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A compendium of existing econometric software packages

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This compendium of existing econometric software packages is intended to be a full census of all existing packages of this type that are publicly available and used by economists today. It is intended to provide the developer's view of each package: in all but a few instances, the person providing each entry is the primary author or current principal developer of the package. These program descriptions generally provide both a development history and a statement of current capabilities. Most entries also include references to more detailed descriptions, including manuals and other publications, as well as providing a website URL.

1. Introduction

This document is a supplement to the introductory article of this volume, "Econometric Software: The first fifty years in perspective". As that article began to be written, it quickly became evident that it would not and could not provide a balanced and reasonably comprehensive description of each of the currently available econometric software packages, both because of its author's lack of direct knowledge of the history, features and capabilities of every package and because no ready reference existed that provided such documentation. Consequently, it seemed sensible to try to provide separately, in the form of this compendium, a document that could generally serve as a public reference and at the same time provide a statement of the state of the art in the year 2003.

The first step taken was to contact the authors or developers of each of the software packages currently listed on the American Economics Association's Resources for Economists on the Internet (www.rfe.org) asking first if the software they provided met the criterion of being econometric software and, if so, then asking them to provide a description. Subsequently, by word of mouth, as well as by recommendation, additional packages were discovered. In every case that a package was found that has subsequently been identified by its author or developer(s) as being an econometric software package, an entry has been provided and is included. It does not appear that any developer has refused to submit a package description.

For inclusion, the criterion applied has been that the package is primarily econometric in its features and capabilities. As a consequence, there are packages that are used by economists, but identify themselves as being primarily statistical software packages, or some other type of software package, and therefore are not included.

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Of course, it is inevitable that one or more packages have been omitted that will subsequently be identified as econometric software packages, but the intention has always been to include every such publicly available package as of 1 June 2003. To this end, drafts of this compendium have been circulated widely during the past six months and more.

Each of the econometric software packages represented is described in some detail and in a roughly consistent style. As an editorial intention, each description identifies the principal author(s), provides brief historical information, and describes the program's salient characteristics. As a rule, the descriptions were provided by the principal, often original author(s) of the program or, in a few cases, the principal current developer, and have simply been edited for style. One of the purposes in the creation of this document is to provide both descriptions of packages and a clear statement of each package's development history, which may include the range of machines the software has been mounted on during its life, as well as operating systems under which the software runs or has run historically. In a few cases – particularly when a package is important historically, but is no longer supported – a description of it and its history has been independently provided, usually in cooperation with former and, in some cases, current users of the package.

The context in which each package is presented depends on its characteristics. Currently available packages are classified into four categories: Independent Econometric Software Packages, Econometric Programming Libraries, Econometric and Mathematical Programming Languages, and Applications of Econometric and Mathematical Programming Languages. A fifth category consists of packages that are of historical interest, but are no longer supported. This classification scheme is not ideal, but it is difficult to determine how else to proceed.

A qualification

As indicated earlier, the packages included here have not been, in any way, "vetted." Dates of original release and subsequent modification should be interpreted as representing developers' claims. Similarly, all claims that a particular package performs some particular operation should be regarded as no more than that. However, the issue here is not so much the ostensible inclusion or not of some technique or feature, but rather that of qualitative assessment: the degree to which each package reliably does what the developer represents that it does. The independent evaluation of econometric software, especially an assessment of the degree to which packages are numerically reliable, is quite recent in origin and still only rarely made. McCullough and Vinod, in their *Journal of Economic Literature* article (June 1999) on the numerical reliability of econometric software, have stated that they "surveyed five journals that regularly publish reviews of econometric software. For the years 1990–1997, over 120 reviews appeared. All but three paid no attention to numerical accuracy, and only two applied more than a single test of numerical accuracy"

(p. 633). What this finding indicates is that economists have not been at all rigorous in the evaluation of the software they use.

These qualifying statements are not made in order to call into question the skill or integrity of the econometricians who develop econometric software. There is no evidence that econometric software is any less reliable than software produced by Microsoft or any other major software developer; in fact, if anything, what evidence exists actually suggests just the opposite. Furthermore, there is no reason to believe that any of the developers of any of the packages described here have done less than their best to insure numerical reliability, nor that the statements about packages made here are not accurate. But it is important for all software users and developers to realize both that insuring numerical reliability is inherently difficult and that the economics profession numbering tens of thousands of people is currently depending upon the dedication of a literal handful of people to insure that numerical reliability. The difficulty in evaluating software reliability in part resides in the fact that, for a developer – representing the first stage of this evaluation, there are very few benchmark test results available in the literature against which packages can be measured. Yet the process of implementing algorithms so as to precisely represent the concepts described in the theoretical econometrics literature is subject to both direct implementation errors and errors of interpretation. Moreover, for a variety of reasons, some of them considered in the aforementioned article that this compendium supplements, independent assessment is a critical element in software validation, quite apart from any self-validation by developers. Econometric software development is not an activity that should be performed in isolation by the few on behalf of the many, for there is a general need for both developers and users of this software to participate in its ongoing evaluation. But until such time as the profession takes such verities to heart, users need to take care when they use this software. Even then, it will still be necessary for users to understand how to apply the software used, which includes an appreciation of the limitations and qualifications associated with the particular techniques that are employed.

2. Independent econometric software packages

The term “independent” refers to the degree to which a package operates as a standalone package: an independent software package requires a computer and a compatible operating system, as a minimum operating environment. For the purpose of this definition, what constitutes the operating system may include one or more “run time” modules of a standard development package such as Microsoft Visual Basic, but it certainly does not include any additional applications software package that the user must license or otherwise acquire separately in order to be able to run the econometric software package.

The software packages presented in this section of the compendium are econometric in orientation, which is to say that they provide the capability to perform operations that ostensibly implement the techniques that are described in the economics and econometrics literature as regards parameter estimation techniques, specification and other hypothesis tests, and the like. These packages range in characteristic from those that incorporate a command structure that permits the user to select specific econometric techniques to those that provide some degree of programming capability and therefore to some extent may allow the user to define the particular intrinsic properties of the operations performed.

In all cases, the packages described are written in a standard programming language (or languages) and operate using a standard computer operating system. Examples of the former are C/C+, FORTRAN, Pascal, and Visual Basic. Examples of the latter are DOS, Linux, Unix, and Windows.

AREMOS

URL: www.globalinsight.com

The precursors of AREMOS are the DEMOS and HASH software systems created by Tim Harrison as part of the University of Southampton's Econometric Model of the UK. The development of AREMOS in the period 1982–1986 was sponsored by CiSi – a French computing services group – both for its own modeling requirements and for use by its then subsidiary Wharton Econometric Forecasting Associates. The system was very heavily influenced by Lawrence Klein's modeling methodology as implemented at Wharton. The system was originally designed with the goal of using a common base for both PC DOS and IBM VM/CMS operating systems with its orientation becoming more heavily PC-oriented as the PC platform developed. Both PC and mainframe versions were extensively used internally at CiSi and Wharton Econometrics in the early '80s with the first public PC release for DOS in July 1985. A Windows version was developed during the period 1994–1995 and first released in September 1995.

AREMOS is designed as an integrated software system comprising data management, analysis and support for the construction and use of econometric models, as well as the production of sophisticated presentation graphics and reports. As a DOS package, AREMOS incorporated both interactive command line operation and an extensive macro language including prompt messages and default values, looping and flow control, Boolean logical operation, subroutines, functions, and a command-line interface. The Windows version of AREMOS preserves many of these features, but incorporates a graphical user interface. The program's report-generating features include a spreadsheet-like report design grid, a table generator, automatic updating of reports, and the use of calculations and functions instead of pre-calculated data.

AREMOS is capable of reading data provided in any of a number of different formats, including XLS and TSD. Output to XLS, RTF, and HTML is also supported.

AUTOBOX

URL: www.autobox.com

The principal author of AUTOBOX is David Reilly. The program began to be developed in 1966 at the University of Wisconsin Statistics Department under the direction of George Box under the title "The Pack Program" with David J. Pack as the principle statistician/programmer. Beginning in 1968, David Reilly, then at the University of Pennsylvania, developed a rule-based heuristics system that is today the Autobox approach to ARIMA modeling. The main thrust was to provide a mechanized or automated option to the Box-Jenkins (ARIMA) approach to modeling a time series process. SAS and BMDP were early source code customers in 1972 for the Pack Program.

The first release of AUTOBOX (then called AUTOBJ) occurred in November 1969 on an IBM 360 located at The American Stock Exchange. The Interactive Data Corporation and Chase Econometric Forecasting Associates provided AUTOBJ in the context of XSIM as a time sharing package. It was also provided in a time sharing environment by Compuserve and Computer Science. AUTOBJ was converted to the PC beginning in 1982, and first released as a DOS application later that year. It was converted to Windows beginning in 1990 and first released as a Windows application in 1991. The name was changed to AUTOBOX in January 1988. It is also available as both a DLL and an object library for Unix/Linux platforms. AUTOBOX has in addition been successfully integrated (OEM) into a number of more general software packages.

