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Book review

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Applied Time Series Analysis

by **Zorica Mladenović and Aleksandra Nojković**

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Methods of time series analysis are relevant techniques in many economic studies that rely on quantitative measurement of macro-economic and financial variables and their dependence. The time series is a chronologically arranged series of observations showing the movement of certain observations over successive time intervals. While the aim of obtaining more efficient representations of the nature of certain time series developments besides graphic analysis, a comprehensive analysis of empirical data of observed variable in the past is also done, as well as the possible prediction of the trend in the future period. In this context, one of the most important advantages of applying the methods of time series analysis is the ability to combine theoretical knowledge with specific, observed behaviors during the selected time series. This is doubtlessly a necessary precondition to adopting appropriate economic policies and conclusions.

The 425 page *Applied Time Series Analysis* includes a comprehensive methodological framework of univariate and multivariate analyses of dynamic systems and stochastic processes in a way that integrates economic theory and econometric analysis with the empirical results of time series modeling. The structure of the book is presented in five different and complementary parts. After getting acquainted with the elementary concepts, objectives and descriptive methods in the time series analysis, the second and third parts are devoted to the analysis of univariate time series. In this respect, the bases of analysis of the one-dimensional stationary time series are presented, followed by a detailed elaboration of specific methods of analysis of economic time series. Relatively complex analysis is primarily related to the present testing algorithms within different unit root tests as a prerequisite for the implementation of the selected modeling setting and specification of an appropriate model. The next instance relates to the analysis of multivariate time series and also includes a complete presentation of the key properties and testing process of the vector autoregressive models and an explanation the concept of cointegration as the dominant framework for modeling time series with a unit root. The final section contains the empirical results of the application of acquired knowledge in the field of econometric time series analysis on selected macroeconomic data.

The first part, “Initial Time Series Analysis,” indicates the essential concepts and fundamentals in time series analysis, in order to introduce readers to the basic notions, objectives and key labels. Theoretical description of specific time series is supported by graphical illustrations of deterministic and stochastic components of trend, seasonal components, structural break and unstable variance. With the aim to ease understanding of the upcoming models and relationships, this section presents the basic labels in the analysis of time series. An explanation of the crucial concepts in this area follows, with an introduction of the terms: a random process, time series, stationarity and ergodicity. Bearing in mind that the initial stage in the time series analysis refers to the descriptive indicators, four methods of descriptive categories are presented: graphical representations, summary indicators, methods of transformation and smoothing methods. Given that the shape of the empirical distribution to some extent determines the direction for future testing, it is important to determine whether a given distribution of time series can be approximated by a normal distribution. For this reason, the authors explain the rules of inference based on the histogram, the coefficient of skewness and kurtosis and Jarque-Bera test statistics. Regarding the method for transformation, approaches which are applied in order to stabilize the variance are discussed: logarithm of the data and application of the operator of the first difference, whereas regression method, moving average method and HP trend are presented as a smoothing method.

In the second part, "Analysis of the Univariate Time Series - the Basics," the key functions and analysis processes of the one-dimensional stationary time series are exposed. It is considered to be appropriate to begin the analysis by examining the special characteristics and features of individual time series using a number of techniques from the domain of univariate analysis, regardless of whether the goal of econometric research focuses on analysis of movement of particular time series or joint analysis of a number of time series. Given the importance of perception of the correlation structure and diversity in motion in autocovariance and autocorrelation functions through different models, specificities and properties of scores for both functions are presented in detail. Since it is used for the same purpose, the partial autocorrelation function is also separately presented in this section. Further elaboration of such key theorems on time series analysis exhibited Wold's decomposition theorem. In other words, definition of the linear process and its variance, autocovariance and autocorrelation function are exposed. In the framework of a model describing the weak stationary time series, the authors extensively present: autoregressive (AR) models, moving average (MA) models and autoregressive moving average (ARMA) models. Along with precise execution of stationarity and invertibility conditions, linear form, autocovariance and autocorrelation functions for the three categories of models, graphical representations of examples that make it much easier to overcome the presented problems are offered to the readers. Given that from the theoretical and empirical point of view, we are witnesses of a number of serious and far-reaching turbulences on the macroeconomic stage, in the section of univariate analysis the authors have paid a special attention to the method of forecasting time series using ARMA models. At the end of the second part, an adequate strategy for parameter estimation for the three groups of stationary time series models is presented.

The next part, "Analysis of the Univariate Time Series: Specificities of the Economic Time Series," is devoted to methods of analysis specificities, testing and modeling strategy for economic time series. Recognizing that the long-term tendency of growth or decline is one of the basic characteristics of macroeconomic time series over time, at the beginning of the third part, the authors present classification of two forms of the model: trend-stationary and difference-stationary. In the present context, the names themselves indicate that the first case is a variant of the stationary time series with variable mean in line with the trend function, whereas the second category applies to models which are characterized by unstable variance that increases linearly with time, while values of autocovariance and autocorrelation functions are conditioned with the delay which defines them k and the time t. Alternative terms for difference-stationary class of models (whose general form is known as ARIMA models): integrated-stationary time series, time series with a stochastic trend, time series with unit root and random walk process were developed and presented below. Since the stochastic variations are important features of economic models, permanent effects of unexpected changes are formally tested by determining the number of unit roots of the observed time series. From the viewpoint of practical application, there is a consensus among researchers regarding the use of Dickey-Fuller test (DF) as an adequate basis for further testing which confirms or refutes previous conclusions. Depending on the included deterministic components, a way of formulating a hypothesis, testing algorithms and procedures for the determination of critical values of DF test statistics are presented in detail. An extended version of the DF test is also explained, of which the original idea relates to the correction of the baseline model by adding new components, with the aim of eliminating autocorrelation in residuals. Apart from the forms that related to testing in accordance with the Dickey-Fuller approach with certain modifications, authors also introduced the KPSS test that starts with an analysis of variance of the random component and consequently, the decision making about stationarity. The presentations of the most used unit root tests are followed by Box-Jenkins view of modeling strategy and approach related to the analysis of residuals, which is the final stage before the final definition of the type and form of the econometric model.

