# *Introduction*

The notion of business cycle nonlinearity goes back a long time. For example, Mitchell (1927) and Keynes (1936) suggested that business cycles display asymmetric behavior in the sense that recessions are shorter and more volatile than expansions. Similarly, Hicks (1950) noted that business cycle troughs are sharper than peaks. Further, Friedman (1964) proposed his ‘‘plucking model’’ of economic fluctuations based upon the observation of asymmetry in correlations between successive phases of the business cycle, in the sense that the amplitude of a contraction is strongly correlated with the strength of the subsequent expansion, while the amplitude of an expansion is uncorrelated with the amplitude of the following contraction.

Neftçi (1984) initiated the modern econometric literature on business cycle nonlinearity with his study of U.S. unemployment rates using Markov chain techniques. His results implied that the U.S. unemployment rate displays ‘‘steepness’’-type business cycle asymmetry, following the taxonomy due to Sichel (1993). Neftçi's paper has been highly influential and since its publication roughly 20 years ago, a great deal of research has been done exploring the magnitude and economic significance of nonlinearity in business cycle fluctuations. For example, Hamilton (1989, p. 359) argued that the now very popular Markov-switching model he introduced is a natural generalization of Neftçi's framework. A useful survey of many important developments in this literature can be found in Clements and Krolzig (2003).

To provide a comprehensive look at current work on this topic, for this book volume we solicited original contributions on business cycle nonlinearity from leading academics and practitioners in the field. Each chapter was subsequently reviewed by an ‘‘internal’’ referee (an author or coauthor of a different chapter in the book), and by an ‘‘external’’ referee. These external referees were Don Harding (University of Melbourne), Christopher Martin (Brunel University), Marcelo Medeiros (PUC Rio), Simon van Nordon (HEC Montréal), Richard Paap (Erasmus University Rotterdam), Jean-Yves Pitarakis (University of Southampton), Tommaso Proietti (University of Udine), Pierre Siklos (Wilfred Laurier University), Peter Summers (Texas Tech University), Timo Teräsvirta (Stockholm School of Economics), Gilles Teyssiere (Université Paris 1), Greg Tkacz (Bank of Canada), Mark Wohar (University of Nebraska at Omaha), and Eric Zivot (University of Washington). We thank both our contributors and referees for their cooperation in keeping to the ambitious time schedule we set at the start of this project.

The papers in this volume can be classified into five groups, each focusing on a particular topic. The first question considered, in a group of three papers, is the role of nonlinearity in dating business cycle turning points and identifying business cycle regimes. Chauvet and Hamilton provide a detailed description of the Markov-switching approach to this issue, including not only the technicalities involved but also paying ample attention to the underlying intuition. They illustrate the promise of this approach by constructing a business cycle chronology for the U.S. based on real-time data for the post-World War II period, i.e. data as they were originally released at each historical date. Their findings demonstrate that the resulting turning point dates closely match those of the business cycle dating committee of the National Bureau of Economic Research (NBER), but the model-based turning points typically become available much sooner than the NBER ones.

Clements and Galvão use the context of predicting business cycle regime probabilities and output growth in the U.S. to consider the specific issue of combining forecasts versus combining information in modeling. The simple models whose forecasts they combine each use a single recession indicator, one of the components that comprise the Conference Board Composite Leading Indicator (CLI), as the explanatory variable to the model. Combining this information set in modeling is achieved by using a model selection strategy. For predicting output growth, their findings support pooling the forecasts of the single-indicator models, whilst the results are more mixed for predicting recessions and recession probabilities.

Morley and Piger consider the ability of linear autoregressive integrated moving average (ARIMA) and nonlinear Markov-switching models to reproduce business cycle-related features in U.S. real Gross Domestic Product (GDP) data. They find that both linear and Markov-switching models are able to reproduce business cycle features such as the average growth rate in recessions, the average length of recessions, and the total number of recessions. However, Markov-switching models are found to be better than linear models at reproducing the variability of growth rates in different business cycle phases. Furthermore, only Markov-switching specifications with three regimes or with a built-in "bounceback" effect are able to reproduce high-growth recoveries following recessions and a strong correlation between the severity of a recession and the strength of the subsequent recovery.

The second topic analyzed, in a set of two papers, is the use of multivariate nonlinear models in econometric modeling of business cycles. Koop and Potter introduce a nonlinear extension of the Vector Autoregressive (VAR) model which they call the Vector Floor and Ceiling (VFC) model. The VFC model is also a multivariate extension of univariate nonlinear models the authors developed earlier with floor and ceiling effects; see Pesaran and Potter (1997) and

Koop and Potter (2003). As a tightly restricted Threshold Autoregressive model, the authors argue that the VFC model provides a parsimonious framework for capturing the type of business cycle nonlinearity suggested by economic theory. They use both classical and Bayesian methods to analyze the estimated models. Their results suggest strong nonlinearities in the contemporaneous relationships between the variables and weaker evidence of conditional mean nonlinearity.

Camacho and Perez-Quiros propose a new framework to analyze pairwise business cycle synchronization across a given set of countries. The approach is based on multivariate Markov-switching procedures, and essentially determines the relative position of two countries' cycles in between the extreme cases of complete independence and perfect synchronization. An empirical application to the G7 countries shows that these can be divided into two groups with distinct common business cycle dynamics, with one group consisting of Euro-zone countries (France, Germany, and Italy) and the other including English-speaking countries (Canada, the U.K., and the U.S.).