AUTOBOX is an interactive program with a Visual Basic wrapper that uses Access as its database. The program's objectives can be summarized under the term Generalized Least Squares inasmuch as it renders a noise process that has constant mean, constant variance and is free of both auto projective structure and dependence on lags of any known input series. The objectives of the Gaussian Assumptions are met and model statistics are then useable. FreeFore is the shareware version of Autobox, announced in 2003.

S. Armstrong (2001), *Principles of Forecasting*, Kluwer Academic Publishers, Boston.

R. Bewley (1988), Review of Autobox, *Journal of Applied Econometrics* **3**(3).

U. Kusters (1995), *Software Review: AUTOBOX 3.0 and SCA PC-EXPERT*, The Forum, International Institute of Forecasters.

K. Ord and S. Lowe (Feb. 1996), Automatic Forecasting, *The American Statistician* **50**(1), 88–94.

D.J. Pack (1971), *The Pack Program User Guide*, Automatic Forecasting Systems, Philadelphia, PA.

D.P. Reilly (1980), Experiences with an Automatic Box-Jenkins Modeling Algorithm, in: *Time Series Analysis*, O.D. Anderson, ed., North-Holland, Amsterdam, pp. 493–508.

D.P. Reilly (1987), Experiences with an Automatic Transfer Function Algorithm, in: *Computer Science and Statistics Interface*, R.M. Heiberger, ed., American Statatistical Association, Alexandria, VA, pp. 128–135.

D.J. Pack (1971), *The Pack Program User Guide*, Automatic Forecasting Systems, Philadelphia, PA.

B34S

URL: www.uic.edu/∼hhstokes

The principal author of B34S is Houston H. Stokes. The program began to be developed at the University of Chicago in 1964 by Hudson Thornber. The program's original name was B34T. It was written in Fortran II and ran on an IBM 7094. Stokes became the developer in 1972 and moved the program to the University of Illinois at Chicago. At that time the program name was changed to B34S, and the code converted to Fortran IV and ported to the IBM 360 MVS operating system. In the 1980's, it was converted to Fortran 77 and moved to an IBM 370 running under CMS at the University of Illinois at Chicago. In 1991, B34S was ported to the PC as a DOS program using the Lahey F77EM32 compiler. In the late 1990's it was ported to the RS/6000 and Sun platforms and in 2000 to Linux. B34S is currently written in Fortran 95.

B34S was originally a regression program that offered OLS and GLS regressions. It was later expanded to include time series modeling (Box Jenkins and VARMA) and a variety of general procedures (Stokes, 2003). B34S essentially has two aspects: it contains a number of procedures and in addition incorporates a programming language that permits matrix operations. Both of these modes are closely linked and the data are equally accessible in either. Both provide extensive links with other systems such as LIMDEP, MATLAB, RATS, SAS, and SPEAKEASY. The MATRIX command in fact allows a user to develop custom applications in a higher language or to link with Fortran programs. User-defined PROGRAMS, SUBROUTINES and FUNCTIONS are supported.

M. Aoki (1987), *State Space Modeling of Time Series*, Springer-Verlag, New York.

L. Breiman (May, 1991), The Π Method for Estimating Multivariate Functions From Noisy Data, *Technometrics* **33**(2), 125–143.

J. Dennis, D.Gay and R. Welsch (1981), An adaptive nonlinear least-squares algorithm, *ACM Trans. Math. Software* **7**(3), 348–368.

J. Friedman (1991), Multivariate Adaptive Regression Splines, *Annals of Statistics* **19**(1), 1–67.

D. Pack (1977), *A Computer Program for the Analysis of Time Series Models Using the Box-Jenkins Philosophy*, Department of Statistics, Ohio State University, Cleveland, Mimeo.

H.H. Stokes (1991, 1997), *Specifying and Diagnostically Testing Econometric Models*, Quorum Books, New York.

H.H. Stokes (2004), The evolution of econometric software design: A developer's View, *Journal of Economic and Social Measurement* **29** (2004), 205–259, this volume.

H. Thornber (1965), *The Autoregressive Model: Bayesian vs. Sampling Theory Analysis*, Technical report No. 6504, Center for Mathematical Studies in Business and Economics, University of Chicago Business School.

H. Thornber (1966), *Manual for B34T* (*8 MAR 66*)*-A Stepwise Regression Program*, University of Chicago Business School Technical Report 6603.

H. Thornber (15 September 1967), *BAYES Addendum to Technical Report 6603: Manual for B34T-A Stepwise Regression Program*, University of Chicago Business School.

H. Thornber (1 August 1968), *BLUS Addendum to Technical Report 6603: Manual for B34T-A Stepwise Regression Program*, University of Chicago Busienss School.

BETAHAT

URL: www.LFSoftware.com

The author of Betahat is Paul Calvert. Development began in 1991 and the first versions ran under DOS and OS/2. These were written in Basic PDS, the predecessor to Visual Basic for Windows. The first general release of Betahat (then called Beta) was in June 1995 as a Windows application. The interface was written in Visual Basic, but the core computations were generally done in FORTRAN DLL's. Starting with version 3.0, most computations were moved to Visual Basic except for the Census X-11 code and some library routines which remain in FORTRAN and Pascal DLL's.

The major single equation model types that can be estimated include OLS, AR-1, ARIMA, linear & nonlinear ARMAX, various types of exponential smoothing, Box-Cox, binomial and multinomial logit, probit, tobit, poisson, multivariate t with uncorrelated errors, multivariate t with independent errors, 2SLS and 2SNL with or without ARMA errors, LIML, linear and nonlinear GMM with options for 6 different lag patterns, and programmable nonlinear maximum likelihood. For pooled or panel data there are 7 different model types. AR-1 correction for each of the panel model types is available. The structural systems model types that can be estimated include SUR, 3SLS, GMM, and FIML. Other system estimators include VAR, vector ARIMAX, and multivariate stochastic variance. The algorithms included for estimation are Marquardt, Gauss-Newton, DFP, BFGS, Newton, and BHHH.

A wide variety of tests and options are incorporated including autocorrelations, Ljung-Box Q statistic, partial autocorrelations, influence measures, recursive residuals, autocorrelation and heteroskedastic consistent covariance matrices, imposition and testing of linear restrictions, and unit root tests. There are also many tests for heteroskedasticity.

Betahat can simulate all of the model types that it can estimate. Estimated, and unestimated equations with user supplied coefficients, can be saved in the database for later use or inclusion in a simulation. There are options for add factors and identities. Stochastic simulation is available for both single equations and systems. There is an automatic comparison of the values from a simulation to a base simulation so the user can easily compare the effect of a changed model. The output is also selectable, permitting display of only equations and identities that are of interest.

The features that are distinctive to the program include robust methods for reading data, and a dual mode interface. Supported file formats for input/output include Access®, dBase, FoxPro, Excel®, Lotus, text, and others. SQL statements can be used when reading most file formats. Betahat was originally developed with a Windows-based GUI interface by using standard interface devices such as spreadsheets, dialog boxes, and pull down menus. This interface works well for exploratory type work with datasets that have a fairly small number of series. Starting with version 2.0 a command/batch interface was added to the program. The command mode interface made larger scale macroeconometric models more feasible using Betahat, since they usually have a very large number of data series, equations, and identities, and they are commonly run as a large set of instructions.

CEF

URL: www.ms.ic.ac.uk/sghall/

The principal author is Stephen G. Hall. The CEF software was originally written in FORTRAN 77 for the IBM PC and compatibles. It developed from model solution software originally created by Richard Pierce at the National Institute of Economic and Social Research in the early 70's, also written in FORTRAN 77, but mainframe computer based. During the first half of the 1980s, CEF was extended to include a range of model analysis and solution techniques (Hall and Henry, 1988). In 1987, CEF was moved to the Bank of England. In 1991, it was installed at the London Business School Centre for Economic Forecasting and used for the LBS model. In the late 1990s, it was converted to Windows.

CEF is a model solution package that runs under Windows. It accesses large data bases. It incorporates a range of different model analysis and solution techniques, including optimal control, stochastic simulation, model inversion rational expectations solutions, and the well known stacked solution algorithm for rational expectations (Hall 1985a, 1985b).

S.G. Hall and S.G.B. Henry (1988), *Macroeconometric Modeling*, North-Holland, Amsterdam.

S.G. Hall (May, 1985a), An Improved Solution Technique for Large Economic Models with Consistent Expectations, *System and Control Letters* **5**.

S.G. Hall (May, 1985b), On the Solution of Large Economic Models with Consistent Expectations, *Bulletin of Economic Research*.

