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1 Introduction

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1.1 Introduction

Methodological revolutions in economics are not new. The major impact of a revolution is that it calls for a fundamental change in our way of thinking about modelling economic phenomena. Such revolutions in economics are invariably controversial, partly because they often imply that existing policy measures are inappropriate and should be abandoned in favour of a new set of policies. The old and new policies may have different adherents depending on their sense of economic fairness and justice. Therefore, it is hard to derive widely acceptable conclusions on the relative merits of these revolutions. The unit roots and cointegration revolution have both economic and statistical implications. Although its economic implications may be controversial, its statistical implications are less controversial. We shall first describe briefly its statistical implications.

1.2 Unit roots and cointegration

The standard classical methods of estimation, which we routinely use in applied econometric work, are based on the assumption that the means and variances of the variables are well-defined constants and independent of time. However, applications of the unit root tests have shown that these assumptions are not satisfied for a large number of macroeconomic variables. Variables whose means and variances change over time are known as non-stationary or unit root variables. Furthermore the unit root revolution has also shown that using classical estimation methods, such as the ordinary least squares (OLS), to estimate relationships with unit root variables gives misleading inferences. This is known as the spurious regression problem, and an intuitive explanation is as follows. If the means and variances of the unit root variables change over time, all the computed summary statistics, in which these means and variances are used, are time dependent and fail to converge to their true values as the sample size increases. Furthermore, conventional tests of hypothesis will be seriously biased towards rejecting the null hypothesis of no relationship between the dependent and independent variables. This is serious if the null hypothesis is true. The spurious regression problem has other implications. Phillips (1986) developed a formal model for regressions between unit root variables to show, for example, that the Durbin–Watson (DW) statistic converges towards zero. This is an important finding because a low DW statistic often indicates that the variables in a regression model are non-stationary. Therefore, pretesting the variables for unit roots has become important in the applied econometric work.

It is convenient to view cointegration as the appropriate technique to estimate the equilibrium or long-run parameters in a relationship with unit root variables. Broadly, there are four major steps in applying unit root and cointegration techniques. First, unit root tests are applied to determine if the variables in a regression are stationary or non-stationary. Second, cointegrating regressions are estimated if the variables satisfy certain conditions. These cointegration regressions are the long-run or equilibrium relationships between these variables, although these relationships may not have a causal interpretation. Therefore, both theoretical insights and statistical tests are necessary to determine what causes what.[1] Third, the short-run or the dynamic disequilibrium relationships are estimated utilising the estimates of the long-run parameters and an adjustment process based on the error correction model (ECM) of Phillips (1954).[2] Last, the robustness of the estimated dynamic disequilibrium relationships is determined by subjecting them to the standard diagnostic tests.

Sometimes it is likely that the unit root null hypothesis can be rejected for a variable by one test but not by another. Therefore, it is important to use a few alternative unit root tests. For example, the unit root null hypothesis can be confronted with a stronger alternative hypothesis, or the more recently developed unit root tests, based on the exogenous or endogenous breaks, can be used. These recent tests have more power to reject the unit root null.[3] Needless to say, if the variables in an equation are stationary, the standard classical methods of estimation can be used. Similarly, there are alternative methods of estimation of the cointegration relationships. Therefore, it is desirable to use more than one technique to estimate the long-run relationships.

The aforesaid outline is a highly simplified and condensed version of the major steps in applying unit root and cointegration techniques. In practice, however, the applied economist will encounter several problems. Nonetheless, it can be said that in the applied econometric works some widely used unit root tests are the augmented Dickey–Fuller test (ADF) and the more powerful alternative tests like the generalized least squares ADF test or GLSADF and the Elliot, Rothenberg and Stock (ERS) test. These tests can be implemented with many standard software packages like EViews, RATS and TSP. For estimating the cointegrating equations the more popular estimation methods are the Engle and Granger two-step method, the general to specific approach (GETS), the Phillips–Hanson technique, bounds test and the Johanson maximum likelihood method. The papers in the first edition of this book adequately explained some of these standard and frequently used procedures. We have included two such papers from the original edition in this volume which cover some basic and widely used procedures.