In order to achieve a higher level of comprehension of the analysis, the properties of time series characterized by the existence of a seasonal component are explained, as well as a way of including this type of variation of the corresponding seasonal ARIMA models. The authors also pay special attention to the analysis of interventions and structural breaks, bearing in mind that many exogenous events can be manifested in a set of observations that are not consistent with previous tendency of time series. The main objectives of modeling structural breaks are related to the testing of its duration, the date of occurrence and level of significance, while as the most popular unit root tests which include breaks in the analysis, the Perron and Zivot-Andrews tests are presented. At the end of the third part, the authors present an econometric framework for the analysis of model with unstable variance and conditional heteroskedasticity, in which the generalized autoregressive conditional heteroskedasticity model is exposed (GARCH model) with additional explanations of the three key stages of the process which relies on GARCH models construction.

The fourth part, “Analysis of Multivariate Time Series,” provides a detailed overview of multidimensional analysis which is applied when the research needs are focused on the application of the models that enable the analysis of cause-and-effect relationship between two or more variables. At the very beginning of this chapter, a theoretical review of alternative strategies in macroeconomic modeling is described, where authors provide a comparative analysis based on the modeling of the system of simultaneous equations and modeling based on vector autoregressive models. On the basis of previously acquired knowledge, it is known that the inclusion of non-stationary time series as explanatory variables results in inconsistent evaluations which do not have normal distributions, and the occurences of spurious correlations or nonsense regression are not rare. As a way of evading these shortcomings of classical linear regression model, the concept of cointegration is defined in the expression of adequate methodological approach for the analysis of time series with a unit root. In the present framework, authors presented the basis for applying Dickey-Fuller test of series residuals (DFR) as the dominant test for testing cointegration in time series data. On the other hand, the procedures for testing the existence of cointegration in panel data are discussed and an algorithm for applying the first-generation tests in this area is derived.

Further exposure provides a consistent elaboration of vector autoregressive models which in the first step involves display settings and defining conditions of weak stationarity of the VAR models which is followed by presentation of specification tests which can be effectively implemented with the aim of analysing the existence of autocorrelation and testing of normality. The analysis procedure in the case where the components of vector time series have a unit root is also showed, depending on whether or not they are cointegrated. Mutual interdependence and connectivity of a large number of economic and financial variables is given special attention in this chapter, and the authors tend to explain the concept of causality and impulse response function well. If one wants to study the effects of the previous movements of a certain time series on the current and future level of the time series which is correlated with them, it is useful to apply one of the presented tests of causality, while impulse response function is suitable for the analysis of the effects of unexpected and random changes in one time series on the movement of all time series in the system of VAR model. Methodological aspects of the analysis of cointegration in VAR model is presented below. Authors also systematize the appropriate tests to verify the existence of cointegration which means to define of the likelihood-ratio test statistic, which is used to test a number of stationary combination (Johansen approach). The final commentary at the end of the fourth section is devoted to various combinations of the presence of deterministic components in cointegration analysis in the VAR model. Given the need to examine the hypothesis that cointegration parameter takes an exact value in economic relations, the application of the test which formally checks the validity of the linear restrictions on the cointegration parameters are also explained.

In the last part, “Empirical Results of Applying the Univariate Models,” the results of the univariate analysis for thirteen time series are summarized. The majority of the investigated time series refer to the real data on selected macroeconomic indicators which thankfully illustrate economic trends in Serbia, while a smaller number is related to European and international frameworks. It is important to note that the data of different frequencies (monthly, quarterly and annual) and lengths are given, with the aim of making it easier to comprehend the specifics of certain categories in econometric analysis. After the initial prediction of the movement of time-series through graph presentation, the comprehensive analysis of autocorrelation and partial autocorrelation function at the level of the time series, and its first difference are provided to readers, with the goal of timely detecting the eventual presence of a seasonal component or structural break, while formal testing verifies the correct number of unit roots. The choice of an appropriate ARIMA specification is based on the application of Box-Jenkins modeling strategy which is standard procedure, which relates to the identification of the model, estimation of parameters and testing the adequacy, implemented in the analysis of each time series.

Readers can check the empirical results reported in the book because the data of the analyzed time series data are available on the website http://avs.ekof.bg.ac.rs.

Taking into account the form in which the book was conceived and its priceless significance for the practical application, we can say that this is the first book in Serbia which in this frame exposes the concepts and issues of the method of time series analysis. At the same time, in an appropriate way it presents an adequate counterpart to the modern trends in the international field of applied time series analysis. In a unique way, the authors have succeeded in their intention to share their own, the most profound knowledge of the most important principles of univariate and multivariate analysis and present them in a form available to the academic, professional and student public. From the point of view of fundamental theoretical and conceptual substrate, on the one hand, and empirical-analytic application context, on the other hand, the book is a precious contribution of the studied theoretical and practical question of the methods of time series analysis in both local scientific research and educational publications.