EasyReg International

URL: econ.la.psu.edu/∼hbierens/EASYREG.HTM

The author of EasyReg (Easy Regression) is Herman Bierens. EasyReg is called International because it accepts dots and/or commas as decimal delimiters, regardless of the local number setting of Windows. Development as a Windows program began in 1995. EasyReg was initially written in Visual Basic 3, and is now further developed in Visual Basic 5. EasyReg is unusual among econometrics program in being genuine freeware. It can be downloaded and distributed freely without restrictions.

EasyReg offers a wide range of estimators of single and multiple equation models, comparable with commercial econometric software. The single equation models supported are: linear regression models, which in the time series case can be extended to models with ARMA errors and/or GARCH errors, discrete dependent variables models (Logit and Probit, multinomial Logit, Poison regression, binomial, negative binomial, and ordered Logit and Probit), Tobit, Heckman's sample selection model, quantile regression, 2SLS, nonparametric kernel regression, and ARIMA models. The multiple equation models that are suported are: linear GMM (with SUR and panel data models as special cases), structural and nonstructural VAR, and Johansen's VECM. Although EasyReg is mainly a point-and-click program, it is possible to program and estimate user-defined nonlinear regression, maximum likelihood and GMM models. The programming itself is still done by point-and-click, though. Moreover, EasyReg contains various data analysis tools, such as unit root and stationarity tests, kernel density estimation, time series plotting, and scatter diagrams.

Two types of data files are supported, namely Excel files in CSV format, and particular space delimited text files containing the number of variables, missing value code, variable names, and the data matrix. EasyReg also comes with its own database which contains data samples.

S.P. Sephton (1998), EasyReg: Version 1.12, *Journal of Applied Econometrics* **13**, 203–207.

EVIEWS

URL: www.eviews.com

EViews is a product of the staff of Quantitative Micro Software. The immediate predecesor of EViews, MicroTSP, was developed by David Lilien, and first released in 1981 for the Apple II personal computer. MicroTSP was subsequently rewritten for IBM compatible PCs, taking direct advantage of the latter platform's increased memory and superior graphical support. All development of MicroTSP ended in 1990 and work began on an all new program for the Windows operating system. The result of this project, EViews, was released in early 1994. Written in C++ and designed from the ground-up to use modern GUI interfaces, EViews provides an integrated environment for estimation and forecasting, large-scale model construction and solution, database management, and presentation of results. Currently available for systems running 32-bit versions of Windows, EViews features an innovative, Windows-based, object-oriented user-interface, as well as traditional command line and programming interfaces.

EViews provides extensive support for estimation and forecasting of linear and nonlinear single and multiple equation econometric models. While the original emphasis of the program was on standard econometric and time series methods such as OLS, TSLS, ARMAX, GMM, VARs, ARCH and Kalman filtering, EViews also supports a wide range of limited dependent variable and panel data estimators, as well as the ability to estimate user-specified maximum likelihood models. In addition, EViews includes a variety of tools for general statistical analysis.

Sophisticated model analysis and simulation tools allow for the construction of and solution of linear and nonlinear models with virtually no limits on the number of equations (save those imposed by Windows' 2GB limit on a single application). These models may be solved using dynamic or static methods, and optionally, stochastic simulation and forward solution. All of EViews' estimation and simulation tools are tied into presentation quality graphics and table construction tools which allow users to quickly and easily summarize results and to exchange them with other Windows programs.

EViews reads and writes ASCII, MDB (Access), TSD, XLS and WKx files, as well as the native files of many econometrics and statistics packages, including PC-Give, RATS, SAS, SPSS, STATA and TSP. EViews also provides access to FAME, Haver Analytics, and DRI-Pro databases. ODBC support is available in EViews 5.

FP

URL: Fairmodel.Econ.Yale.Edu

The authors of FP (The Fair-Parke Program for the Estimation and Analysis of NonlinearEconometric Models) are Ray C. Fair and William R. Parke. The program is written in FORTRAN, and source code is distributed for use on any machine with a FORTRAN compiler. An executable version is also distributed for use on PCs. The program runs in DOS on PCs. The original release date is 1980 for the mainframe version; the PC version was first released in 1990. The current version can be obtained free of charge from the website.

The FP program allows one to estimate and analyze dynamic, nonlinear, simultaneous equations models. The models can include 1) nonlinearity in variables, 2) nonlinearity in coefficients, 3) autoregressive and moving average errors of any order, and 4) rational expectations. The estimation techniques include OLS, 2SLS, 3SLS, FIML, LAD, 2SLAD, and some versions of Hansen's method of moments estimator. Many single equation tests can be performed. Other options include 1) running forecasts, 2) calculation RMSEs, 3) calculating multipliers, 4) solving optimal control problems, and 5) performing stochastic simulation and bootstrapping. One of the advantages of the program is that it allows one to move easily from the estimation of the individual equations to the solution and analysis of the entire model. The Parke algorithm is used for 3SLS and FIML estimation. The extended path method is used for the solution of models with rational expectations. For stochastic simulations the draws can either be from estimated distributions or from estimated residuals. The data can be read in free or fixed format. Each technique in the program is discussed in at least one of the three references below, and all of the techniques used in the three references are in the program. Appendix C in Fair (1984) is a discussion of the logic of the program.

R.C. Fair (1984), *Specification, Estimation, and Analysis of Macroeconometric Models*, Harvard University Press.
R.C. Fair (1994), *Testing Macroeconometric Models*, Harvard University Press.
R.C. Fair (2004), *Estimating How the MacroeconomyWorks*, Harvard University Press, forthcoming.

GRETL

URL: Gretl.sourceforge.net

The principal author of gretl is Allin Cottrell. Gretl inherited an initial code base from Ramu Ramanathan, in the form of Ramanathan's ESL (Econometrics Software Library), the DOS program that accompanied his textbook *Introductory Econometrics*. ESL was originally written in Fortran, and then converted to C. gretl extends ESL into a cross-platform package supporting both graphical and command-line user interfaces. Although C is the language used, some extensions ("plugins") use the fortran-based Lapack library. gretl is unusual among econometrics programs in being open-source and free, in the specific sense of the Free Software Foundation. Binary packages are available for Windows and various Linux versions; the source, which uses the GNU autoconf apparatus, should compile on any unix variant that supports GTK.

gretl offers a reasonably full range of single-equation least-squares estimators (OLS plus several autocorrelation- and heteroskedasticity-corrected variants), Two-stage Least Squares, SUR systems, Least Absolute Deviations regression, and ML estimation of binomial logit and probit. It also offers VARs, unit-root tests and cointegration tests. For users who wish to carry out further analyses not available within gretl itself, the program offers several links to other software, allowing data to be saved in GNU Octave (closely related to Matlab) and GNU R (closely related to the "S" statistical system); there are also gretl plugins that can exchange data with X-12-arima and TRAMO/SEATS, for analysis of seasonality and ARIMA modeling. In batch mode, gretl permits Monte Carlo analysis and iterative estimation of non-linear specifications.

The program will read Excel and Gnumeric worksheets, BOX1 data (from the Bureau of the Census), comma- and space-separated plain text data files, and RATS 4 databases.

IDIOM

URL: www.camecon.com

The principal current developer of IDIOM is Terry Barker; earlier authors are given in the references below. It is a FORTRAN90 program designed for the specification and solution of large-scale econometric non-linear simulation models incorporating a wide range of relationships, including input-output equations. IDIOM was originally written by the Cambridge Growth Project, Department of Applied Economics, University of Cambridge, the original package being funded by UNIDO to help provide software tools for industrial development. Since 1987, the use and development of IDIOM was taken over by Cambridge Econometrics Ltd, following the closure of the Project in that year. IDIOM has been revised and extended by Cambridge Econometrics as the software platform for a number of econometric models covering economic, energy and environmental models for countries and regions, namely, the UK models MDM-E3 and LEFM, the Europe regional E3 model E3ME, and the global model E3MG. In 1989, IDIOM was re-written for compilation and solution using the Salford FORTRAN compiler FTN77 and the operating system DBOS, so that it could run models unconstrained by the 640k limitations of the IBM-PC-compatible 386 and 486 PCs. In 1997 the software was further developed so that it could be used as part of a user-friendly system for solving models under Windows 95. The latest version uses the Salford compiler FTN95.

The purpose of IDIOM is to provide a means of organizing the historical data, the assumptions and the relationships of large econometric models, including those for inter-relating economies and regions of one economy, then solving the models over a number of periods and finally storing and presenting the results.

Various features of IDIOM are common across the models built and solved using the package (the housekeeping routines) and are described in the model manual. Other features have to be provided by the model builder as specific to the model. Builders of models should prepare a separate manual for model users; and users of the models should consult the appropriate model manual for details of a particular model.