1.3 Economic implications

The economic implications of the unit roots and cointegration literature are also important especially to provide some perspective to those who are interested mainly in applying alternative unit root tests. The mainstream Keynesian and neoclassical alternative macroeconomic paradigms have treated economic fluctuations as temporary deviations from a stable trend rate of growth of output and offered different explanations for these fluctuations. These dominant macroeconomic paradigms also assume that economic fluctuations are due to aggregate demand shocks and these fluctuations, sooner or later, die down and the economy will eventually reach its full employment equilibrium. Therefore, by and large, demand shocks are unlikely to have any permanent effects on the full employment output. In contrast, the real business cycle theories argued that economic fluctuations are due to shocks to aggregate supply and that they are likely to have permanent effects on the level of output.

While it may be hard to directly evaluate these two theories, developments in time series econometrics offered a simpler and an indirect method of evaluation. The now classic Nelson and Plosser (1982) unit root tests have shown that several US macro variables are unit root variables. Doubts have been raised on the separation of cycles and trends in the traditional macroeconomic theories, and therefore the real business cycle theories have received considerable interest. Since the Nelson and Plosser results have been supportive of the real business cycle theories, it has become important to examine the robustness of their tests, because it is well known that the ADF test lacked power against the null hypothesis of a unit root. Several alternative and more powerful unit root tests have been developed. Some of these alternative tests are explained, albeit briefly, in the recent textbooks, and updated versions of some software packages like EViews, TSP and RATS can be used to implement such tests.

There has been also some important changes in the subsequent development of the unit root tests. Perron (1989) argued that if the standard unit root test is modified to allow for an a priori known break (e.g. oil shock) in the intercept and/or a trend of the variable, the modified tests show that many variables in the Nelson and Ploser simple are stationary. Another equally significant development is a series of tests in which the break date is endogenously determined and also tests with more than one brake date. At this stage, it is hard to say we would ever discover a perfect test to determine, once for all, whether the key macro variables are stationary or non-stationary. Nevertheless, currently some widely used sequences of tests in applied work are the ADF test, GLSADF test and the Zivot and Andrews (ZA) test where the break date(s) are endogenously determined.

Compared to the progress made in developing alternative unit root tests with brake dates and so on, it may be said that the progress made in the estimation of cointegrating relations and error-correction models, with structural breaks in the variables, is modest.[4] Nevertheless, it is useful to know how some, if not all, of these important developments can be used in the routine applied economic work. At the same time, it is important to know the limitations of the unit root and cointegration techniques, because, at times, they have been used to answer questions related to the specification issues which are beyond their scope.[5]

The main objective of this book is to provide a good methodological perspective and introduction to these recent developments. This book will also help the applied economists to understand how some of these recent techniques can be used in the routine applied econometric work. Therefore, the contributors to this volume have been specially requested to keep in mind the needs of the average applied economist with a modest background in the estimation theory. Readers may download the data and instructions for the papers in this book for replication from this book's homepage or contact the authors.

1.4 An overview of the papers

We have included two papers from the first edition of this book because many readers said that they have been very useful. These are the classic paper on the demand for money by Dickey, Jansen and Thornton and an equally valuable expository and slightly revised paper on unit roots and cointegration by Holden and Perman.

Dickey, Jansen and Thornton use the Dickey–Fuller and the ADF tests to test for unit roots in the variables of the demand for money function. Both tests yield similar conclusions. Next, they explain how the cointegrating regressions can be estimated using three different approaches namely, the Engle and Granger two-step, the Johansen ML, and the Stock–Watson procedures. The Johansen ML method seems to yield more satisfactory results. A much appreciated aspect of this paper is a detailed step-by-step explanation of the Johansen ML and the Stock–Watson methods in the Appendix.

Holden and Perman's paper is somewhat similar in scope to the Dickey, Jansen and Thornton paper, illustrating among other things, the usefulness of the Phillips and Perron non-parametric test. The discussion of various unit root tests is very comprehensive, and an easy to follow step-by-step sequential procedure to conduct these tests is explained. The error-correction formulation is discussed in some detail. Although the Johansen ML method is used, there is a detailed discussion of the application of cointegration in econometric modelling. They apply some of these tests to the UK consumption function in their Appendix.

The remaining five papers in this volume by Ron Smith, Joseph Byrne and Roger Perman, Amit Sen, Roselyne Joyeux and Vasudeva Murthy – are new and discuss various aspects of the recent developments in the unit roots and cointegration literature.

In his 'Significance of Unit Roots and the Pitfalls of Mechanical Statistics', Ron Smith says that unit roots, vector auto-regressions (VARs) and cointegration play a central, though controversial, role in modern time series econometrics. His paper uses these concepts to examine one aspect of applied econometrics, the prevalence of mechanistic application of statistical techniques and the problems with such an approach. After reviewing the general methodological questions, Smith examines the issues of estimation and testing, using a small macro-model of the US as an example.

