A Continuous Time Econometric Model of the United Kingdom with Stochastic Trends

Over the last thirty years there has been extensive use of continuous time econometric methods in macroeconomic modeling. This monograph presents the first continuous time macroeconometric model of the United Kingdom incorporating stochastic trends. Its development represents a major step forward in continuous time macroeconomic modeling. The book describes the new model in detail and, like earlier models, it is designed in such a way as to permit a rigorous mathematical analysis of its steady state and stability properties, thus providing a valuable check on the capacity of the model to generate plausible long-run behavior. The model is estimated using newly developed exact Gaussian estimation method for continuous time econometric models incorporating unobservable stochastic trends. The book also includes discussion of the application of the model to dynamic analysis and forecasting.

The late ALBERT REX BERGSTROM was Emeritus Professor of Economics, a former Dean of the School of Social Studies, Chairman of the Department of Economics and Pro Vice Chancellor at the University of Essex and a Fellow of the Econometric Society. He was one of the world's leading authorities on continuous time econometric modelling. Professor Bergstrom was formerly Professor of Econometrics at the University of Auckland and Reader at the London School of Economics. His professional papers appeared in leading journals such as *Econometrica* and *Econometric Theory*. Professor Bergstrom's earlier books include *The Construction and Use of Economic Models* (1967), *Continuous Time Econometric Modelling* (1990), *Statistical Inference in Continuous Time Economic Models* (editor, 1976) and *Stability and Inflation: Essays in Memory of A. W. Phillips* (edited with A. J. L. Catt, M. H. Peston and B. D. J. Silverstone, 1978).

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CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo

Cambridge University Press
32 Avenue of the Americas, New York, NY 10013-2473, USA

www.cambridge.org
Information on this title: www.cambridge.org/9780521875493

First published 2007

Printed in the United States of America

A catalog record for this publication is available from the British Library.

Library of Congress Cataloging in Publication Data

Bergstrom, A. R. (Albert Rex)
A continuous time econometric model of the United Kingdom with stochastic
trends / Albert Rex Bergstrom, Khalid Ben Nowman.
p. cm.
Includes bibliographical references and index.
ISBN-13: 978-0-521-87549-3 (hardback)
ISBN-10: 0-521-87549-8 (hardback)
1. Great Britain – Economic policy – Econometric models. 2. Finance – Great
Britain – Econometric models. 3. Econometric models.
4. Stochastic processes. I. Nowman, Khalid Ben, 1962– II. Title.
HC256.7.B47 2007
330.941′086 – dc22 2006037265

ISBN 978-0-521-87549-3 hardback

BN: To Miho

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Foreword

The daunting complexity of aggregate economic behaviour has led recent generations of macroeconomists to pursue a rich diversity of approaches in modelling. Some have focused on the development of tightly specified small scale systems that embody rational expectations, real business cycle mechanisms and intertemporal optimization principles to strengthen the economic foundations of the models and furnish meaningful prior restrictions. Others have preferred the use of model formulations that are more convenient in coping with the time series properties of the observed series, using both parametric and semiparametric approaches, and allowing for mechanisms that can accommodate the regime changes that can occur in practice. Still others have begun to work with large dimensional panels and dynamic factor decompositions.

Foreword

One unifying force amongst the growing diversity of empirical modelling research in macroeconomics has been acknowledgement of the importance of long-run behaviour and the recognition that trending mechanisms in economics are stochastic. A second area of commonality lies in the use of nonlinear dynamics, both systems dynamics and volatility dynamics, the latter being especially important in financial market applications.

The present volume reports the construction and implementation of a new macroeconomic model of the UK economy that embodies most of these themes. While the model differs from much of the mainstream of modern macroeconomics in terms of its genesis and form, it shares some commonality with mainstream work in its detailed attention to nonlinear dynamics, its concern for stochastically trending data and its use of dynamic optimization principles in the derivation of adjustment relations. The model developed here is capable of describing diverse patterns of cyclical behaviour in economic aggregates and long-run growth. It is formulated in continuous time as a system of mixed-order stochastic differential equations. It synthesizes real, monetary, financial, labour and production sectors of the economy. It allows for market disequilibria in a systematic way, with parameterized adjustment mechanisms that measure responsiveness to deviations from partial equilibria whose values are internally consistent and determined by economic theory. The model's long-run properties are explored analytically, an explicit steady state growth path is obtained and plausible regions of the parameter space are determined a priori, thereby providing useful guidelines for empirical model evaluation. In many of these respects, the model is very different from prevailing traditions in empirical macroeconomic modelling.