IDIOM differs from other economic model solving packages, such as AREMOS, EViews, MODLER, or TROLL, in two respects. Firstly the organising concept and principle of IDIOM is that of matrix algebra. In this it is more like the GAUSS or Ox packages than MODLER and others. The specification of equations can be in terms of industries or regions or both, so that one line of commands can replace many lines required by a package organised around scalar variables and equations for each such variable. This is particularly useful for cross-section, time-series econometric modelling involving large datasets. Secondly, IDIOM does not provide facilities for estimating equations or managing associated databanks. These tasks must be done using the MREG software package or the Ox applications developed by Cambridge Econometrics.

The main benefits from such specialisation are time-saving in computer calculations and ease of managing large models by organising solutions about matrix variables. IDIOM can solve and store large-scale E3 models (e.g. involving about 10,000 estimated equations and over a million variables) taking a few seconds for each year of solution on a year on a PC with Pentium 3, 1Ghz processor and 192 MB RAM. IDIOM operates by interpreting directives from the model-builder defining the specification of the model required and the computations to be performed. Since these directives are interpreted rather than compiled, substantial changes in the model structure can be made without knowledge of the internal program structure. In addition, the provision of facilities for the conditional or repeated execution of directives provides the model-builder with much of the control over the models normally obtained by writing in a conventional high-level computer language.

T. Barker, W. Peterson and A. Winters (1984), An international dynamic input-output model, *Proceedings of the Seventh International Conference on Input-Output Techniques*, UNIDO, ed., United Nations, New York, pp. 183–192.

Cambridge Econometrics (2002), *IDIOM User's Manual*, at www.camecon.com.

W. Peterson (1987), Computer software for a large econometric model, in: *The Cambridge Multisectoral Dynamic Model of the British Economy*, T. Barker and W. Peterson, eds, Cambridge University Press.

LIMDEP

URL: www.limdep.com

The author of LIMDEP is William H. Greene. Development of the program began in 1974 on a Univac 1108 at the University of Wisconsin, based upon a Fortran implementation of Nerlove and Press's multinomial logit model (1973). Development of what ultimately became program modules continued at Cornell University in 1976–1980, primarily the probit, tobit, and sample selection model estimators. Wide usage began in 1981 after it was ported to a VAX at New York University, where the parts were integrated and gathered under a common interface and distribution to other mainframe installations began. In 1986 LIMDEP was converted for use on the PC. In 1997, it was converted to Windows. The Windows version is a mixed language package, with roughly equal amounts of Fortran and C++ code and heavy implementation of the API in the Microsoft Foundation Class library in C++. The numeric code includes low level implementation of most algorithms and methods as well as integration of numerous IMSL routines.

The first version of LIMDEP was created to implement Ray Fair's (1977) EM algorithm for the tobit model, hence the name LIM(ited) DEP(endent) variable modeling. An obvious extension was to incorporate truncation and discrete choice (probit, ordered probit, logit) models. The second major extension was to Heckman's sample selection model in 1980; see Heckman (1979) and Greene (1980). The third major development was estimators for McFadden's conditional logit model, and a very early limited information maximum likelihood estimator for the nested logit model. Subsequent development has included the automation of a large number of related limited and discrete dependent variable models, as well as a constellation of nonlinear econometric techniques such as survival, count, and other types of applications. The most recent developments have extended many models for use with panel data, the present primary focus of the package, as well as the estimation of stochastic frontier models. LIMDEP and Tim Coelli's FRONTIER are unique in containing any variety of estimators for this model. LIMDEP is currently an integrated program for the estimation of linear and nonlinear single equations model, using any of three types of data: cross section, time series and panel. LIMDEP provides a wealth of estimators. The discrete choice (multinomial logit and probit) estimation component was embodied in NLOGIT in 1995 and in 2002 (with version 8.0 of LIMDEP) NLOGIT was made available as a separate package and is described elsewhere in this compendium.

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W.H. Greene (2003), *Econometric Analysis*, 5th Ed., Prentice-Hall, Englewood.

J. Heckman (1979), Sample Selection Bias as a Specification Error, *Econometrica* **47**, 153–161.

M. Nerlove and S. Press (1973), *Univariate and Multivariate Log-Linear and Logistic Models*, RAND – R1306-EDA/NIH, Santa Monica.

MICROFIT

The authors of MicroFit are Hashem and Bahram Pesaran. Originally called DataFit, as a program for the microcomputer, MicroFit was originally implemented under DOS in 1986. It was converted to Windows in 1999.

MicroFit is an interactive econometric software package designed specifically for the econometric modeling of time series data. It incorporates some data file management capabilities and graphics display facilities, but primary focuses on providing a range of parameter estimation techniques for estimation, hypothesis testing, and forecasting under a variety of univariate and multivariate model specification. It provides a large variety of diagnostic and non-nested specification tests, based upon the work of L.G. Godfrey, Hashem Pesaran and others.

MicroFit accepts ASCII, binary data files, Excel worksheets, and other data files with a variety of formats, including CSV, PRN, and TSD. Data can be exported in CSV and TSD formats.

L.G. Godfrey (1988), *Misspecification Tests in Econometrics. The Lagrange Multiplier Principle and Other Approaches*, Cambridge University Press, Cambridge.

L.G. Godfrey, ed. (1992), *The Implementation and Constructive Use of Misspecification Tests in Econometrics*, Manchester University Press, Manchester.

M.H. Pesaran and L.J. Slater (1980), *Drynamic Regression. Theory and Algorithms*, Elim Horwood, Chichester.

M.H. Pesaran and B. Pesaran, *Working with MicroFit 4.0*, Oxford University Press, Oxford.

Modeleasy+

URL: www.modeleasy.com

The program was originally written in Fortran IV at the U.S. Federal Reserve Board of Governors (FRB), Washington, D.C., under the direction of Jim Condie.

The first release of Modeleasy was in the mid-1970's on an IBM 360 system located at the FRB. The Bank of Italy also had a copy on an IBM 360 system. The program has since been further developed and expanded by Giuseppe Bruno, Andrea Cividini, and William Teeters. Today, the principle authors of Modeleasy+ are the staffs of the Research Department of the Bank of Italy and Econometric Modeling & Computing Corporation (EMCC). A substantial rewrite of the code during the mid-1990's allowed a port of the program (renamed Modeleasy+) to other systems; its first general release was in 1997. The program is written in Fortran 95 and runs mainly on AIX, Solaris, Linux, and Windows platforms.

The initial purpose of Modeleasy was to allow users easy access to estimation and simulation tools. Modeleasy+ is today an econometric computing environment incorporating array, matrix, and time series manipulation capabilities as well as graphical and reporting tools. User written programs, subroutines and functions are supported. The command-line/GUI interface allows users access to a wide variety of econometric analysis tools. Interfaces to databases such as FAME are supported. Models written in a model description language can be estimated and simulated with simple commands. Tools for VAR analysis, coefficient sensitivity analysis, and computation of elasticities and multipliers are included.

Econometric Modeling & Computing Corporation (2003) *The Modeleasy+ Reference Manual*, Palm Harbor, FL.

Econometric Modeling & Computing Corporation (2003) *The Speakeasy Reference Manual*, Palm Harbor, FL.

C. Bianchi, G. Bruno and A. Cividini (1992), Analysis of Large-Scale Econometric Models Using Supercomputer Techniques, *Computer Science in Economics and Management* **5**, 271–281.

G. Bodo, G. Bruno, G. Parigi and S. Siviero (1994), Diagnostic Checking of Large-Size Econometric Models: an application to the Models of the Bank of Italy, *Economic Notes by Monte dei Paschi di Siena* **23**(1), 26–52.

MODLER

URL: www.modler.com

The principal author of MODLER is Charles G. Renfro; co-authors are identified in the references below. MODLER began to be developed in 1968/69 on an IBM 7040, to support the estimation of a version of the Brookings Quarterly Econometric Model of the United States. In 1969–1970 it was ported to a Digital Equipment Corporation PDP-10, and there first developed as an interactive, network-resident program. During the period 1970-1981, it was mounted on a series of IBM mainframe computers, in certain cases providing the core networked facilities of a publicly-available, time-sharing economic data base and econometric modeling system.

Beginning in October 1981, MODLER was ported to the IBM PC. It was first released in October 1983 as a DOS-based program (Dun & Bradstreet Corporation being the first licensee), versions of which still operate: the oldest version still in daily use dates to 1987 and runs as a DOS application under Windows. In September 1984, PC-Mark7/MODLER, incorporating a 250+ equation Wharton Quarterly Econometric Model of the United States, was inaugurated by Wharton Econometric Forecasting Associates as the central element of the first microcomputer-based forecasting service. In early 1985, the full 600+ equation Wharton Mark7 model was both estimated and solved in MODLER. Beginning in 1985, the Economist Workstation, developed jointly with Data Resources, Inc, was created with MODLER as its core software. Other companies that have made their models available to their clients in MODLER include Chase Econometrics, Merrill Lynch Economics and UBS bank, among many consulting companies and organizations worldwide. In 1996, the first Windows version was released. Significantly, the current Windows version of MODLER is sufficiently backwardly-compatible functionally that data banks and models from 1984 can still be used; customarily, as each new Intel processor is released, PC-Mark7 – first solved on the original PC – is once again solved with the latest MODLER version: a 12-quarter solution that took approximately 4 minutes on the original PC takes less than 1 second on a 2-gigahertz Pentium IV or later machine. A Unix version was also developed during the 1980s for a Pyramid super-mini computer, originally for Townsend-Greenspan & Company.

