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New Developments in Time Series Econometrics: An Overview[1]

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Empirical data in economics are typically non-experimental, especially in finance and macroeconomics where researchers usually rely on time series gathered by official agencies or other investigators. This raises two basic problems for econometric modeling: first, to understand the dynamic structure of such series, both individually (e.g., stationarity and persistence properties) and jointly (dynamic relations between series); second, to use these series in order to identify and assess potential explanatory ("structural") models. Because such data are non-experimental, so that observations cannot be made independent and optimal experimental designs are not available, modeling and inference often require an exceptional degree of sophistication. Fortunately, in recent years, statistical methods for the analysis of time series have developed considerably and several remarkable innovations have been introduced.

The eleven articles in this special issue provide empirical applications as well as theoretical extensions of some of the most exciting recent developments in time-series econometrics. Several leading econometricians have contributed to this collection. The papers have been grouped around three broad themes: (I) the modeling of multivariate time series (five papers); (II) the analysis of structural change (three papers); (III) seasonality and fractional integration (three papers). Of course, these themes are closely inter-related, and several other topics covered are worth stressing: vector autoregressive (VAR) models (Juselius; Palm, Peeters and Pfann; Perron and Campbell; Tiao, Tsay and Wang), cointegration and error-correction models (Ghysels, Lee and Siklos; Juselius; Kunst; Lütkepohl; Palm, Peeters and Pfann; Perron and Campbell; Quintos and Phillips; Tiao, Tsay and Wang), nonparametric methods in time series

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(Campbell and Galbraith), and fractionally integrated models (Chung and Baillie). Another interesting feature of these contributions is that the majority of the papers (9 over 11) are mostly empirical or contain empirical illustrations, while five of them contain new methodological results (Quintos and Phillips; Perron; Ghysels et al.; Perron and Campbell; Chung and Baillie). A brief overview of these contributions is presented below.

The five papers in the first section (Tiao et al.; Juselius; Palm et al.; Perron and Campbell; Campbell and Galbraith) deal with relatively general issues relevant to the modeling of multivariate time series, especially in the context of VARMA and VAR models. In particular, the concept of cointegration, which provides a way of distinguishing between long-run equilibrium relations and short-run dynamics, plays a central role in these analyses. It is also interesting to note that the papers by Tiao et al., Juselius, and Palm et al. nicely illustrate increasing degrees of structural modeling, as opposed to a relatively model-free statistical analysis. Then the paper by Perron and Campbell makes an interesting theoretical contribution to the analysis of equilibrium relations (cointegration) in such systems, while the paper by Campbell and Galbraith shows how a finite-sample distribution-free technique can be useful in studying relationships between two time series.

More specifically, the article by George Tiao, Ruey Tsay and Tsychang Wang illustrates how several recently developed statistical techniques for analyzing multivariate time series from a relatively "atheoretical" standpoint can be fruitfully applied to economic time series. The authors have made important theoretical contributions to the development of several techniques used here, some of which have been little exploited by econometricians. The authors analyze the behaviour of three interest rates (on one-, three- and six-month deposits) in Taiwan (monthly, from 1961 to 1991). They study first whether these series have unit roots and whether they are cointegrated. To analyze cointegration, they use procedures proposed by Engle and Granger (1987), Johansen (1988), Stock and Watson (1988), and Chan and Tsay (1991), and conclude that the interest rates have unit roots but are not cointegrated. To analyze the dynamic relationships between the interest rates, the authors then employ the class of vector autoregressive moving average (VARMA) models and use the modeling approach proposed by Tiao and Box (1981). They find that a VAR(4) model appears to be appropriate. The aforementioned model is further improved and analyzed by using canonical correlation analysis (Box and Tiao, 1977). The results suggest a complex feedback system without any particular unidirectional relationship. Finally, the authors analyze the same series using the more recent technique of scalar component models (Tiao and Tsay, 1989), which can reduce the number of parameters to be estimated and reveal interesting underlying structures. The results suggest a VARMA (1, 1) model and indicate that the dynamic structure can be greatly simplified by transforming the series into (i) "an average component reflecting the general comovement of the data," and (ii) "two linear contrasts of the rates."

