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SOFTWARE REVIEWS

A GUIDED TOUR OF TSMod 4.03

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SUMMARY
We review the time series econometrics package TSMod. The new features in TSMod 4.03, released in April 2004, are described and its potential for teaching is analysed. Copyright © 2005 John Wiley & Sons, Ltd.

1. INTRODUCTION

TSMod is an efficient, user-friendly, flexible Ox package for time series econometric analysis offering a wide range of univariate and multivariate, linear and nonlinear models. There are several things that we particularly like about TSMod.

First, TSMod is easy to use since it features a menu driven, click and point, graphical user interface (GUI). Thus the user does not need to know Ox, the object-oriented, matrix programming language which is at the heart of TSMod. Moreover, the fact that TSMod is written in efficient Ox code makes it fast and hence particularly suitable to conduct Monte Carlo or bootstrap simulations.

Second, the number of nonlinear time series parameterizations—including GARCH and related forms of conditional heteroscedasticity, long memory and regime-switching models—offered by TSMod's menus far exceeds what is currently available in popular packages such as EViews, Pc-Give, Rats, S-Plus and TSP.

Third, it is an integrated package. Using the TSMod menus, it is straightforward to set up, estimate and test a model and then generate forecasts using the selected model.

Fourth, it is inexpensive to buy. (Currently, the time-limited, academic version of TSMod is free. However, James Davidson, the author of TSMod, plans to charge a modest fee for it in the future.)

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Finally, advanced users can use TSMod to estimate any nonlinear dynamic equation that can be supplied as a function in Ox code. They can also call TSMod routines from within Ox when, for example, running Monte Carlo experiments.

Of course, one can use TSMod just to calculate summary statistics and practice the standard OLS regression tools taught in basic undergraduate econometrics courses. However, this would be a waste of potential since the main comparative advantage of TSMod lies in its advanced features. TSMod is aimed primarily at researchers and students who have a good understanding of the econometric methods that they are applying.

2. OVERVIEW

A large range of models can be estimated using TSMod. In order to get a feel for the capabilities of TSMod, we looked at some recent financial econometrics textbooks—Franses and van Dijk (2000), Mills (1999), Tsay (2002) and Wang (2002)—and picked out some widely used models. We then checked whether or not TSMod facilitates them. TSMod provides the following tools *inter alia*:

- ARIMA and ARFIMA model estimates by ML with a pre-set maximum order feature allowing easy model selection;
- Bilinear autoregressive models by ML;
- ML and QML estimates of conditional heteroscedasticity models including GARCH, FIGARCH, HYGARCH, threshold ARCH, APARCH, EGARCH and GARCH-M;
- Regime switching models including simple Markov switching, Hamilton's dynamic Markov switching model, explained switching and smooth transition model components by ML;
- Linear equations using OLS, IV, 2SLS and GMM estimation methods;
- Linear systems using 3SLS, SUR, LIML/LGV and FIML methods;
- Nonlinear GMM models;
- Fully modified least squares (FMLS) estimation and models with equilibrium relations such as single-equation error correction models (ECM) and vector error correction models (VECM);
- Nonparametric (Naradaya–Watson) bivariate regression models;
- Parametric bootstrapped standard errors and p-values for test statistics.

One powerful feature of TSMod is its flexibility in that many of the models listed above can easily be combined. For example, it is possible to estimate an ARFIMA model with a GARCH skewed Student's t random error including exogenous regressors in both the conditional mean and conditional variance equations. ARFIMA models can be estimated in both the time and frequency domains.

There are a number of other attractive features. For instance, parameters can be fixed or subject to inequality constraints using a logistic map. Wald tests of linear restrictions are available. Score/LM and conditional moment tests can be calculated. The concentrated criterion function can be plotted in one or two dimensions. Rolling and recursive estimation options are available. Numerical optimization is carried out using the BFGS algorithm with the option of using the simulated annealing algorithm for starting values. In addition, stochastic simulation of the aforementioned models can be carried out and multi-step *ex ante* point forecasts including median forecasts of the mean and variance alongside 95% interval forecasts can readily be produced.