MODLER is designed as a comprehensive time series economic data base management and econometric modeling package that permits its users to construct, maintain, and solve essentially structural econometric models, generally ranging in size from 1 to 1000 equations, although models of as much as 3000 equations have been solved with it. These models can be linear or nonlinear, dynamic or static, and simultaneous or recursive. Input-output structures and various types of objective functions can also be embedded. MODLER's estimation facilities are characteristically those normally used to estimate equations of a large-scale macroeconometric model. Its model construction and solution facilities are similarly oriented, including those that aid in the evaluation and debugging of a model during its construction. The presentation facilities are extensive and can be closely integrated with Microsoft Office and other such combination suites. MODLER can be tightly connected to the Internet via a standard browser.

The program reads TSD, PRT, XLS, and WKx files, as well as a (configurable) range of ASCII text files. It writes TSD, PRT, and XLS files. Historically, links have been made by MODLER users to virtually all the major economic data vendors of the past 20 years, as well as to data formats supported by organizations such as the European Commission, the IMF, OECD, the UN, and the World Bank, as well as European and North American government statistical agencies.

A. Drud (1983), A survey of model representations and simulation algorithms in some existing modeling systems, *Journal of Economic Dynamics & Control* **5**, 5–35.

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C.G. Renfro (1970), *An Interactive Regression Program for the PDP-10, Description and User Manual*, Brookings Quarterly Model Project, Brookings Institution, Washington, DC.
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MODLER BLUE

URL: www.modler.com

MODLER BLUE was originally created in 1986 as a separate DOS PC application by Charles G. Renfro and Paul A. Coomes. It is a MODLER "spin off" and its creation reflected the RAM space constraints then existing under DOS, which made it difficult to progressively add facilities to a program without either exceeding the 640 KB RAM limit, or using program overlays. Functionally, MODLER BLUE makes available the subset of MODLER facilities related to parameter estimation and model construction, including all the data bank maintenance facilities and the capability to create models of up to 1000 equations, but excludes the model compilation and solution routines, as well as certain model-related table display facilities. In their stead, MODLER BLUE provides support for system estimators, in particular Seeming Unrelated Regression Equations (SURE), Three Stage Least Squares, and related variants, implementing these in such a way as to maximize the number of simultaneously estimated equations and parameters. The reference below (Renfro, 1997) considers in detail the whys and wherefores of the development of MODLER BLUE and its characteristics. The first Windows version was released in 1996, although the DOS version also continues to be used and, to some degree, supported.

C.G. Renfro (1997), Normative considerations in the development of a software package for econometric estimation, *Journal of Economic and Social Measurement* **23**, 315–368, [Paper originally presented at the *Society for Computational Economics Third International Conference on Computing in Economics and Finance, Stanford University*, 30 June-2 July 1997.]

MOSAIC

URL: www.informetrica.com

MOSAIC is a direct decendant of the DATABANK system first created by Michael McCracken on a CDC 1604 at Southern Methodist University in 1964–1965, and then transferred to the Economic Council of Canada. The MASSAGER component was added in 1968 and the SIMSYS component in 1970/71. In an evolutionary process, MOSAIC was developed by Michael McCracken and Keith May at Informetrica from DATABANK/MASSAGER/SIMSYS, beginning in the late 1970s, and as MOSAIC/SIMSYS was field tested by using it for the construction of Informetrica's first macroeconometric model in 1978. MOSAIC was publicly released in 1979 through several IBM OS/360 service bureaus. It was subsequently ported to VAX/VMS in 1984 and to the IBM PC in 2002.

MOSAIC is designed to support the development, use and maintenance of large econometric models, ranging in size to more than 10,000 equations and with the added capability to embed Input-Output and other types of submodels. Its facilities include those for data base management, parameter estimation, model construction and use, and presentation quality report generation. Using a command interface, it can be operated interactively or in batch mode. The modeling language of MOSAIC is effectively a superset of Fortran, which allows users to integrate arbitrary modules/code. Equations are translated into Fortran and thus models run "natively." The Informetrica T1 model of over 10,000 equations, and with an embedded I-O module runs a 25 year annual solution on a 1 GHz PC in under 10 seconds.

Issues arising from model size include equation coding errors, run-time performance, and the analysis of solution results. Coding errors are addressed through an algebraic coding language and an explicit solution mode to verify that model equations replicate estimation results and database identities. Model solutions are analyzed and models debugged using an interactive solutions browser. Solutions can be viewed and compared, results traced through equations via cross-references. "Impact" lists can be generated to display "significant" differences.

The PC version permits the creation of a DLL containing the model, using a standard interface for model control. This permits management and control of models using third party software, such as VBA in Excel. The Informetrica T1 model has been integrated with the Canadian version of the NEMS energy model being developed at Natural Resources Canadian in this way. MOSAIC/SIMSYS functionality is being exposed through the use of Microsoft's Component Object Model (COM). COM objects are well suited for use in Visual Basic/VBA applications.

NLOGIT

URL: www.nlogit.com

The primary author of NLOGIT is William H. Greene. David Hensher and Kenneth Train have also participated in the development of the package. NLOGIT is an extension (superset) of the LIMDEP package described elswhere in this compendium. The specific content of NLOGIT is a collection of estimators and analysis tools for discrete choice models such as McFadden's conditional logit (multinomial logit) model and the multinomial probit model. Prior to the release of Version 8.0 of LIMDEP in 2002, NLOGIT was one of the model commands in LIMDEP. (Please see the description of LIMDEP for technical details on the program's development.)

The first module in what ultimately became LIMDEP was a Fortran program for estimating Nerlove and Press's (1973) multinomial logit model. The more familiar form pioneered by McFadden (1973) was added to LIMDEP soon after the package was integrated in 1983. A limited information (two step) estimator for a two level nested logit model, with correction for the asymptotic covariance matrix along the lines of Murphy and Topel (1985) was added in 1986. Various minor extensions of this model constituted this part of LIMDEP until 1992-1994 when a major development effort began for full information maximum likelihood estimation of the nested logit model. The multinomial probit model, and several other variants were also added to the package at this time. NLOGIT took form at this time as a distinct package of routines within the LIMDEP program. Version 7.0 of LIMDEP was released in 1997, with these new developments embedded in the package as the NLOGIT extension. NLOGIT as an option was marketed with Version 7.0 of LIMDEP. Concurrent with the development of Version 8.0 of LIMDEP, a number of major extensions to NLOGIT were produced, including a latent class model, an implementation of the mixed logit (random parameters) model and various devices for simulation of discrete choice models. NLOGIT Version 3.0 (which includes all of LIMDEP as well as the suite of discrete choice models) was released in 2002 concurrently with the release of LIMDEP Version 8.0. NLOGIT is now marketed as a separate product by Econometric Software, Inc.

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K. Murphy and R. Topel (1985), Estimation and Inference in Two Step Econometric Models, *Journal of Business and Economic Statistics* **3**, 370–379.

M. Nerlove and S. Press (1973), *Univariate and Multivariate Log-Linear and Logistic Models*, RAND – R1306-EDA/NIH, Santa Monica.

PcGets

URL: www.pcgive.com/pcgets and www.oxmetrics.net

PcGets is an automatic econometric model selection program written by David F. Hendry and Hans-Martin Krolzig that combines the user friendliness, powerful graphics and flexible data management of GiveWin with the latest methods for model selection, presently in a regression context. PcGets is an Ox Package (see Doornik, 2001), and is part of the OxMetrics family, so is a fully-interactive and menu-driven program as described in Hendry and Krolzig (2001).

An initial general model – designed to embed all the relevant information – is first tested for congruence with the evidence. The theory of reduction delineates what information losses accrue during simplifications, and how they can be evaluated empirically: see Hendry (1995). Then by implementing a general-to-specific (Gets) approach to econometric modelling, PcGets automatically selects an undominated, congruent model even though the precise formulation of the econometric relationship is not known a priori. PcGets currently focuses on linear, dynamic, regression models, so can also be applied to equations within (e.g.) vector autoregressive representations (VARs), or cross-section models.

Following Hoover and Perez (1999), PcGets adopts a multi-path search strategy, exploring the consequences of all initially feasible paths, and collecting the 'terminal' models resulting from each search. If many 'terminal' models are found, these are tested for parsimoniously encompassing their union, namely the smallest model that nests all the contenders. Multi-path searches re-commence from the latest union as needed, until either a unique congruent 'final' model emerges, or no further elimination is possible, in which case, model selection is made using an information criterion.

