality	115
Moving Average Representation and Innovation Analysis.....	117
Impulse Response Functions	118
Cholesky Ordering	120
Summary.....	122
References	123
Chapter 6: Forecasting with Vector Autoregressions & the Model Object	125
Background and Motivation	125
Forecasting with the Model Object.....	126

VAR Model Specification	126
Forecasting with the Model Object.....	129
Forecast Evaluation	133
Exercise: Interest rate spreads as predictors of output growth rate.	136
Conclusion	138
References	139
Appendix: The Factor Augmented VAR (FAVAR).....	139
Forecasting with the FAVAR.....	143
Chapter 7 – Cointegration and Error Correction Models (ECMs): Least Squares Approach	147
Introduction	147
Concepts and Definitions.....	148
Testing for Cointegration: The Engle-Granger Approach.....	149
Dynamic OLS (DOLS) Estimation of Cointegrating Equations	151
Exercise 1: Cointegration Testing with Saving - Investment Data.....	152
Exercise 2: Engle-Granger Test of Capital Mobility for South Korea	159
Exercise 3: Engle-Granger Test on Spot-Forward Exchange Rates	159
The Error Correction Model	161
Exercise 4: ECM for Savings/Investment.....	161
Exercise 5: ECM for Savings/Investment for South Korea	166
References	167
Chapter 8 - Cointegration and error correction models (ECMs) II: Maximum Likelihood Methodology	169
Introduction: Motivation and Overview of Maximum Likelihood Methodology	169
Cointegration, VARs, and the Vector Error Correction Model	170
Johansen’s Tests for the Number of Cointegrating Relations	173
Implementation of the Johansen Cointegration Testing Procedure: a Model of Monetary Equilibrium	174
Estimation and Testing of the VECM	180
Short Run Dynamics in the VECM	186
Granger Causality.....	186
Impulse Response Functions	188
Variance Decompositions	189
The VAR in (Log)-Levels	191
Forecasting with the VECM and the Model Object	194
Advanced Exercise: A Model of Fertility and Female Labor Supply with Multiple Cointegrating Equations	201
References	207

Technical Appendix	208
EViews Command Summary	210
Time Series Functions	212
Plots of representative time series	213
 PowerPoint Presentation	 217