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2.1. Recent Features

The current version is TSMod version 4.03. A useful review of the earlier version 3.24 can be found in Bos (2004). However, as TSMod is continually evolving, the latter is already a little out of date. The fact that James Davidson has produced three new versions of TSMod in the first four months of 2004 bears this out! We should also note that TSMod's author is very open to suggestions and comments and, quite importantly, responds very promptly to queries. We envisage an active internet discussion list for TSMod users in the near future!

The major changes in v4.03 relative to v3.24 are: (i) The addition of useful system estimation routines—simultaneous equations models, VECMs, univariate and multivariate Markov-switching equations and multivariate GARCH models—including the ability to estimate user-programmed nonlinear systems; (ii) Johansen-type tests of cointegrating rank and MINIMAL analysis of the cointegrating space; (iii) the graphical user interface has been improved and icons for common commands have been added.

The multivariate GARCH model may interest many users. In the univariate case, the basic GARCH model may be expressed as $y_t = \gamma + u_t$ where $u_t = h_t^{1/2} e_t$, $e_t \sim iid(0, 1)$ and $\beta(L)h_t = \kappa + \alpha(L)u_t$. The multivariate extension of this has the vector form $\mathbf{u}_t = \widehat{\mathbf{H}}_t^{1/2}\mathbf{e}_t$, where $\widehat{\mathbf{H}}_t = \text{diag}(\mathbf{h}_t)$, $\mathbf{e}_t \sim iid(0, \mathbf{C})$ where $\mathbf{C}$ is a correlation matrix with ones on the main diagonal.

3. GETTING STARTED

3.1. Installation

Comprehensive instructions for installing TSMod in Windows and Linux operating systems are given in the documentation (Appendix A) provided with the program. The latest version of TSMod can be downloaded from James Davidson's web page `http://www.ex.ac.uk/~jehd201/`. Several other necessary software components—such as GnuDraw, GnuPlot and OxJapi—are bundled along with TSMod.

In order to use TSMod in the standard GUI or windows point-and-click form, the following two programs need to be installed: (i) the free console version of Jurgen Doornik's Ox 3.3 program which may be downloaded from `http://www.doornik.com/`; (ii) the free Java Runtime Environment (JRE) downloadable from `http://java.sun.com/j2se/1.4.2/download.html`. Installation is completed in four steps. The current version of the program usually resides in `c:/program files/ox/packages`.

Most users will probably launch TSMod using an easily set up Windows shortcut. However, it can also be run as a module from within OxEdit (or GiveWin) by clicking on `File→Open→TSMod Run` and then `Modules→Run Default Module`. A nice feature of TSMod is that advanced users can call the TSMod routines and access their output when programming Monte Carlo experiments or bootstrap simulations in Ox code.

3.2. Documentation

There is a learning curve when first using TSMod, because the program is so flexible, but it is not very steep. TSMod comes with a range of documentation: (i) a *Guide* to the package; (ii) a *User's Manual* which is also accessible through the program Help pages; (iii) a series of *Appendices*; and (iv) a *Programming Reference*.

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TSMod is not a commercial package as yet and it is designed for relatively experienced users. Nevertheless, the *Guide* is too cryptic at times when describing the large variety of models which TSMod can handle. New users would find it helpful if some of the more popular models were described in more detail. For instance, the sequence of menu and option settings used to set them up could be discussed. Basic examples of how to test joint parameter restrictions and analyse the cointegrating space would be useful. More detailed examples using available data sets could also be presented so that new users could familiarize themselves with the software by trying to replicate the results.

New TSMod users should print out a copy of the *User's Manual* since a lot of the information they need is set out there. The *User's Manual* provides a detailed description of the menus and options available in the GUI version of TSMod. However, if some of the technical aspects were illustrated via examples based on real data, it would be more fun to read through it. Also an alphabetically ordered index of contents for easy reference would be very useful in order for the user to find specific information quickly. Advanced users will find the *Appendices* and the *Programming Reference* clear and helpful. The *Appendices* show how to include user-coded (Ox) functions in the TSMod routines, how to call TSMod routines from an Ox program and how to generate artificial data (simulations) using the different models available.