Monte Carlo experiments demonstrate that PcGets recovers the correct specification from a general model with size and power close to commencing from the data-generating process (DGP) itself. Moreover, the reported standard errors provide essentially unbiased estimates of the uncertainty from estimating the DGP parameters; and bias-corrected parameter estimates can be obtained despite having selected the model from the data: see Hendry (2000), Hendry and Krolzig (2003a,b), Krolzig (2000), and Krolzig and Hendry (2001).

J.A. Doornik (2001), *Object-Oriented Matrix Programming using Ox*, 4th Ed., Timberlake Consultants Press, London.

D.F. Hendry (1995), *Dynamic Econometrics*, Oxford University Press, Oxford.

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PcGive

URL: www.pcgive.com and www.oxmetrics.net

PcGive is an interactive econometric modelling package, emphasizing ease-of-use and extensive graphics to complement the statistical diagnostic procedures. PcGive provides advanced econometric techniques, from least-squares and instrumental variables single equation methods, for linear and non-linear specifications; system cointegration with any form of restriction; volatility models (GARCH, EGARCH and many variations of these models); static and dynamic panel-data models; time-series models such as ARFIMA(p,d,q); discrete choice and count-data models; and X-12-ARIMA for seasonal adjustment and ARIMA modelling. The focus, however, is more on modelling than estimation, so many evaluation procedures are also implemented, including recursive graphics.

PcGive is distributed with 4 books: Doornik and Hendry (2001a,b,c) and Hendry and Doornik (2001). The econometric volumes can be used as stand-alone textbooks, as well as providing a comprehensive reference for the PcGive system.

PcGive, as it is now called, began life in the late 1960s as a mainframe FORTRAN package, on punched cards, with complex job control commands that took some expertise to master (Hendry, 1970, 1974). The original aim was simply to make available the latest econometric estimators and tests: the rest, specifically how to apply such methods, was up to users. However, the ever-increasing demand for the suite led to a major effort to document and explain it, leading to the analysis of the role of computer software in implementing implicit methodologies in Hendry and Srba (1980).

The mainframe FORTRAN version was ported to the PC in 1983–1984, just after Hendry had moved to Nuffield College, University of Oxford. The first PC-GIVE release, version 2 in 1984, had only character-based plots, but was followed a year later by the next release with graphics and menus with defaults and colours. This was highly limited by the available hardware. The PC vintages of the program explicitly acknowledged the formal methodology of econometric modelling: see Hendry (1986, 1988). Version 6.01 (Hendry, 1989) was the last of the FORTRAN generation; up to that point development of PC-GIVE had been done largely by David Hendry, with assistance from Frank Srba and Adrian Neale.

In 1990, Jurgen Doornik started rewriting PcGive in C, resulting in a first release of version 7 (Doornik and Hendry, 1992). Also, the program was renamed from PC-GIVE to PcGive. Because the methodological innovations were starting to become mainstream, and adopted by other software packages, the rigid enforcement of the modelling methodology was dropped. With version 8, in 1994, PcFiml was finally translated into C. Version 7 and 8 had an MS-DOS based windowing system. This did not allow for text and graphics to be shown simultaneously on screen. Next, the Windows development was started, and the assembly graphics library, written by Doornik, could be dropped.

Starting from version 9 (1996), the front-end of PcGive was separated into a stand-alone 'desk-top' for econometric modules, called GiveWin. This front-end for graphics, text and data is now used by many modules, collectively denoted by 'OxMetrics'. Version 10 (2001) saw yet another rewrite of PcGive, this time in Ox, extended by some left-over C code via a dynamic link library. Versions 9 and 10 use the Microsoft Foundation Class (a C++ library) for the graphical user interface.

J.A. Doornik and D.F. Hendry (1992), *PcGive 7: An Interactive Econometric Modelling System*, Institute of Economics and Statistics, University of Oxford, Oxford.

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J.A. Doornik and D.F. Hendry (2001b), *Modelling Dynamic Systems using PcGive: Volume II*, 2nd Ed., Timberlake Consultants Press, London.

J.A. Doornik and D.F. Hendry (2001c), *Econometric Modelling using PcGive: Volume III*, Timberlake Consultants Press, London.

D.F. Hendry (1970), *The estimation of economic models with autoregressive errors*, Unpublished Ph.D. thesis, London University.

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D.F. Hendry and J.A. Doornik (2001), *Empirical Econometric Modelling using PcGive: Volume I*, 3rd Ed., Timberlake Consultants Press, London.

D.F. Hendry and F. Srba (1980), AUTOREG: A computer program library for dynamic econometric models with autoregressive errors, *Journal of Econometrics* **12**, 85–102.

PcNaive

URL: www.oxmetrics.net

The authors of PcNaive are Jurgen A. Doornik and David F. Hendry. Versions of the software have been in use since mainframe days (see Hendry and Harrison, 1974) and the first menu-driven version dates to 1990 (Hendry, Neale and Ericsson, 1991). The present release appeared in 2001.

PcNaive is an interactive menu-driven Monte Carlo program, operating under Windows, for simulating on artificial data the range of estimators, tests, and modelling methods provided in PcGive for econometric modelling. Such experiments allow the finite-sample properties of these econometric methods to be evaluated in relevant settings. PcNaive formulates experiments in a design menu, then writes Ox code, which is executed by OxRun. Particular features of the program are its ease in designing complicated Monte Carlo experiments, and its focus on recursive methods, supported by powerful graphics through GiveWin. Screen editors make experimental design simple yet flexible for experiments involving linear stochastic dynamic systems: a vast range of correct and mis-specified models can be investigated, for both stationary and non-stationary data processes. The output includes live automatic graphing of recursive estimates and distributions. Ox code from PcNaive also can be edited prior to implementation.

The general artificial data generation process (DGP) covers a wide range of dynamic processes, density functions, and other data features of relevance to empirical econometrics. The baseline DGP is a multi-equation, stochastic, dynamic, linear, simultaneous system, allowing between- and within-equation contemporaneous and lagged feedbacks; constants; trends; unit roots, where sets of variables may or may not be cointegrated; structural breaks in conditional or marginal processes; scalar or vector autoregressive-moving average errors; autoregressive conditional heteroscedasticity; measurement errors; and many different forms of error (or data) distributions. Many model formulations and statistics of interest are available to study the consequences of mis-specifications, changes in data properties, and alternative estimators and tests.

J.A. Doornik and D.F. Hendry (2001), *Interactive Monte Carlo Experimentation in Econometrics using PcNaive*, Timberlake Consultants Press, London.

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D.F. Hendry and F. Srba (1980), AUTOREG: A computer program library for dynamic econometric models with autoregressive errors, *Journal of Econometrics* **12**, 85–102.

RATS

URL: www.estima.com

The principal author of RATS is Tom Doan. The program began as an extension of the program SPECTRE written by Christopher Sims, initially at the University of Minnesota and the Federal Reserve Bank of Minneapolis in 1979. It was written in FORTRAN for a CDC. In 1979–1980, it was ported to a VM-CMS machine at Harvard and a Prime minicomputer at MIT. In 1980, the company VAR Econometrics was formed to market the program more broadly, and it was ported to many mainframe and minicomputer platforms during the next four years. The initial PC release was in 1984. It was made available for the Macintosh in 1989, and the first Windows release was in 1995. The programming language was switched from FORTRAN to C in 1991. It is available today for Windows, Macintosh, DOS, and (in a non-GUI form) for UNIX.

RATS is largely a command-driven program with some interactive features for the GUI platforms. Its econometric emphasis is on time series, including VAR's, ARIMA models and spectral analysis. One of its strong points is a very extensive programming language which includes not only loops, procedures and matrix calculations, but user-programmable interactive features such as menus and dialog boxes. This allows the development of very complex menu and dialog-driven procedures within the RATS language, such as CATS, a co-integration program written by Katarina Juselius, Henrik Hansen and Soren Johansen from the University of Copenhagen.

RATS can handle its own native format and in addition TSD, Excel, WKS, DBF, DIF, and data describable using Fortran formats. It can also link to both FAME and Haver Analytics.

REG-X

URL: www.ms.ic.ac.uk/sghall/

The principal author of REG-X is Stephen G. Hall. It was first developed in the late 1970s at the National Institute of Economic and Social Research in London as a direct clone of David Hendry's Give, which was not widely available at the time. The program was originally developed using FORTRAN on a Tandy microcomputer. Early development continued on a small minicomputer, which ran 6 terminals and had 20 MB of hard disk space. In this context, the program was run using card image files. With the introduction of the PC in the early 1980s, REG-X was converted to the PC again running from card image files. As PC's came in during the early 80's a proper interactive version was developed and it began extending well away from the basic GIVE structure. It is freely available for download from the above website.

