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# OxMetrics news

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# Announcing OxMetrics 8

We are happy to introduce the new release of OxMetrics. OxMetrics is a powerful software for econometric, statistical, and financial modelling and forecasting. Below we touch upon some of the new features in OxMetrics 8. Further information on fixes can be found in the online documentation. OxMetrics is a modular system, and we present generic new features, before delving in some of the modules. CATS is an entirely new module for cointegration analysis.

## Contents

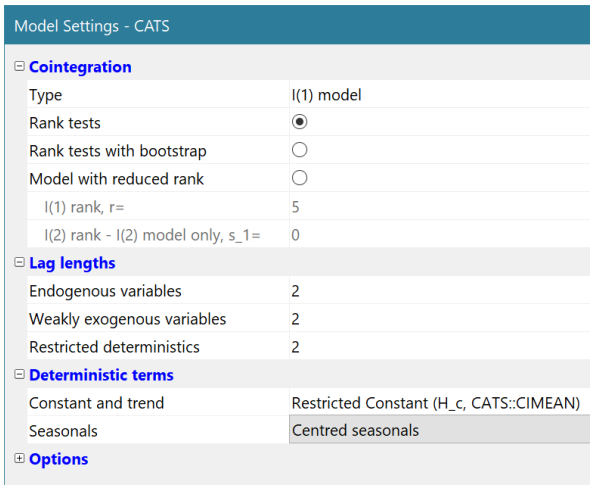


## 1 OxMetrics

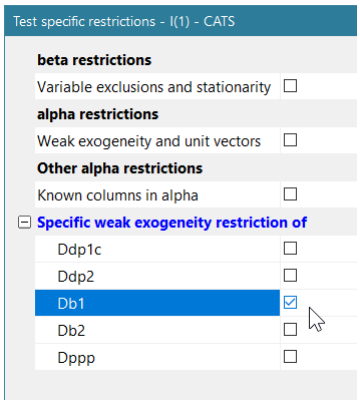
The refreshed interface is the most visible change in OxMetrics 8. We have dropped the old-fashioned floating windows interface, and moved to a bar with tabs along the top. Tabs can be dragged to the side or bottom for a split view. The 'run' toolbar button is a more conventional triangle, and buttons for graphic analysis, recursive graphics and forecasting have been added.
OxMetrics for Windows now supports high resolution screens throughout. Such screens are increasingly found on modern notebooks. This update removes the slightly fuzzy look of version 7 – as if you were wearing the wrong glasses.
OxMetrics on macOS is now entirely 64-bit software, thus avoiding the warning that accompanies version 7 on High Sierra.
Graphs can now be saved as an SVG file. Scalable Vector Graphics (SVG) is an open standard that is supported by all modern web browsers.
Installation of OxMetrics 8 is more convenient. There is only one installer under Windows (there where 12 previously!), and it will automatically install the 64-bit version when running on 64-bit Windows.
A final important change is that Ox Professional is now installed with OxMetrics, so no separate installation is required to run any Ox code that is generated.

## 2 CATS

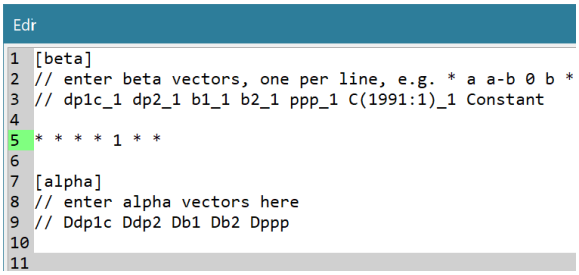
CATS is a new OxMetrics model for cointegration analysis of time series, both I(1) and I(2), developed by Katarina Juselius and Jurgen Doornik. It combines a convenient interactive interface with powerful computational features. This is the model settings dialog:




A range of commonly used tests is preprogrammed:




While a convenient new way to express restrictions is introduced:




Moreover, many aspects are much faster than previous implementations of the cointegrated vector autoregressive (CVAR) model.

### 2.1 CATS I(1)

Here is a brief summary of new features in the I(1) part of CATS:

- The Bartlett correction and recursive estimation are much more efficient, sometimes by several orders of magnitude.
- The Bartlett correction is always included when valid.
- New line-search algorithms for all switching estimations, see Doornik (2018, *Scan J Statistics*).