3.3. Data Handling

TSMod can read data from the following sources: (i) Excel (.xls) and Lotus (.wk1,.wks) worksheets; (ii) Ox/GiveWin (.in7, .dat) datafiles; (iii) Stata (.dta, versions 4 to 6) datafiles; (iv) Gauss (.dht) datafiles; (v) ASCII files with the .mat file extension containing a data matrix with variables in columns, observations in rows and the number of rows and columns in the first line. Data can be written to Excel, Lotus, Ox/GiveWin and ASCII data files but, unfortunately, not to Stata or Gauss data files. Of course, a program like StatTransfer can be used to transfer data from other data file types. Two or more data files can be merged in TSMod.

TSMod is a reasonably robust package. It will crash on occasion if you play around enough with a variety of model settings. However, in almost all cases, the problem is resolved when you start up TSMod again. The latest settings are restored and one can estimate the model previously set up. New users should generally reset the settings in TSMod whenever they start formulating a new model.

4. USING TSMOD FOR TEACHING

We believe that the main reasons why an applied econometrics lecturer might choose to adopt TSMod for teaching purposes are (i) TSMod is an advanced package offering state-of-the-art time series estimation methods and models, (ii) TSMod uses a menu-driven GUI and (iii) TSMod is inexpensive. It is ideal for research purposes and for teaching advanced undergraduate and postgraduate econometrics courses. Students and researchers who can program in Ox will also certainly benefit from the easy interaction between TSMod and Ox. Below we outline a series of advantages (*pros*) and disadvantages (*cons*) of TSMod.

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4.1. Transforming Data, Session Logs and Data Summaries

Through the GUI, most common data transformations (logarithms, lags, differences, scaling, etc.) can be performed, dummy variable and trends can be created and individual observations can be edited on the fly (*pro*). However, more complicated transformations will have to be performed prior to reading the data in TSMod since the package does not have a calculator or algebra editor tool similar to those in GiveWin (*con*). Take the daily S&P series used in Franses and van Dijk (2000). It can be transformed into daily returns through `Setup→Data Transformation→Log-Difference`. This automatically creates a new variable called D1Log_S&P. The user can then rename the series if desired. The new data file (that contains both the original series and the transformed series) can be saved through `File→Data→Save`. Various default file types can be specified (*pro*). A listing of data transformations appears in the session log file and on the screen (*pro*).

How does TSMod handle missing data? Suppose that a single observation for a single variable, say the 30th data point, is missing from the data set. TSMod will estimate a model including this variable by dropping all observations up to observation number 30. This is fine for most dynamic time series models, the focus of TSMod, but not if you want to estimate a static OLS regression.

One nice feature of TSMod is that the output of the session can be cumulated in an output/session log file (*pro*). This feature is useful for teaching purposes. For example, when correcting course-work/assignments this provides an easy way to re-trace the student's steps in the econometric analysis. This can be specified at the beginning of a session through `File→Results→Enable Background Saving` or `New Results File`. Perhaps the default setting should be to keep a session log. Of course, the user can save selected results using `File→Results→Save Selected Text`.

One can produce summary statistics through the `Actions→Compute Summary Statistics options`. Besides the usual statistics, the latter provides several I(0)/I(1) tests by default (*pro*). These are Lo's RS test, the KPSS test, the Phillips–Perron test and Robinson's d test. In contrast with other common packages such as EViews, it gives the observation number at which the *max* and *min* occurs (*pro*). Perhaps the data transformation, summary statistics and data graphs options should appear under the same menu heading. In addition, a check box could be added to the summary statistics dialogue to enable statistics, correlations and so forth to be calculated in one go (*con*).

4.2. Econometric Analysis

Different estimators, as well as the sample to be used, can be chosen through `Setup→Estimation and Sample` option. One can also specify systems estimation and the use of differenced data. The regression model is specified using `Model→Linear Regression`. One can also access IV, GMM, 2SLS, 3SLS and FMLS using this menu. ARFIMA, GARCH, regime-switching models and other parameterizations involving equilibrium relations (e.g. ECM and VECM) are selected through the `Model→Dynamic Equation` option.