REG-X is a general econometric estimation package. Extensions from the original basic GIVE structure include Kalman filter options for stochastic trend models and time varying parameter estimation, GARCH estimation, a general Kalman filter option for state space modelling and various other specialized options. In the second half of the 80's, cointegration techniques were added. In particular it was the first software available to apply the Johansen reduced rank regression (Hall, 1989)

S.G. Hall (1989), *Maximum Likelihood Estimation of Cointegrating Vectors: An Example of the Johansen Procedure*, Oxford Bulletin of Economics and Statistics.

SHAZAM

URL: www.econometrics.com

The principal authors are Ken White, Diana Whistler, David Bates, and Donna Wong. SHAZAM is a comprehensive computer program for econometrics and is available for Windows, DOS, Unix, and Macintosh operating systems. The primary strength of SHAZAM is for the estimation and testing of many types of regression models. The SHAZAM command language has great flexibility and provides capabilities for programming procedures. SHAZAM has an interface to the GNUPLOT package for high quality graphics.

SHAZAM includes features for:

- data transformations, handling missing observations, matrix manipulation, evaluation of derivatives and integrals, data sorting, computation of cumulative distribution functions for a variety of probability distributions;
- descriptive statistics, calculation of price indexes, moving averages, exponential smoothing, seasonal adjustment, financial time series, ARIMA (Box-Jenkins) time series models, Dickey-Fuller and Phillips-Perron unit root tests, tests for cointegration, nonparametric density estimation;
- OLS estimation, restricted least squares, weighted least squares, ridge regression, distributed lag models, generalized least squares, estimation with autoregressive or moving average errors, estimation with heteroskedastic errors, ARCH and GARCH models, Box-Cox regressions, probit models, logit models, tobit models, estimation using regression quantiles (including MAD estimation), regression with non-normal errors (including exponential regression, beta regression and poisson regression), regression with time varying coefficients, nonparametric methods, generalized entropy methods, fuzzy set models;

- linear and nonlinear hypothesis testing, calculation of confidence intervals and ellipse plots, computation of the Newey-West autocorrelation consistent covariance matrix, regression diagnostic tests (including tests for heteroskedasticity, CUSUM tests, RESET specification error tests), computation of p-values for many test statistics (including the p-value for the Durbin-Watson test), forecasting;
- nonlinear least squares, estimation of systems of linear and nonlinear equations by SURE, 2SLS and 3SLS, generalized method of moments (GMM) estimation, pooled time-series cross-section methods;
- principal components and factor analysis, principal components regression, linear programming, minimizing and maximizing nonlinear functions, solving nonlinear simultaneous equations.

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SORITEC

URL: www.fisisoft.com

The principal author of SORITEC is John Sneed. Initial development was begun in 1977, for access over the Control Data Corporation CYBERNET time-sharing service. This original version was derived from ANALYZE, written at the University of Minnesota by John Sneed; NSTOK, another system written for the IBM 1130, also by John Sneed; and several public domain versions of TSP, notably the University of Maryland version compiled by Elizabeth Chase MacRae, and the San Francisco Fed version. George Hill was instrumental in the early development of SORITEC, contributing the first version of the databanking facility, which is essentially the same as that supported by the system today. The first release of the system was in early 1979, and in the next four years, SORITEC was implemented on several other time-sharing systems in the US and the UK, including the ICL 2900. It has since been ported to about 35 mainframe, minicomputer and microcomputer systems, including MVS/TSO, CMS, Univac, HP, DEC, DG, Cray, Convex, Burroughs, Honeywell, Sun, Nord, Prime, and most of the Unix workstations available up to the time of release of the IBM PC. The British Treasury was an early user, and SORITEC was used in many UK government departments in the 1980's.

In 1983, SORITEC was released on the PC with all the features of the mainframe product. Starting about 1984, SORITEC was sold by Data Resources, Inc., as its PC econometrics solution while EPS was being converted to the PC. In 1983, the SORITEC SAMPLER was also released on the PC, which made small-scale econometrics a free good for the first time.

In 1995, SORITEC was released with a full Windows interface. Most of its techniques are selectable from point-and-click windows (all techniques are also available from the command line, as before). The principal author of the Windows version is James Streets. SORITEC is currently distributed by Full Information Software, Inc. It is also incorporated into the TESLA electric load forecasting system, sold by TESLA, Inc.

SORITEC combines a large array of estimation techniques with a databanking facility, a report writer, a broad array of statistical commands, time-series estimation/forecasting, an algebraic command language (with integrated matrix algebra expressions), and a large-scale multi-equation simulation facility. The nonlinear estimation routines, including 3SLS, SUR and FIML, were likely the first to effectively utilize advanced Newton's method techniques (secant methods, esp. BFGS), which gave very fast convergence and accurate standard errors for the coefficients. Other methods supported include regression with ARMA errors, exponential smoothing, Shiller and Almon lags with AR corrections, rational distributed lags, logit, probit, and principal components. From the outset, SORITEC combined batch and interactive (command-line) availability with an econometric 4GL. Do loops and procedures can be opened in the interactive version, and closed on a subsequent line even in interactive mode. Procedures and macros can be stored on SORITEC databases.

STAMP

URL: www.stamp-software.com and www.oxmetrics.net

The authors of STAMP are Siem Jan Koopman, Andrew C. Harvey, Jurgen A. Doornik and Neil Shephard. It is a package designed to model and forecast time series, based on structural time series models. These models use advanced techniques, such as Kalman filtering, but are set up so as to be easy to use – at the most basic level all that is required is some appreciation of the concepts of trend, seasonal and irregular. The hard work is done by the program, leaving the user free to concentrate on formulating models, then using them to make forecasts.

Structural time series modelling can be applied to a variety of problems in time series. Macro-economic time series like gross national production, inflation and consumption can be handled effectively, but also financial time series, like interest rates and stock market volatility, can be modeled using STAMP. STAMP is also used for modelling and forecasting time series in medicine, biology, engineering, marketing and in many other areas.

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STATA

URL: www.stata.com

Stata was developed in C and first released in 1985. Originally designed by William Gould, it is now developed by a team of people. Originally implemented as a DOS program, Stata is now available for Windows, Macintosh, and Unix, including Linux on a variety of hardware platforms. The first Unix port was to Interactive 386/ix in 1989 with 32 and 64-bit Unix ports to Sun, HP, DEC, Iris, Convex, and Linux following. Stata was ported to Macintosh in 1992 and to MS Windows in 1994.

Stata was designed as a complete system for data management, graphics, statistics. In 1985 that meant file management facilities, match-merging, variable management, summary statistics, OLS, 2SLS, and graphics, with modern publication-quality graphics added later. By the end of 1986, the first limited dependent variable estimators had been added – logit and probit – along with ANOVA and factor analysis. Limited dependent variables continued to be a focus with multinomial and conditional logit, Heckman selection models for continuous and binary data, choice models, Poisson regression, tobit, zero-inflated inflated count models, bivariate probit, and other models added later. Some of the first commercially available survival models, including Cox proportional hazards and parametric models, were implemented in 1988. Survival analysis expanded to include many nonparametric methods, more parametric families, individual and group frailty (random effects), censoring, and truncation. During 1991 and 1992 bootstrapping was introduced along with quantile regression, and proper treatment of survey sampling weights. Later developments added stratification and clustering and extended survey coverage to most estimators, including survival analysis and limited dependent variables. Additions in 1993 and 1994 included maximum-likelihood estimation of user-programmed likelihoods, nonlinear least squares, linear constraints, matrix programming facilities, generalized linear models (GLM), and importantly fixed- and random-effects estimators for linear panel-data models. Panel-data methods expanded to include Generalized Estimating Equations (GEE), Hausman-Taylor, random-effects frontier models, fixed- and random-effects with endogenous regressors or autocorrelated disturbances, fixed- and random-effects binary and count-data models, random-effects interval regression (including tobit), and the Arellano-Bond estimator for dynamic panel data. Recently time-series features were expanded to include time-series operators, ARIMA and ARMAX, GARCH (with many variants), a complete toolkit for estimating and analyzing VARS and SVARS and their IRFs, several smoothers, and a host of tests. Other features recently added include nested logit, marginal effects and elasticities for virtually all models, and HAC variance estimates for many models.

Possibly the most important addition occurred in April 1986 when programming features were expanded to include the ability for users to add new commands whose syntax and behavior appeared as though they were inbuilt commands. This spurred formation of an active community of Stata users and contributors who have extended Stata's capabilities by writing and sharing program files. To provide a forum for sharing programs, the Stata Technical Bulletin (STB) began publication in April 1991. The Bulletin later transformed into the Stata Journal, a refereed quarterly publication "about statistics, data analysis, teaching methods, and the use of Stata's language." In the Fall of 1994 an independent mail list, Statalist, began operation out of Harvard and has since grown to over 1,500 users who share Stata and statistics questions, answers and programs through the list. The "open system" capability was further enhanced in the Fall of 1998 when Stata became web aware, meaning it could locate, download, and install user written commands or datasets from either shared program archives or individual author websites.