Five of the papers explore a third topic, the extent to which nonlinearity can account for the well-documented instability and structural change which has been observed in macroeconomic time series; see, e.g. Stock and Watson (1996). Marcellino's paper is motivated by the many economic and political changes which have occurred in what is now called the Euro-zone since the early 1980s. Such changes, he argues, increase the difficulty of modeling macroeconomic time series for Euro-area countries with constant-parameter linear models. To explore this idea he carries out a simulated out-of-sample forecasting competition using linear, nonlinear, and time-varying models to predict the future values of 500 macroeconomic time series for these countries. It turns out that, for roughly two-thirds of the series studied, nonlinear and time-varying models work best. These results lead him to conclude that use of such models should be strongly considered by practitioners.

Kapetanios and Tzavalis use a new model of structural breaks, one which allows for parameter changes to be triggered by large economic shocks. In contrast to other structural break models in the literature, their approach allows them to examine such parameter changes without fixing either the number or magnitude of the breaks. The results support the view that the observed instability in U.S. macroeconomic time series is due to the oil-price shocks of the 1970s and the changes in the Fed's operating procedures in the late 1970s and early 1980s.

There are many nonparametric and model-based methods available for extracting the business cycle component from a macroeconomic time series. Koopman, Lee, and Wong use a parametric trend-cycle decomposition procedure in which the parameters governing the dynamics of these components are allowed to vary in a nonlinear but smooth manner. They find substantial evidence of smooth time variation in these parameters. Of particular interest are their results suggesting that business cycle volatility for the U.S. economy has decreased. While these findings are consistent with results reported earlier in the literature on the ‘‘great moderation,’’ it is the first to do so within the trend-cycle decomposition framework.

Becker, Enders, and Hurn develop a methodology to model a time-varying intercept. The methodology relies on a Fourier approximation, which uses trigonometric functions to capture the unknown functional form of the intercept term. Two empirical applications illustrate the use of the methodology. The first example demonstrates how a time-varying intercept can be used to capture a structural break in the U.S. inflation rate. The second example relates to the U.S. long-run money demand function. The authors show that the apparent instability in the cointegrating vector among M3, income, prices and interest rates disappears once a time-varying intercept is taken into account.

Anderson and Low extend the family of smooth transition autoregressive (STAR) models by proposing a specification in which the autoregressive parameters follow random walks. The random walks in the parameters capture permanent structural change within a regime-switching framework, but in contrast to existing specifications, structural change in the random walk STAR (RW-STAR) setting follows a stochastic process rather than a deterministic function of time. Using industrial production data for several countries, they find evidence of nonconstant parameters in a setting where there is also evidence of regime-switching. In addition, they find that RW-STAR models seem to be able to capture different types of time-varying behavior of parameters.

The fourth topic, the importance of nonlinearity for econometric analysis of monetary policy, is addressed in three of the papers in this volume. Kesriyeli, Osborn, and Sensier estimate smooth transition monetary policy rules for the U.S., U.K., and Germany. They find significant nonlinear structure in the monetary policy rules associated with interest rate changes rather than movements in the inflation rate or the output gap. The nonlinear models also identify a significant shift in the parameter values of the U.S. and U.K. interest rate reaction functions occurring around mid-1985.

Dolado and María-Dolores examine the issue of the asymmetric effects of monetary policy shocks on output in the Euro area. Assuming a nonlinear aggregate supply curve, they derive monetary policy shocks as the residuals from a nonlinear interest rate reaction function. The authors proceed by estimating a multivariate Markov-switching model for EU output and find that monetary policy shocks have a greater effect on output in recessions.

Akram, Eitrheim, and Sarno adopt a different nonlinear model but reach similar conclusions on the effects of monetary policy on output. The authors use multivariate smooth transition models to characterize the behavior of output, money, and the real exchange rate in Norway over a period of almost two centuries. They find evidence of asymmetric effects of monetary policy on output. In particular, large contractionary monetary policy shocks tend to have significant effects on output, while small expansionary monetary policy shocks tend to have negligible effects on output.

Finally, two of the papers study the statistical and economic impact of allowing for business cycle regime-dependent behavior in models of important macroeconomic and financial time series. Bhardwaj and Swanson compare the ability of fractional ARIMA (ARFIMA), non-ARFIMA, and other nonlinear models to forecast U.S. daily stock returns in recessions versus expansions and for larger versus smaller samples. The findings of their paper suggest that ARFIMA models do not predict better or worse than any other model across the business cycle. On the other hand, the forecasting ability of ARFIMA models increases with larger samples.

Dahl and Kulaksızoğlu use a nonlinear autoregressive distributed lag model to study the relationship between housing completions and housing starts in the U.S. economy. Their results suggest that builders change the speed of construction depending upon whether the home construction industry is in a recession or expansion. In particular, the mean lag between housing completions and housing starts is significantly shorter in recessionary than in expansionary periods. This finding is consistent with what has been called the ''accordion effect'' in the literature; see van Alphen and Merkies (1976).

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