- New alpha-beta-switching algorithm allowing linear restrictions on the loadings $\alpha$ without requiring identification.
- Bootstrap of rank tests and of test of restrictions.
- More Monte Carlo facilities: ability to generate a draw from the estimated model, either with estimated or with specified coefficients.
- General-to-specific CATSmining helps with identification of the cointegrating space.
- Automatic generation of Ox code.
- New convenient way to express cointegrating restrictions.
- Most algorithms are QR based for numerical stability.

### 2.2 CATS I(2)

And for the I(2) part of CATS:

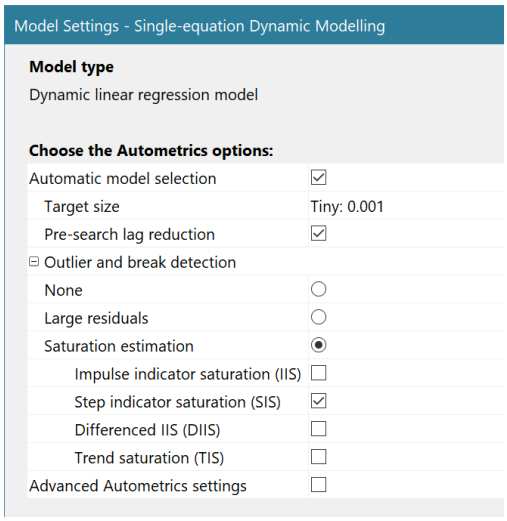
- Improved tau-switching algorithm and new delta-switching algorithms.
- New triangular representation, Doornik (2017, *Econometrics*), with corresponding triangular-switching algorithm allowing linear restrictions on $\alpha, \beta, \tau$.
- Estimation with $\delta = 0$.
- Bootstrap of rank tests and of test of restrictions.
- Simulation of the asymptotic distribution of the rank test.
- Monte Carlo: draw from estimated model, either with estimated or with specified coefficients.
- Automatic tests of unit vectors and variables.
- CATSmining.
- Improved computation of standard errors.
- Automatic generation of Ox code.
- All algorithms are QR based for numerical stability.

## 3 PcGive

The improvements in PcGive mainly relate to (1) model formulation, (2) saturation estimation using *Autometrics*, (3) automatic model selection in simultaneous equations models (SEM).

### 3.1 Model settings

We have considered RALS estimation to be obsolete for many years and have finally dropped it as a choice in single-equation modelling. The IV option has also disappeared: it is now automatically assumed when there is more than one dependent (Y) variable.
*Autometrics* options are presented differently, offering more flexibility in the choice of saturation:




The option to activate recursive estimation has been removed from the next dialog, because it is now computed 'on demand'. Instead, just select the recursive estimation dialog from the toolbar or the Test menu:

The three marked buttons are for graphic analysis, recursive graphics, and forecasting respectively.

### 3.2 Multivariate modelling

Several adjustments were made to SEM estimation and evaluation, in part to prepare for automatic model selection.
We've added recursive estimation and the AR test for models estimated by 1SLS, 2SLS, and 3SLS, as well as an ARCH test for all simultaneous models.
The AR test after FIML has been changed, using the 3SLS likelihood instead of estimating the extended model by FIML. This avoids a numerical maximization, which is particularly useful when doing automatic model selection.
SEM t-probabilities, standard errors of recursive residuals, and degrees of freedom of recursive Chow tests are now based on $T - c$ instead of $T - k$, where $c$ is the average number of coefficients per equation. OxMetrics 7 used $k$, which is the total number of Z and U variables in the system (but note that not all need to appear in the model, so $c \leq k$).
*Autometrics* implements automatic model selection for SEM.