The second article, by Katarina Juselius, discusses general issues concern-

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ing the modeling of macroeconomic time series and presents an illustration of macroeconometric modeling which is intermediate between a purely statistical approach, such as the one illustrated by the preceding paper, and structural modeling. Juselius starts from the recent critical appraisal of "empirical macroeconomics" by Summers (1991) to emphasize the importance of distinguishing between two types of analysis: (i) the application of statistical methods to estimate the parameters of an economic model, and (ii) the analysis of a statistical model in view of economic questions of interest (Haavelmo, 1944). When data are obtained by passive observation (which is typically the case in macroeconomics), the latter activity then appears to be especially important to establish a link between observations and theory. She then describes how, in the context of nonstationary series, a strategy based on the analysis of cointegrating relationships and error-correction mechanisms (Engle and Granger, 1987) can provide insight into long-run (equilibrium) relationships and short-run dynamics. This strategy is illustrated by looking at Danish monetary data on money, real income, the price level and three interest rates (quarterly, 1969–1987). She identifies three long-run relations between these variables (a relation between the nominal interest rates and the inflation rate, a second one between real income, inflation and two interest rates, and a long-run "money demand" relation), analyzes the short-run dynamics, and finds the results to be both statistically and economically acceptable.

The article by Palm, Peeters and Pfann goes one step further by undertaking to formulate and estimate a model which is both derived from an explicit optimization model and is empirically acceptable. The authors study factor demand (for labor, structures and equipment) in U.S. manufacturing using a model that accounts for adjustment costs (Lucas, 1967) and gestation lags (Kydland and Prescott, 1982). While these two approaches are generally viewed as alternative explanations, the authors innovate by taking both elements into account in a model based on intertemporal optimization. The theoretical model so obtained has various implications concerning the time-series structure of the variables involved, including the presence of three cointegration relationships between factor quantities and prices. The authors then use quarterly data on the manufacturing industry in the U.S. (quantity used and price for each one of the three basic factors, 1960–1988) to assess whether the model is acceptable and study its properties. This is done first by analyzing the time-series properties of the data (order of integration, ARMA structure, cointegration), and then by estimating a "structural" VAR model that takes into account the restrictions implied by the theoretical model. Notable findings here include: the confirmation that three cointegration relationships appear to hold in the system considered (one for each factor demand with the factor prices), unidirectional Granger causality from production prices to production factors (another prediction of the theoretical model), and the fact that time-to-build considerations are at least as important as adjustment costs in the model.

In the following article, Pierre Perron and John Campbell consider the problem of testing the presence of r cointegrating relationships in a finite-order

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VAR model when linear trends are present. They emphasize first the importance of distinguishing between "stochastic cointegration" and "deterministic cointegration", a distinction introduced by Ogaki and Park (1992). Stochastic cointegration is a weaker concept which allows cointegrating relationships to be stationary around a deterministic trend, while deterministic cointegration assumes that such trends are eliminated by the cointegration vectors. The authors argue that the hypothesis of stochastic cointegration is the one of most interest in empirical applications. Typical precedures for testing cointegration, however, such as those proposed by Johansen (1988, 1991), consider the more restrictive assumption of deterministic cointegration. The authors then show that not taking into account linear trends may lead to misleading inferences, e.g., with respect to causality properties. Finally, they propose a modified procedure for testing the hypothesis of r cointegrating relations, which is similar to the one of Johansen (1991), but allows for the presence of linear trends. They also provide a short table of asymptotic critical values.

The fifth article in this section, by Bryan Campbell and John Galbraith, applies recent finite-sample nonparametric techniques to test the expectations theory of the term structure of interest rates from Canadian and U.S. data (monthly 3- and 6-month interest rates, 1960–1989). Data on interest rates are delicate to analyze because they involve non-normal distributions and heteroskedasticity, so that standard parametric or non-robust statistical techniques can be very unreliable. Here, the authors use sign- and signed-rank tests which are especially well adapted to such situations because of their strong finite-sample validity and robustness properties (Campbell and Dufour, 1991; Dufour and Hallin, 1993). They conclude that the expectations theory is rejected for the U.S. but not for Canada. The authors also investigate the possibility of a time-varying risk premium. They find some evidence of systematic variability but conclude that it cannot be the primary source of deviation from the expectations theory.

The three articles in the second section (Quintos-Phillips; Perron; Lütkepohl) consider the more specific but important problem of detecting and taking into account structural change in the analysis of time series. Structural constancy is a perennial issue in time-series econometrics [see Lucas (1976) and Dufour (1982)], but an exceptional number of new developments in the econometrics of structural change have occurred in recent years.