We strongly recommend that readers also read Smith (2002) to get a good methodological perspective on the present developments in the econometrics of time series and to be aware of why some leading proponents of alternative approaches take strong positions on the usefulness of a particular technique or development. Lack of such a methodological perspective seems to have caused considerable confusion about the merits of alternative approaches to time series econometrics. Consequently, a good number of applied works are little more than mere mechanical statistics. Smith's paper in this volume, which further explores his views, provides valuable additional methodological perspectives to the current developments on this subject.[6]

In 'Unit Roots and Structural Breaks: A Survey of the Literature', Byrne and Perman survey various developments in the unit root tests. It is well known that since Perron (1989), the time series literature has emphasised the importance of testing for structural breaks in typical economic data sets and pronounced the implications of structural breaks when testing for unit root processes. In the paper presented here, Byrne and Perman survey recent developments in testing for unit roots that take into account a variety of structural breaks. In doing so they discuss the distinction between taking structural break dates as exogenously determined, an approach initially adopted in the literature and endogenously testing break dates. That is, they differentiate between testing for breaks when the break date is known and when it is assumed to be unknown. Also, important is the distinction between discrete breaks and gradual breaks. Additionally, they describe tests for both single and multiple breaks, and discuss some of the pitfalls of the latter.

Although they do not discuss structural break tests based on the systems methods, their lucid discussion based on the single equation methods is easy to understand and implement. Furthermore, their guidelines on the software packages for these tests are timely. At a time when many applied workers are increasingly becoming interested in unit root tests based on structural breaks, there is not much expository literature that can be easily understood by applied economists. The Byrne and Perman paper fills this gap, and therefore it is likely to be widely read and cited.

Amit Sen examines the finite sample size and power properties of some new unit root tests, which are designed to have power against the trend-break stationary alternative. He discusses versions of these statistics with both a known and an unknown breakdate. He tabulates the corresponding critical values that will be handy for many applied workers who may not have easy access to the critical values of some recent tests. The tests discussed by Sen belong to the class of J-tests that were originally proposed by Park and Choi (1988), and complement other unit root tests such as those proposed by Zivot and Andrews (1992); see the paper by

Byrne and Perman for further details. The programmes to compute Sen's tests can be obtained from his homepage or by contact him. He illustrates the use these tests to evaluate all series in the extended Nelson–Plosser data set and finds evidence against the unit root null hypothesis for the US real GNP, real per capita GNP, industrial production, employment, and common stock prices series. He also tests for the presence of a unit root in the real per capita GDP series of 18 OECD countries. The unit root null is rejected for Austria, Belgium, Canada, Denmark, the United Kingdom and the United States. Therefore, his findings raise fresh doubts on the support for the real business cycle theory in the original Nelson–Plosser tests.

In 'How to Deal with Structural Breaks in Practical Cointegration Analysis?', Roselyne Joyeux illustrates how to estimate a cointegrating equation with a known structural break. Structural breaks have to be accounted for when testing for cointegration among the variables in a VAR model. Her paper shows how to specify and include intervention dummies, and illustrates with an example the latest developments in the use of intervention dummies when testing for unit roots and cointegration in a VAR framework. A simple explanation of the specification of intervention dummies is provided together with an application. This is another important gap filler in applied work, because there are very few guidelines on how to proceed further if it is found that all or some variables contain unit roots with structural breaks.

From the applied economist's point of view, if the break dates are different for different variables, it is even more difficult to estimate cointegrating equations. In our view, the problems caused by structural breaks, although well explored for the unit root tests, are not adequately addressed for the estimation of cointegrating equations. Burke and Hunter (2005) for example, point out that 'Probably the main future of economic time series that is capable of undermining cointegrating analysis is that of structural beaks'. If the unit root tests with structural breaks show that all the variables in a model are stationary in levels, then the standard classical methods of estimation with appropriate shift dummies can be used.[7] However, as noted above, if the break dates are different and some variables are stationary in their levels and others are not, cointegration techniques become difficult to apply. A pragmatic methodological alternative is to determine the dominant common break date in a set of variables, as briefly mentioned by Byrne and Perman, through a systems method. By and large, the Gregory and Hansen (1996) method does this within the Engle–Granger cointegration framework, by identifying an endogenous break. Their procedure is briefly explained in

Harris and Sollis (2005) and can be implemented with RATS Version 6.[8] Joyeux goes one step further, to illustrate how cointegrating equations can be estimated, with a known structural break, within the Johansen maximum likelihood framework.[9]

Joyeux explains in the appendix the capabilities of CATS[10] (versions 1 and 2), EViews (version 5), MALCOLM (version 2.9) and Microfit (version 4.1) for handling cointegration tests and VECM estimation in the presence of structural breaks. We hope that her paper will stimulate a number of applied works with the latest techniques in the unit root tests and estimation of cointegrating equations with structural breaks.