### 3.3 *Autometrics* for more variables than observations

Automatic model selection using *Autometrics* for $T > k$ has been around for quite a while. This is also used for saturation estimation such as IIS (impulse indicator saturation) and SIS (impulse indicator saturation). Over the years we noted that in some applications the algorithm was too slow. The *Autometrics* algorithm in OxMetrics 8 has been improved, leading to huge speedups in some cases. The drawback of any change in the search algorithm is that different paths will be taken, so (slightly) different models found.
*Autometrics* for $k > 0.8T$ alternates between expansion and reduction steps. Four aspects of the expansion were potentially slowing the algorithm down and have been modified:

1. The block size shrank as the selected model was growing. The new version sets the blocksize as a fraction of the sample size ($0.2T$ by default; the selected model must be $< 0.6T$), so it stays constant.
2. Continuation if the model in stage A was too small or large: this could create many extra steps for little gain. Now limiting this to one continuation and then selecting by p-value if too many omitted variables are detected.
3. More efficient expansion stages:

   **Stage A** Now looking for one terminal (bad blocks could mean that the search for further terminals is too slow).

   **Stage B** and onwards searches for further terminals, except in quick mode (as before).

   **Stages CD** C now expands at $2p_\alpha$, then does reduction at $0.5p_\alpha$ and running D at $p_\alpha$ (previously this was $2p_\alpha$, $p_\alpha$, and $4p_\alpha$ for the start of D).

4. The multivariate version wrongly penalized block size by dividing it by the number of equations.

In one of our applications using SIS in a VAR ($T = 1000$, $n = 3$), the new version takes under two seconds rather than almost three minutes using OxMetrics 7.
One final change applies to lag presearch in large models that have enough observations for direct model selection. When the lag length exceeds 12, the presearch uses lag blocking and a more efficient search for contrasting terminals. In the BigT10 example when there is no lag presearch, time is reduced from almost 14 hours to 20 seconds. With presearch, it is reduced from almost 8 minutes to just over one.

## 4 G@RCH

- The G@RCH book is now available in pdf format.
- G@RCH 8.0 comes alongs with Ox Professional. This major change allows G@RCH users, who did not purchase OxMetrics Enterprise, to run Ox programs and in particular the numerous example files provides with G@RCH as well as the codes generated with 'Alt+O' after the estimation of a model with the rolling menus.
- A new option is available for the Lee & Mykland and Lee & Hannig tests for jumps. This implements the correction proposed by Laurent and Shi (2018), giving both tests better finite sample properties when the underlying process deviates from the random walk hypothesis.
- Following the simulation method advocated by Blasques, Lasak, Koopman, and Lucas (2016, *Int J Forecasting*), in-sample confidence bands for the conditional mean and conditional variance of univariate GARCH-type models are now available. This allows to visually investigate the precision of the estimates of the first two conditional moments.
- The tool introduced in version 7 to convert a date of the format yyyymmdd, yyyyddmm, ddmmyyyy or mmddyyyy into a proper OxMetrics format is now also accessible via the rolling menus in Category 'Other Models' and Model Class 'Convert Date using G@RCH'.
- The G@RCH classes for Ox (Garch, MGarch and Realized) use enumerations to define lists of integer constants. These enumerations have been moved into the class declaration as public members. They can still be accessed from outside with the classname prefixed: `mgarchobj.MLE(MGarch::HESS)` instead of `mgarchobj.MLE(HESS)`.
- The test for additive jumps in AR-GARCH/GJR models proposed by Laurent, Lecourt, and Palm (2016, *Comput Statist Data Anal*) is available in Category 'Other Models' and Model Class 'Descriptive Statistics using G@RCH'. It is called from Ox using `Run_Test_Additive_Jumps` of the Garch class or the RGARCH class directly (which is available in the same folder as Garch.oxo). Several example files are also provided to estimate a BIP-AR-GARCH/GJR model and to extract the detected jumps in Ox as illustrated here:

```
#include <oxstd.oxh>
#import <packages/Garch/garch>
main()
{   decl g = new Garch();
    g.Load("./data/nasdaq.xls");
    g.Select(Y_VAR, {"Nasdaq",0,0});
    g.SetSelSample(-1, 1, -1, 1);
    g.Initialization(<>);
    g.Run_Test_Additive_Jumps(
       1, 0, 1, 1, 0.1, 0.025, 1, 1);
    g.Save("./Jumps_NASDAQ.xlsx");
    delete g;
}
```

## 5 STAMP

STAMP is a powerful program for modelling and forecasting time series using the unobserved components framework. In the new version 8.4, several bug fixes have been made and there are some new features for enhancing univariate and multivariate unobserved component time series analyses in OxMetrics 8:

1. The Ox Batch Code generator for STAMP is implemented for univariate models. Ox code for univariate models can be generated by selecting 'Ox Batch Code' from the OxMetrics Model menu;
2. Lagged dependent variables can be selected as exogenous variables.
3. AIC and BIC added to default output.
4. The confidence bounds of seasonal, cycle, and AR components can be centered around zero or following the components.