The article by Carmela Quintos and Peter Phillips proposes tests of parameter constancy for a linear regression model where the regressors are integrated of order one. The alternative considered is one where the regression coefficients follow a random walk. So, in contrast with usual tests which consider the null hypothesis of no cointegration, the null hypothesis tested is the hypothesis of cointegration (which is the one of primary interest) against a special form of no cointegration. For this purpose, the authors consider LM-tests and establish the asymptotic distributions of the test statistics under the null hypothesis and for local alternatives. As usual, in such situations, the asymptotic distributions are non-standard and the authors provide tables of asymptotic critical values. The new procedures are applied to a number of specifications of the aggregate Aus-

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tralian consumption function (quarterly data, 1965–1988) and compared with those of other procedures. Though some of the results appear to conflict (due probably to the fact that alternative tests consider different null hypotheses), the authors conclude that cointegration appears to hold for a simple equation with consumption and disposable income.

The contribution of Pierre Perron illustrates the importance of taking into account structural breaks in the analysis of economic series. His purpose is to assess whether macroeconomic shocks are short-lived and, in particular, whether their effects are "hump-shaped" as the pre-Nelson-Plosser (1982) conventional wisdom suggested. For that purpose, Perron extends in two ways his well-known 1989 paper on structural breaks and unit roots. First, he applies to various macroeconomic series (GNP series, Nelson-Plosser data) the approach of Cochrane (1988) and Campbell-Mankiw (1987), which is based on estimating the spectral density of the first-differences of the series at the zero frequency [for related results, see also Raj (1992, 1993)]. The advantage of this method is that it is unaffected asymptotically by (non-repetitive) structural breaks. His results suggest that the effects of shocks vanish over long horizons, and thus tend to confirm his earlier findings. Second, he analyzes directly the stochastic structure of the series after they have been "detrended" using an appropriate "breaking trend". He then finds that the moving-average representation of these detrended series is hump-shaped.

In the third article of this section, Helmut Lütkepohl reconsiders the important question of money demand instability in the U.S. For that purpose, he uses "flexible least squares", a technique recently proposed by Kalaba and Tesfatsion (1989, 1990). Even though it is mainly descriptive, this technique can shed light on the pattern of parameter variation over time, and which coefficients are the most and least stable. The author applies it to an error-correction model of demand for M1 in the U.S. using quarterly data (1954–1987). He finds that the coefficients of long-run money demand are relatively stable: the instability of the relation is mainly associated with short-term dynamics, the coefficient of interest rate being the most unstable. These results appear consistent with a financial innovations explanation of money demand instability.

The third section contains contributions to the analysis of seasonal movements (Ghysels et al., and Kunst) and fractionally integrated models (Chung and Baillie). Many economic time series exhibit seasonal behaviour, which investigators either try to model or to eliminate by seasonal adjustment. Finding the right way of modeling seasonal behaviour and understanding the consequences of seasonal adjustment remains an important macroeconometric problem. The articles by Ghysels et al. and Kunst consider various aspects of this problem.

Eric Ghysels, Hahn Lee and Pierre Siklos consider two issues related to the problem of seasonal adjustment. First, they examine U.S. quarterly data on GNP, consumption and money (1946–1985) and study how various methods of eliminating seasonal fluctuations affect the univariate time-series properties of these series. The methods studied include seasonal differencing, X-11 and seasonal dummies. They find that these various methods produce series with widely

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different autocorrelations, so that the selection of a seasonal adjustment procedure can have an important impact on the analysis of dynamic properties. Second, they extend the procedure of Hylleberg, Engle, Granger and Yoo (HEGY, 1990) for analyzing seasonal unit roots in order to take into account the fact that selection of the order of the autoregressive process in the HEGY procedure is typically data-based. Then they apply the HEGY procedure to several U.S. macroeconomic series. They find little evidence of seasonal unit roots at the annual frequency but several roots at the biannual frequency. They conclude that none of the standard transformations captures the patterns suggested by the HEGY tests. Both seasonal dummies and seasonal unit roots appear to be required to model seasonal patterns appropriately.

The article by Robert Kunst considers the related idea of seasonal cointegration, introduced by Engle et al. (1989) and HEGY (1990), and tries to assess its value for prediction. By using both German and British macroeconomic data as well as a Monte-Carlo experiment, he finds that seasonal cointegration may be difficult to exploit to improve prediction. A misspecified VAR model in first differences which ignores the cointegration restriction can easily have a better predictive accuracy.

Finally, the paper by Ching-Fan Chung and Richard Baillie provides results on the estimation of fractionally integrated ARMA models (ARFIMA models). This class of processes, introduced by Granger (1980), Granger and Joyeux (1980) and Hosking (1981), exhibits autocorrelations which decay more slowly than those of ARMA models, even though they remain stationary. They may thus offer an attractive alternative to integrated processes which exhibit complete persistence. Such models, however, may be relatively difficult to estimate. The authors study by simulation the finite-sample properties of a relatively simple estimator suggested by Hosking (1984), the conditional sum-of-squares (CSS) estimator. They find that the CSS estimator can be a useful technique for estimating ARFIMA models in moderate to large samples, but the estimation of the mean can cause substantial bias in smaller samples (say, less than 150 observations).