The model is the latest and most sophisticated in a succession of empirical econometric models of the United Kingdom that have been developed under the leadership of the senior author Rex Bergstrom. The present model therefore represents the culmination of a long research agenda in which the cardfile of models has steadily increased in complexity. The incorporation of internally embedded stochastic trends, the allowance for temporally aggregated flow data and the introduction of higher order and more complex lag responses distinguish the present contribution, giving the new model important elements of realism and features that are comparable to and in some ways exceed those of other empirical macro models. Indeed, the reduced form discrete time version of the present model is a higher order vector autoregressive (VAR) moving average model with exogenous variables that involves 18 endogenous variables, 27 speed of adjustment parameters, 33 long-run coefficients and 3 trend parameters. In this respect, it has time series dynamics that are considerably more complex than those of most structural and unrestricted VAR specifications, many other time series models and dynamic structural equation macroeconomic models.

Bergstrom and Wymer (BW, 1976) developed an early model in this general class for the UK economy. The BW model is widely recognized as the first aggregate model of economic activity that was formulated in continuous time as a set of interdependent stochastic differential equations. That model was highly successful as a parsimonious representation of economic activity in a modern industrialized economy and it has since served as a prototype for similar models in many other countries. The present volume continues the BW tradition of continuous time macroeconometrics; it integrates modelling enhancements that were introduced in the subsequent higher order model reported in Bergstrom, Nowman and Wymer (BNW, 1992), and it breaks new ground in empirical continuous time modelling by embedding stochastic trend elements into the system and growth paths.

Foreword

This book carries the indelible signature of Bergstrom's superb scholarship. The theoretical model is developed with great attention to underlying economic ideas, the econometric methodology is systematically built on the extraction of an exact discrete model and an algorithm that constructs the Gaussian likelihood, the empirical implementation is painstakingly conducted, the size of the system and its complex transcendental matrix nonlinearities push to the limits of present computational capacity and the empirics involve specification testing and prediction evaluation against a highly competitive VAR system with exogenous inputs.

Ragnar Frisch, one of the founders of the Econometric Society and a co-recipient of the first Nobel Prize for economics, believed that the ultimate strength of econometrics as a scientific tool for understanding economic activity comes through the combined use of three elements – mathematics, statistical analysis and economic theory. This Frisch mantra is easy to cite as a guiding principle in quantitative economic research, yet it is far more difficult to implement in practice. The present work makes a substantive contribution to econometric knowledge but is of wider methodological interest because it succeeds in meeting Frisch's criteria and aspirations for productive research in econometrics. In so doing, it lays out a paradigm for others to follow.

This volume sadly concludes Rex Bergstrom's distinguished work on continuous time econometric modelling, the manuscript being completed just a few months before his unexpected death on 1 May 2005 and subsequently revised by his former student and co-author, Ben Nowman. We hope that the research agenda will continue into the future and attract further generations of researchers as well as those who were themselves trained by Bergstrom or his students. The present volume will remain a distinguished magnum opus that concludes Bergstrom's own work, a testimony to his sustained accomplishments in founding this field, a resource for present and future researchers and a basis for further work as the frontiers of macroeconometric modelling and continuous time econometrics continue to unfold.

Peter C. B. Phillips
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May 2006

Preface

Over the last 30 years there has been a growing use of continuous time econometric methods in macroeconomic modelling. Economy-wide continuous time macroeconometric models have been developed for most of the leading industrial countries of the world. This monograph presents the first continuous time macroeconometric model of the United Kingdom incorporating stochastic trends. Its development represents a major step forward in continuous time macroeconomic modelling. The book describes the new model in detail and like earlier models it is designed in such a way as to permit a rigorous mathematical analysis of its steady state and stability properties, thus providing a valuable check on the capacity of the model to generate plausible long-run behaviour. The model is estimated using exact Gaussian estimation methods for continuous time econometric models incorporating unobservable stochastic trends. The book also includes discussion on the application of the model to dynamic analysis and forecasting.

An earlier version of this work was presented at the Cowles Foundation Conference on Recent Developments in Time Series Econometrics, Yale University, 1999; the 3rd Japan Economic Policy Association International Conference, Tokyo, 2004; Westminster Business School, 2004; and the 3rd Nordic Econometric Meeting, Helsinki, 2005. We are grateful for comments from these presentations. Ben Nowman would like to give special thanks to Peter Phillips for his extensive comments and support in helping him to revise the book. I also thank Peter Phillips for kindly sending me the photo of Rex Bergstrom and for permission to use it. He also thanks his colleagues at Westminster Business School for their support and especially Len Shackleton. I also thank William Barnett and Yijun He for sending me research papers. We are very grateful to Marcus Chambers for his comments and constant support over many years in our work. We would like to thank Scott Parris, the economics editor of Cambridge University Press, for his encouragement and support in this project and two anonymous referees for valuable comments. Lastly we both give our warmest thanks to Miho Takashima for her constant support during the

writing of this book. Royalties from this volume will be used to contribute to the A. R. Bergstrom Prize in Econometrics established in 1993 for research excellence in econometrics.

A. R. B. and K. B. N.
January 2005