There are also a number of small corrections which have improved the identification of unobserved components that slowly evolve over time (in more technical terminology, components with low signal-to-noise ratios).

## 6 Ox

- Changes to `Modelbase` mean that oxo files of derived classes need to be recompiled.
- `Y_VAR` style constants have been moved into the class (derived classes should do the same with their constants). This avoids clashes when using multiple classes in one project. So we need to write (e.g.)

  ```
  model.Select(Arfima::Y_VAR, ...
  ```

  instead of `model.Select(Y_VAR, ...`
  For convenience a mechanism has been added to use strings instead of constants:

  ```
  model.Select("Y", ...
  model.SetMethod("NLS");
  ```

  To support this, `Modelbase` has two new virtual functions `FindGroup`,`FindMethod` which rely on the new virtual functions `GetGroupLabels`,`GetMethodLabels`. The derived class should override `GetGroupLabels`,`GetMethodLabels` to return the correct array of strings.
- Can save graphs as SVG file.
- `savesheet` to save two-dimensional array as Excel file (complementing `loadsheet`).
- Improved handling of array entries with no value (`.Null`):
  - when created using new, array elements will be `.Null`
  - can test `.Null` equality (only) using `arr[i] == .Null`
  - can assign `arr[i] = .Null`
  - but using a variable with a `.Null` value in an expression remains a run-time error.
- The three dots in a function header, indicating variable number of arguments, can now be followed by a variable name. E.g:

  ```
  func(...args)
  {   decl a = 1;
  }
  ```

  is convenient shorthand for

  ```
  func(...)
  {   decl args = va_arglist();
      decl a = 1;
  }
  ```

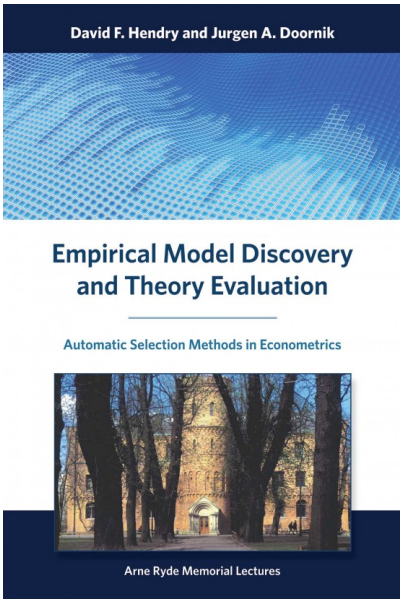
  (Unless used in main, as in main(...args), in which case `arglist` is called to get the command line arguments.)
- Three dots in a function call spreads an array, so `func1(...a)` equals `func1(a[0], a[1], a[2])` if a is an array with three elements. The array cannot have more than 256 elements.
- Read Stata 13 and 14 .dta files.
- Can skip items in multiple assignment, as well as use it in decl, e.g.:

  ```
  decl [a, b, c] = {1, 2, 3};
  [a,,c] = {1, 3};
  ```

- `%#v` on array of strings: omit top level `{}` (useful when generating code).
- `fwrite/fread` can have a filename as the first argument. E.g., `fread("filename", &s, 's')` reads an entire file into one string, `fwrite("filename", s)` saves a string as a file.
- `diagcat(a, b, ...);` to concatenate more than two matrices.
- Added p-value format for printing: e.g. `print("%9.3P", 1e-6)` prints `"[0.000]***"`. The format is three stars for significance below 0.001, two for below 0.01, one for below 0.05.
- The default line length for output is now 1024 (was 80 before). This can be changed using the `format` function.
- using G,E,F format to print . for .NaN.
- Added `%rs` and `%cs` to matrix format to specify row and column separator