In the final paper, Vasudeva Murthy explains how the unit roots and cointegration techniques can be used with the panel data. He uses the Feldstein–Horioka (1980) puzzle to illustrate the application of the first generation panel unit root tests of Pedroni, based on his Group-Mean Panel Fully-Modified Ordinary Least Squares (GMPFMOLS) technique. Using these Pedroni techniques, he tests for the validity of the Feldstein–Horioka puzzle, with non-stationary heterogeneous panel data for 17 African countries for 1965–2001. Furthermore, he surveys briefly some recent developments in the panel cointegration analysis and tests. His results show that the Feldstein–Horioka puzzle is not applicable to these 17 countries due to imperfect capital mobility.

This paper is perhaps one of the best expositions of this strand of literature and can be easily understood by many applied economists. This is also a timely paper and fills a gap in the growing interest in applied growth econometrics based on the cross-section data. The appendix to this paper explains in detail how all the procedures can be implemented with EViews and RATS.

1.5 Concluding observations

The table of contents is exhaustive and should enable rapid location of where a topic of interest is discussed in the book. The index is thorough but by no means exhaustive. It is impossible to list every citation of frequently cited names like Dickey and Fuller, Phillips and Perron, Engle and Granger and concepts such as the ADF test, Phillips–Perron tests, the Johansen maximum likelihood method and so on. Nonetheless, an attempt has been made to include all the important concepts, contributions and names in the index. Chapter numbers are prefixed to the section and sub-section numbers 3.2.1 means that it is subsection 1 of section 2 of chapter 3. Similarly all the tables and figures start with the relevant chapter number. For example, Table 4.2 is Table 2 in Chapter 4.

Chapter numbers, however, are not prefixed to equations because none of the chapters refers to the equations in another chapter.

Since one of the objectives of this book is to encourage replications, all the data sets used in the papers are made available on the publisher's book homepage. Further details on any missing data and software routines can be obtained by contacting the respective authors. An old Chinese proverb goes something like this: If I hear, I know. If I see, I believe. If I do, I understand. Therefore, applied economists are strongly advised to replicate the results from various papers. It is our hope that our book will encourage many to do quality research with the help of some recent econometric techniques.

Notes

1. An intuitive explanation of the identification and endogeneity concepts in cointegration is given in Rao (2007).
2. For an informative survey of ECM see Alagoskafis and Smith (1991).
3. Alternative unit root tests have also economic implications, and we shall examine them shortly.
4. In applied work, some have used shift dummies in the cointegrating or in the short-run dynamic equations. Some others have estimated separate cointegrating equations for the sub-samples after determining the break dates. Needless to say, these are arbitrary procedures.
5. A bright graduate student has asked if he can estimate a cointegrating equation between the bank rate, and imports to tests whether a recent rise in the bank rate in Fiji, from 3.5 per cent to 3.75 per cent, will decrease the high growth in imports. There are a number of ad hoc applications of the unit roots and cointegration techniques, especially in the time series applied growth literature with grossly misspecified equations, where the growth rate is simply regressed on a single variable like foreign aid or even defense expenditure etc.
6. See also Rao (2007) which is very much influenced by Smith's methodological views.
7. The well-known GETS method, developed at the London School of Economics, can be used to distinguish between the long- and short-run relationships. GETS was originally developed for this purpose, well before the unit roots and cointegration methods had much impact. The distinguishing feature of GETS is the dynamic adjustment process based on the error-correction model, which is later used in all the time series models.
8. Rao and Kumar (2007), inspired by Byrne and Perman and Joyeux, is an easy to read application of the Gregory and Hansen (1992) technique to estimate cointegrating equations with a single endogenous structural break.
9. See also Franses (2001) for a discussion of cointegration with structural breaks. The dominant break date, for example, may be first determined endogenously with the Gregory and Hansen method and then used to implement the Johansen procedure.
10. CATS and MALCOLM were run using RATS version 6.02b.

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