By default, TSMod reports several diagnostic tests alongside the estimation results (*pro*). These include the residual skewness and kurtosis, the Jarque–Bera test for normality, a residual autocorrelation test (Box–Pierce) and a test for heteroscedasticity (Box–Pierce test for the squared residuals). The lag length for these tests can be set using `Options→Test and`

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`Diagnostics Options`, since the default value of 12 may not be appropriate in many cases. Additional tests for autocorrelation and heteroscedasticity, including neglected ARCH effects, may also be called for (*pro*). In the case of ARMA models, TSMod reports the real and imaginary part of the AR roots and their moduli (*pro*) but not the inverted MA roots as EViews does (*con*). The reported standard errors are obtained from the White robust covariance matrix by default. However, either the conventional or the Newey–West HAC robust standard errors may be selected instead using `Options→Test and Diagnostics Options`.

TSMod also offers a nonparametric (Naradaya–Watson) bivariate regression module and some advanced estimation methods for cointegrating models such as FMLS. However, TSMod does not include a number of estimators which are widely used in conventional undergraduate econometrics courses such as GLS estimation (e.g. weighted least squares in the context of heteroscedastic errors), logit and probit time series models, and baseline panel time series models such as fixed effects and random effects (*con*). However, a wide range of time series models within the GARCH class are provided to deal with conditional heteroscedasticity (*pro*).

With regards to inference, it is possible to compute score or conditional tests of hypotheses using `Actions→Compute Test Statistics`. Take the model $y_t = \alpha + \beta_1 x_{1t} + \beta_2 x_{2t} + \varepsilon_t$ and suppose that we want to test $H_0 : \beta_1 + 4\beta_2 = 1$. In EViews this can be done simply by writing $c(2) + 4 \times c(3) = 1$ in the test window. However, it is less obvious how to do this in TSMod and so, as noted earlier, it would be useful if the TSMod manual contained some data-based examples (*con*). It is possible to impose multiple parameter restrictions, such as the one above, in estimation through `Model→Parameter Constraints` (*pro*). Simple Chow breakpoint tests are not readily set up from the menus after model estimation in TSMod (*con*).

TSMod allows for recursive estimation based on increasing-size windows or a fixed-size rolling window and the sequence of parameter estimates can be subsequently plotted (*pro*). With regards to ARMA analysis, the estimated coefficients for AR models are virtually equal to those obtained in EViews (with the backcasting option off) and Pc-Give. However, the estimated coefficients and standard errors in ARMA models can differ. Table I reports estimates for an ARMA(1,1) model of the daily S&P Composite series over the period 1/06/86 to 12/31/97 from Franses and van Dijk (2000).

This example illustrates that the MA parameter estimate in TSMod is nearly identical to that from EViews and Pc-Give but with opposite sign! The reason for the latter is that their ARMA estimation routines are based on different default parameterizations of the MA lag polynomial. In TSMod, the latter is $\theta(L) = 1 - \theta_1 L - \ldots - \theta_q L^q$, which accounts for the apparent sign discrepancy. The TSMod and EViews heteroscedasticity robust (White-type) standard errors for AR model estimates are virtually identical. However, they differ somewhat in the case of ARMA models, as Table I

Table I. ARMA(1,1) estimates

	Parameter (robust s.e.)		
	TSMod 4.03	EViews 4.1	Pc-Give 10.0*
Intercept	0.00048 (0.0001)	0.00049 (0.0002)	0.00048 (0.0001)
AR1	−0.71519 (0.1351)	−0.71519 (0.2072)	−0.73553 (0.0929)
MA1	−0.75705 (0.1104)	0.75706 (0.1757)	0.77509 (0.0863)

* Using the ARFIMA 1.01 package for Ox (Doornik and Ooms, 2003).

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illustrates. The reason for this discrepancy is not obvious. The White standard errors from TSMod and Pc-Give are relatively close.