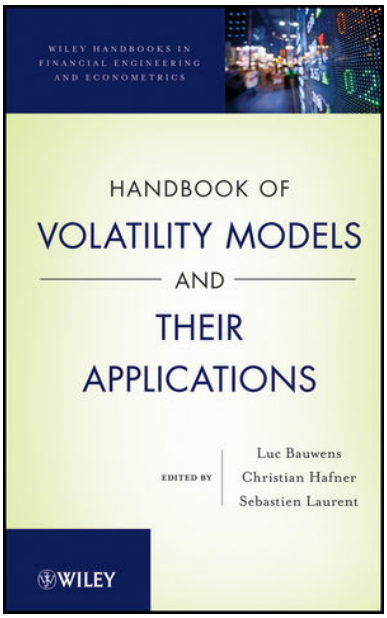
# 7 Bookshelf

## 7.1 Empirical Model Discovery



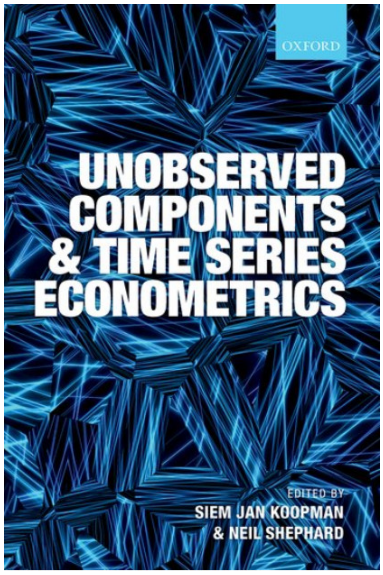

A synthesis of the authors' groundbreaking econometric research on automatic model selection, which uses powerful computational algorithms and theory evaluation.
Economic models of empirical phenomena are developed for a variety of reasons, the most obvious of which is the numerical characterization of available evidence, in a suitably parsimonious form. Another is to test a theory, or evaluate it against the evidence; still another is to forecast future outcomes. Building such models involves a multitude of decisions, and the large number of features that need to be taken into account can overwhelm the researcher. Automatic model selection, which draws on recent advances in computation and search algorithms, can create, and then empirically investigate, a vastly wider range of possibilities than even the greatest expert. In this book, leading econometricians David Hendry and Jurgen Doornik report on their several decades of innovative research on automatic model selection.
*Go to `www.doornik.com/Discovery` for a supplement to the book containing a description of all the experiments together with the code to replicate the results. All code uses Ox and PcGive.*

## 7.2 Handbook of Volatility Models




Featuring contributions from international experts in the field, the book features numerous examples and applications from real-world projects and cutting-edge research, showing step by step how to use various methods accurately and efficiently when assessing volatility rates. Following a comprehensive introduction to the topic, readers are provided with three distinct sections that unify the statistical and practical aspects of volatility:
(1) Autoregressive Conditional Heteroskedasticity and Stochastic Volatility presents ARCH and stochastic volatility models, with a focus on recent research topics including mean, volatility, and skewness spillovers in equity markets
(2) Other Models and Methods presents alternative approaches, such as multiplicative error models, nonparametric and semi-parametric models, and copula-based models of (co)volatilities
(3) Realized Volatility explores issues of the measurement of volatility by realized variances and covariances, guiding readers on how to successfully model and forecast these measures
*Many of the techniques referred to in the Handbook are available in the G@RCH module for OxMetrics.*

## 7.3 Unobserved Components and Time Series Econometrics

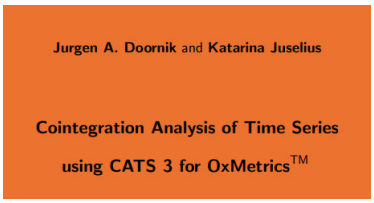



This volume presents original and up-to-date studies in unobserved components (UC) time series models from both theoretical and methodological perspectives. It also presents empirical studies where the UC time series methodology is adopted. Drawing on the intellectual influence of Andrew Harvey, the work covers three main topics: the theory and methodology for unobserved components time series models; applications of unobserved components time series models; and time series econometrics and estimation and testing. These types of time series models have seen wide application in economics, statistics, finance, climate change, engineering, biostatistics, and sports statistics.
The volume effectively provides a key review into relevant research directions for UC time series econometrics and will be of interest to econometricians, time-series statisticians, and practitioners (government, central banks, business) in time series analysis and forecasting, as well to researchers and graduate students in statistics, econometrics, and engineering.
*STAMP and SsfPack provide the computational tools for many of the chapters in this volume.*