Researchers and students interested in macroeconometrics and empirical finance will find in this collection a remarkably representative sample of recent work in this area. We are confident it will be a source of inspiration for many of them and lead to further research.

References

Box GEP , Tiao GC (1977) A canonical analysis of multiple time series. Biometrika 64:355–365

Campbell B, Dufour J-M (1991) Over-rejections in rational expectations models: A nonparametric approach to the Mankiw-Shapiro problem. Economics Letters 35:285–290

Copyright © 2001. All Rights Reserved.

Campbell JY, Mankiw NG (1987) Are output fluctuations transitory? Quarterly Journal of Economics 102:857–880
Chan NH, Tsay RS (1991) On the use of canonical correlation analysis in testing common trends. Technical report, Department of Statistics, Carnegie Mellon University
Cochrane JH (1988) How big is the random walk in GNP? Journal of Political Economy 96:893–920
Dufour J-M (1982) Recursive stability analysis of linear regression relationships: An exploratory methodology. *Journal of Econometrics* 19:31–76
Dufour J-M, Hallin M (1993) Improved Eaton bounds for linear combinations of bounded random variables, with statistical applications. Journal of the American Statistical Association (forthcoming)
Engle RF, Granger CWJ (1987) Co-integration and error correction: representation, estimation and testing, Econometrica 55:251–276
Engle RF, Granger CWJ, Hallman JJ (1989) Merging short- and long-run forecasts: An application of seasonal cointegration to monthly electricity sales forecasting. Journal of Econometrics 40:45–62
Granger CWJ (1980) Long memory relationships and the aggregation of dynamic models. Journal of Econometrics 14:227–238
Granger CWJ, Joyeux R (1980) An introduction to long memory time series models and fractional differencing. Journal of Time Series Analysis 1:15–39
Haavelmo T (1944) The probability approach in econometrics. Econometrica 12 (supplement):1–118
Hosking JRM (1981) Fractional differencing. Biometrika 68:165–176
Hylleberg S, Engle RF, Granger CWJ, Yoo BS (1990) Seasonal integration and cointegration. Journal of Econometrics 44:215–238
Johansen S (1988) Statistical analysis of cointegration vectors. Journal of Economic Dynamics and Control 12:231–254
Johansen S (1991) Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. Econometrica 59:1551–1580
Kalaba R, Tesfatsion L (1989) Time-varying linear regression via flexible least squares. Computers and Mathematics with Applications 17:1215–1245
Kalaba R, Tesfatsion L (1990) Flexible least squares for approximately linear systems. IEEE Transactions on Systems, Man and Cybernetics. SMC-20:978–989
Kydland FE, Prescott EC (1982) Time to build and aggregate fluctuations. Econometrica 50:1345–1370
Lucas RE (1967) Adjustment costs and the theory of supply. Journal of Political Economy 75:321–334
Lucas RE (1976) Econometric policy evaluation. In: Brunner K, Meltzer AH (eds) Carnegie-Rochester Conference Series on Public Policy, Volume 1, Journal of Monetary Economics, supplement 19–46
Nelson CR, Plosser CI (1982) Trends and random walks in macroeconomic time series. Journal of Monetary Economics 10:139–162
Ogaki M, Park JY (1992) A Cointegration approach to estimating preference parameters. Technical Report, Department of Economics, University of Rochester
Perron P (1989) The great crash, the oil price shock and the unit root hypothesis. Econometrica 57:1361–1401
Raj B (1992) International evidence on persistence in output in the presence of episodic change. Journal of Applied Econometrics 7:281–293
Raj B (1993) The size of the random walk in macroeconomic time series. Journal of Macroeconomics 15:139–151
Stock JH, Watson MW (1988) Testing for common trends. Journal of the American Statistical Association 83:1097–1107
Summers LH (1991) The scientific illusion in empirical macroeconomics. Scandinavian Journal of Economics 93:129–148

Copyright © 2001. All Rights Reserved.

Tiao GC, Box GEP (1981) Modeling multiple time series with applications. Journal of the American Statistical Association 76: 802–816

Tiao GC, Tsay RS (1989) Model specification in multivariate time series. Journal of the Royal Statistical Society B51: 157–213

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