This book presents the numerous tools for the econometric analysis of time series. The text is designed with emphasis on the practical application of theoretical tools. Accordingly, material is presented in a way that is easy to understand. In many cases intuitive explanation and understanding of the studied phenomena are offered. Essential concepts are illustrated by clear-cut examples. The attention of readers is drawn to numerous applied works where the use of specific techniques is best illustrated. Such applications are chiefly connected with issues of recent economic transition and European integration. The outlined style of presentation makes the book also a rich source of references.
Elements of Time Series Econometrics: an Applied Approach

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Layout and cover design Jan Šerých
Typeset by Studio Lacerta (www.sazba.cz)
Second edition

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ISBN 978-80-246-2315-3
Ukázka knihy z internetové knihkupectví www.kosmas.cz, UID: KOS196818
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To Monika and Alžběta
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INTRODUCTION

This book, in its second edition, presents the numerous tools for the econometric analysis of time series. The text is designed so that it can be used for a semester course on time series econometrics, but by no means is the text meant to be exhaustive on the topic. The major emphasis of the text is on the practical application of theoretical tools. Accordingly, we aim to present material in a way that is easy to understand and we abstract from the rigorous style of theorems and proofs. In many cases we offer an intuitive explanation and understanding of the studied phenomena. Essential concepts are illustrated by clear-cut examples. Readers interested in a more formal approach are advised to consult the appropriate references cited throughout the text.

Many sections of the book refer to influential papers where specific techniques originally appeared. Additionally, we draw the attention of readers to numerous applied works where the use of specific techniques is best illustrated because applications offer a better understanding of the presented techniques. Such applications are chiefly connected with issues of recent economic transition and European integration, and this way we also bring forth the evidence that applied econometric research offers with respect to both of these recent phenomena. The outlined style of presentation makes the book also a rich source of references.

The text is divided into five major sections. The first section, “The Nature of Time Series”, gives an introduction to time series analysis. The second section, “Difference Equations”, describes briefly the theory of difference equations with an emphasis on results that are important for time series econometrics. The third section, “Univariate Time Series”, presents the methods commonly used in univariate time series analysis, the analysis of time series of one single variable. The fourth section, “Multiple Time Series”, deals with time series models of multiple interrelated variables. The fifth section “Panel Data and Unit Root Tests”, deals with methods known as panel unit root tests that are relevant to issues of convergence. Appendices contain an introduction to simulation techniques and statistical tables.

Photographs, and illustrations based on them, that appear throughout the book are to underline the purpose of the tools described in the book. Photographs, taken by Monika Kočendová, show details and sections of Fresnel lenses used in lighthouses to collimate light into parallel rays so that the light is visible to large distances and guides ships. Tools described in this book are used to process information available in data to deliver results guiding our decisions.

1 For rigorous treatment of specific issues Greene (2008) is recommended.
2 Patterson (2000) and Enders (2009) can serve as additional references that deal specifically with time series analysis.
When working on the text we received valuable help from many people and we would like to thank them all. In particular we are grateful for the research assistance provided by Ľuboš Briatka, Juraj Stančík (first edition), and Branka Marković (second edition). We also thank Professor Jan Kmenta for consenting to our use of the title of his book (Kmenta, 1986) as a part of our title. Special thanks go to Monika (EK) and Alžběta (AČ).
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There are two major types of data sets studied by econometrics: cross-sectional data and time series. Cross-sectional data sets are data collected at one given time across multiple entities such as countries, industries, and companies. A time series is any set of data ordered by time. As our lives pass in time, it is natural for a variable to become a time series. Any variable that registers periodically forms a time series. For example, a yearly gross domestic product (GDP) recorded over several years is a time series. Similarly price level, unemployment, exchange rates of a currency, or profits of a firm can form a time series, if recorded periodically over certain time span. The combination of cross-sectional data and time series creates what economists call a panel data set. Panel data sets can be studied by tools characteristic for panel data econometrics or by tools characteristic for multiple time series analysis.

The fact that time series data are ordered by time implies some of their special properties and also some specific approaches to their analysis. For example, the time ordering enables the estimation of models built upon one variable only – so-called univariate time series models. In such a case a variable is estimated as a function of its past values (lags) and eventually time trends as well. As the variable is regressed on its own past values, such specification is aptly called an autoregressive process, abbreviated as "AR". Because of the time ordering of data, issues of autocorrelation gain prominent importance in time series econometrics.