## 7.4 Cointegration Analysis of Time Series

This book provides the tools for empirical modelling using the cointegration framework developed by Søren Johansen and Katarina Juselius. The first part introduces the multivariate cointegration model, followed by a practical I(1) analysis of purchasing power parity and uncovered interest parity between

Germany and the United States. The second parts presents the cointegrated I(2) model, as well as an empirical analysis.



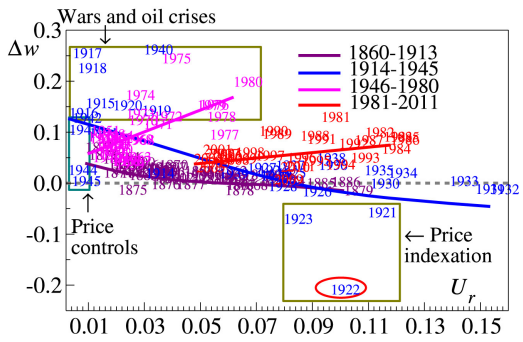


*The examples in the book by Doornik and Juselius can be followed step by step using the new CATS for OxMetrics software.*

# 8 Research Corner

## 8.1 Deciding between alternative approaches in macroeconomics

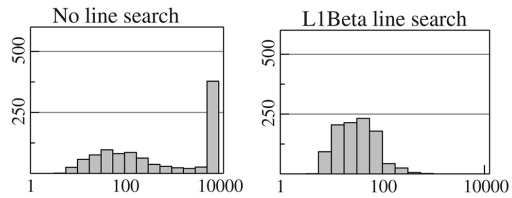
Macroeconomic time-series data are aggregated, inaccurate, non-stationary, collinear and rarely match theoretical concepts. Macroeconomic theories are incomplete, incorrect and changeable: location shifts invalidate the law of iterated expectations and 'rational expectations' are then systematically biased. Empirical macro-econometric models are non-constant and mis-specified in numerous ways, so economic policy often has unexpected effects, and macroeconomic forecasts go awry.
We propose nesting 'theory-driven' and 'data-driven' approaches, where theory-models' parameter estimates are unaffected by selection despite searching over rival candidate variables, longer lags, functional forms, and breaks. Thus, theory is retained, but not imposed, so can be simultaneously evaluated against a wide range of alternatives, and a better model discovered when the theory is incomplete.




*This is an open access paper in the International Journal of Forecasting by David Hendry (2018). All results and graphics where obtained with OxMetrics 7 and PcGive.*

## 8.2 Accelerated Estimation of Switching Algorithms

Restricted versions of the cointegrated vector autoregression are usually estimated using switching algorithms. These algorithms alternate between two sets of variables but can be slow to converge. Acceleration methods are proposed that combine simplicity and effectiveness. These methods also outperform existing proposals in some applications of the expectation-maximization method and parallel factor analysis.



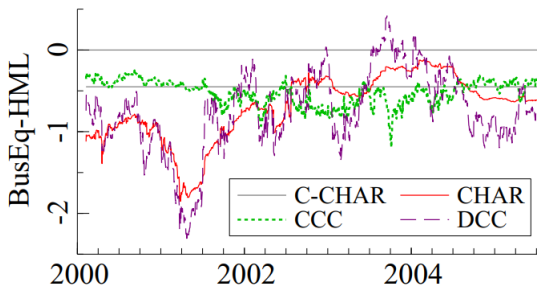

*This is an open access paper in the Scandinavian Journal of Statistics by Jurgen Doornik (2018). All results and graphics where obtained with OxMetrics 7 and Ox.*