A wide range of ARCH models can be estimated. At first sight (i.e. when using the default specifications), the results seem to differ greatly from those in other packages. However, users should be aware of the different ARCH parameterizations that TSMod permits. Take a simple GARCH(1,1) model. Estimates for the 'ARMA-in-squares' form of the GARCH equation are reported by default. However users may want to opt for the 'conventional form' of reporting results through `Options→ML and Garch Options`. Care should also be taken in that, depending on how the GARCH model is written, two different intercepts (referred to as 'Type 1' and 'Type 2') are reported. Most users will probably prefer the latter type of intercept which conforms with that reported in EViews and Pc-Give, namely δ in the equation $\sigma_t^2 = \delta + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2$, whereas the former is ω in $\boldsymbol{\beta}(L)(\sigma_t^2 - \omega) = \alpha\varepsilon_{t-1}^2$. By default, TSMod reports the 'Type 1' intercept but one can always revert to the conventional one through `Options→ML and Garch Options`. Perhaps it would be more intuitive if the conventional parameterization options were the default ones, instead of the other way round. Table II reports the GARCH(1,1) parameter estimates and standard errors for the S&P series.

As noted earlier, one of the strengths of TSMod is the wide range of univariate and multivariate models it offers for nonlinear time series analysis. In addition, TSMod allows richer dynamics by readily combining different models, e.g. an ARFIMA–GARCH specification.

Inevitably, the current version of TSMod has some limitations in terms of modelling/inference tools but the author is very open to suggestions. VAR models may be estimated in TSMod but the impulse response to an innovation shock is not automatically generated. It would be useful if the MacKinnon–Haug–Michelis critical values for cointegration tests were added to the package. As TSMod stands, some users may prefer alternative packages such as Pc-Give to carry out Johansen-style analysis of cointegrating vectors. Stochastic volatility and state space (Kalman filter) models are not included in TSMod but they both may be estimated using the Ox packages Stamp and SsfPack/SVPack. Bandpass (frequency) filters such as the Baxter–King, Christiano–Fitzgerald fixed length and Christiano–Fitzgerald asymmetric full sample filters would also be nice to have. The forecast capabilities of TSMod could be expanded somewhat to provide a range of forecast accuracy measures, to generate combined forecasts and to conduct baseline Diebold–Mariano type forecast accuracy tests and the Pesaran–Timmermann predictor dependence test.

Table II. GARCH(1,1) estimates

	Parameter (robust s.e.)		
	TSMod 4.03	EViews 4.1	Pc-Give 10.0
Intercept (mean)	0.00065 (0.0001)	0.00065 (0.0001)	0.00065 (0.0001)
Intercept (GARCH)	0.00133 (0.0005)*	1.72e-06 (6.32e-07)	1.701e-06 (6.28e-07)
GARCH-AR	0.09261 (0.0538)	0.09174 (0.0514)	0.09092 (0.0514)
GARCH-MA	0.89261 (0.0607)	0.89438 (0.0432)	0.89527 (0.0432)

* Square root of Type 2 intercept as reported in TSMod output.

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4.3. Graphs

Unlike other Ox packages, TSMod does not make use of the graphics menu offered by GiveWin. Instead it comes with its own graphical platform which provides graphs with the same GiveWin layout and precision. Overall, the graphics capabilities in TSMod are reasonable. They are on a par with those in EViews. However, they lag behind those in GiveWin and in packages such as Pc-Give, TSP and Stamp which make use of the GiveWin interface directly.

Data plots include time series plots, correlograms, histograms and normal QQ plots. Equation plots include actual values and fitted values, residuals, conditional variances, *ex ante* forecasts and plots of recursive and rolling parameter estimates. In terms of precision and colour display, the TSMod graphics are nicer than those in EViews.

TSMod graphs may be exported/saved to a range of file types but not with ease if compared, for instance, with GiveWin. Moreover, it would be nice if the graphics saving capabilities were enhanced and some frequency domain plots were added.

5. CONCLUDING REMARKS

TSMod is an inexpensive, easy to use, flexible package for econometric research using time series data. TSMod currently dominates most econometrics packages in terms of the variety of nonlinear time series specifications it can handle. It can be used advantageously for teaching advanced undergraduate and postgraduate courses. We recommend it highly and hope that James Davidson will continue to produce regular updates.

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