## 8.3 Modified efficient importance sampling for partially non-Gaussian state space models

The construction of an importance density for partially non-Gaussian state space models is crucial when simulation methods are used for likelihood evaluation, signal extraction, and forecasting. The method of efficient importance sampling is successful in this respect, but we show that it can be implemented in a computationally more efficient manner using standard Kalman filter and smoothing methods. Efficient importance sampling is generally applicable for a wide range of models, but it is typically a custom-built procedure. For the class of partially non-Gaussian state space models, we present a general method for efficient importance sampling. Our novel method makes the efficient importance sampling methodology more accessible because it does not require the computation of a (possibly) complicated density kernel that needs to be tracked for each time period. The new method is illustrated for a stochastic volatility model with a Student's t distribution.
*This is an open access paper in Statistica Neerlandica by Siem Jan Koopman, Rutger Lit and Thuy Nguyen (2018). All results where obtained with Ox 7 and SsfPack.*

## 8.4 Asymptotics of Cholesky GARCH Models and Time-Varying Conditional Betas

This paper proposes a new model with time-varying slope coefficients. Our model, called CHAR, is a Cholesky-GARCH model, based on the Cholesky decomposition of the conditional variance matrix introduced by Pourahmadi (1999) in the context of longitudinal data. We derive stationarity and invertibility conditions and prove consistency and asymptotic normality of the Full and equation-by-equation QML estimators of this model. We then show that this class of models is useful to estimate conditional betas and compare it to the approach proposed by Engle (2016). Finally, we use real data in a portfolio and risk management exercise. We find that the CHAR model outperforms a model with constant betas as well as the dynamic conditional beta model of Engle (2016).




*This is a paper in the Journal of Econometrics by Serge Darolles, Christian Francq and Sébastien Laurent (2018). All results where obtained with Ox 7 and G@RCH 7*

## 9 20th OxMetrics Conference

**10-11 September 2018**
**Cass Business School, London**

- *Selecting a Model for Forecasting* Jennifer L. Castle with D. F. Hendry and J. A. Doornik
- *Forecasts for M4* Jurgen A. Doornik with J. Castle and D. F. Hendry
- *A False Sense of Security: The Impact of Forecast Uncertainty on Hurricane Damages* Andrew B. Martinez
- *The Wisdom of Committees* Neil R. Ericsson with D.F. Hendry, S. Yanki Kalfa, J. Marquez.
- **Ana Timberlake Memorial Lecture** *Organizational Complexity and Systemic Risk* Robin L. Lumsdaine
- *Modelling Australian Electricity Price using Indicator Saturation* James Reade with S. Wang
- *Are Soybean Yields Getting a Free Ride from Climate Change? Evidence from Argentine Time Series* Hildegart Ahumada with Magdalena Cornejo
- *Analyzing Differences between Scenarios* David F. Hendry with Felix Pretis
- *Markov-Switching Dynamic Factor Models after the Great Recession* Pierre-Alain Pionnier with C. Doz and L. Ferrara
- *Maximum Likelihood Estimation and Inference for High Dimensional Nonlinear Factor Models with Application to Factor-augmented Regressions* Fa Wang
- *Two-Step Estimation of Large Scale Dynamic Factor Models: General Consistency Results in Stationary and Non-Stationary Frameworks* Catherine Doz with M. Bessec.
- *Missing Observations in Observation-Driven Time Series Models* Siem Jan Koopman with F. Blasques and P. Gorgi.
- *High-Frequency Quoting and Liquidity Commonality* Riccardo Borghi
- *Small-sample Tests for Stock Return Predictability with Possibly Non-Stationary Regressors and GARCH-type Effects* Richard Luger with S. Gungor.
- *What Triggers Systemic Risk in the European Financial System?* Giovanni Urga with C. Bellavite Pellegrini, P. Cincinelli and M. Meoli.
- *Identification and Persistence-Robust Exact Inference in DSGE Models* Lynda Khalaf with Z. Lin and A. Reza
- *Modelling how Macroeconomic Shocks affects Regional Employment: Analysing the Brazilian Formal Labour Market using the Global VAR Approach* Emerson Fernandes Marçal with B. Tebaldi
- *Forecasting Long Memory through a VAR Model* Sébastien Laurent with L. Bauwens and G. Chevillon
- *Models for Realized Volatility* Andrew Harvey
- *On the Robustness of the Principal Volatility Components* Pedro L. Valls Pereira with C. Trucios and L.K. Hotta
- *Simple Estimators and Inference for Higher-order Stochastic Volatility Models* Jean-Marie Dufour with N. Ahsan.