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TROLL

URL: www.intex.com/troll (*in Europe: www.hendyplan.com*)

TROLL (Timeshared Reactive OnLine Laboratory) exists in two versions: Mainframe and Portable. Development of Mainframe TROLL began at MIT in 1966 under the guidance of Edwin Kuh, with Mark Eisner as principle designer; the first version was finished in 1971. The system was written in AED, with portions in assembler language and FORTRAN. It was designed as an interactive system with an algebraic modeling language, free-format English-like commands with prompts, online help, email, and a hierarchical filesystem for online storage of numeric data (timeseries, constants, vectors), models, and "macro" programs. Symbolic differentiation improved performance on nonlinear problems. In 1971, TROLL was running on an IBM System 360 Model 67 under CP-67 (precursor to VM); address space was 24-bit (16 MB), and a typical user allocation was 440K. TROLL ran on many generations of IBM mainframes, and in the mid-1970's Mark Gelfand ported it to other mainframe operating systems such as CMS (under VM), MVS/TSO and MTS. TROLL was hosted by the National Bureau of Economic Research from 1972 through 1977, at which point it returned to MIT. TROLL served as a testbed for new algorithms, including the GREMLIN system-estimation package, the NL2SOL nonlinear least-squares optimizer, Belsley-Kuh-Welsch regression diagnostics, and LIMO eigenanalysis to study the dynamics of simulation models. Large model solution capabilities were provided using Newton-Raphson and sparse-matrix technology.

Peter Hollinger has been chief developer since 1979. In 1987, MIT licensed to Intex Solutions the exclusive right to develop and distribute TROLL. Intex released the final update to Mainframe TROLL, Version 14.1, in 1991. At that time a totally new "Portable" TROLL began to be developed in order to provide the capabilities of Mainframe TROLL in a more flexible package with no size limitations. Portable TROLL is written in 'C' and supports a variety of datatypes (numeric, string, date, boolean) and shapes (scalar, timeseries, multi-dimensional arrays, and timeseries-of-arrays); time dimensions may have calendar-based periodicities such as hourly, daily, business-daily or weekly. It has been ported to: PCs running DOS, OS/2, SCO UNIX, Windows (3.x, 95, 98, ME, NT, 2000, XP) and Linux; Cray X-MP running UNICOS; IBM RS/6000 running AIX; PA-RISC running HP-UX; Sun Sparc running Solaris 1.x and 2.x; and DEC Alpha running Tru64. A GUI front-end is available, developed by Hendyplan.

A particular feature of TROLL is its ability to simulate large macroeconometric models, including forward-looking "rational expectations" models with simultaneity over time; maximum model size ranges upwards of 3000 equations times 200 periods, using a Stacked-Time Newton algorithm. Simulations can be fully simultaneous or equation-by-equation, dynamic, static or periodically constrained. Estimation methods include linear and nonlinear least-squares, distributed lags, ARMA corrections, two-stage least squares, and principle components. TROLL also provides optimization (including user-written functions), and a variety of time series methods (Kalman filtering with maximum likelihood estimation of hyperparameters; estimation, testing and forecasting of cointegrated systems; estimation, testing, and forecasting of VAR systems).

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TSP

URL: www.tspintl.com

TSP's development was begun at MIT in 1965–1966 and at UC Berkeley in 1967–1969 by Robert E. Hall, in association with Robert Gordon, Charles Bischoff, and Richard Sutch, and later at Princeton with Ray Fair and J. Phillip Cooper. The early versions featured essentially linear, single equation techniques, but in the late 1960s nonlinear single equation techniques were added by Hall based upon an analytic derivative algorithm that is still the basis of all the nonlinear estimation in the program. Beginning in 1970, at Harvard and continuing during 1977-1985 in Palo Alto, Bronwyn Hall became the principal developer, assisted by Rebecca Schnake, Sean Becketti, and Clint Cummins. During this period TSP took its present form. Bronwyn Hall added the non-linear estimators for two and three stage least squares, SURE, and FIML. Sean Becketti programmed the Box-Jenkins routines and incorporated the Beech-MacKinnon AR(1) algorithm. Rebecca Schnake created the first interactive version of the program for IBM 370 series computers. Post 1977, TSP was ported to a variety of mainframe and minicomputers, including those of Honeywell, Univac, DEC, ICL, Burroughs, and Siemens. In 1985, TSP began to be ported to the IBM PC. In 1985, Clint Cummins became the principal developer and has been responsible for the incorporation of a wide variety of procedures, including GMM, Probit, Logit, Poisson, Negbin, and the general purpose maximum likelihood routine, MaxLik. Most recently, TSP has been ported to the Apple Macintosh and a native version for MAC OS version X, is expected to be released in June 2003.

TSP is operated using free-format commands and offers all the standard econometric estimation methods, including ordinary least squares, two and three stage least squares, GMM, LIML, FIML, ARIMA, Kalman filter, ARCH and other time series techniques. It also provides a "roll-your-own" maximum likelihood estimator, where the likelihood function can be evaluated either by a single equation or using a user-programmed procedure. It provides variety of diagnostic and testing facilities, including a procedure to test nonlinear hypotheses. Recently TSP has joined the Ox-metrics family of packages, using GiveWin as an interactive Windows shell; in this implementation it can be run either as a traditional batch program or interactively. TSP also incorporates programming features, including support for matrix algebra and user-written procedures, that permit users to use it for the development of new econometric techniques.

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WinSolve

URL: www.econ.surrey.ac.uk/winsolve/

The principal author is Richard G. Pierse. WinSolve arose from a 1994 commission from the UK Economic and Social Research Council to create a modern model solution program to replace existing software such as the author's own NIMODEL. It was written in C++ for the IBM PC although a version for Unix systems also exists.

WinSolve is a model solution package for Windows that accepts models defined in a simple algebraic language. It can read and write data in a wide variety of formats including those of the major econometrics packages. It offers a range of solution methods for both backward-looking and rational-expectations models, including traditional first order methods such as Gauss-Seidel, (stacked-) Newton methods (using automatic analytic derivatives) and other specialised methods such as parameterised expectations. In addition, it offers the facility for the user to define new solution methods using a flexible language. WinSolve has flexible facilities for stochastic simulation and optimal control as well as for model linearisation. Blanchard-Kahn solution methods are also available for linear models.

R.G. Pierse (2000), WinSolve Version 3: An Introductory Guide, available at URL: http://www.econ.surrey.ac.uk/winsolve/.

WYSEA

The author of Wysea is Clifford R. Wymer. Wysea is a set of programs for the estimation, dynamic analysis, forecasting and simulation of difference or differential equation systems. Development began in 1965 at the London School of Economics using the Atlas computer of the UK Atomic Energy Research Establishment, Harwell. This Atlas was one of only three ever built, the other two being installed in the University of London and University of Manchester. The programs were initially written in Hartran (Harwell's version of Fortran, in some ways closer to Fortran 95 than earlier versions) but were later modified to standard Fortran. The programs were installed on an ICL computer which replaced the Atlas, IBM 360, 370, 3090 and VAX computers at a number of universities and other organizations, and other mainframes such as a CDC Cyber of CSIRO, Canberra, and a Burroughs B7800 at the International Monetary Fund. Development on mainframes continued until about 1985 but then was switched to PCs and IBM workstations such as RS6000. The current versions are written in Fujitsu-Lahey Fortran 95 for PC's and IBM Fortran 95 for workstations such as IBM 43P. String handling procedures are written in C and an interface for all programs is in Java; the suite of programs runs on Windows, AIX and Linux platforms.

The aim of the programs throughout was to allow, as directly as possible, the estimation of models derived from economic theory, hypothesis testing within these models, and their use for dynamic analysis, simulation and forecasting. In general, such models will be heavily over-identified. The earliest program, Simul, was developed at the London School of Economics in 1965/66 for 2SLS, 3SLS and FIML estimation of linear difference equation models but with special features to allow estimation of differential equation systems. In 1967/68 Resimul provided FIML estimates of linear models with non-linear within and across equation constraints on the parameters and Discon provided similar estimates for the exact discrete model equivalent to a differential equation system. A feature introduced in Resimul but then used in all programs is an algorithm which allows the true partial derivative (not a numerical approximation) to be calculated from function specifications without the need for symbolic partial differentiation. Subsequent programs such as Contines

(1968) calculated the eigenvalues (with asymptotic standard errors) of discrete or continuous systems systems, together with a sensitivity analysis of the eigenvalues, and Predic for forecasting, again with (dynamic or static) asymptotic standard errors. Programs for the estimation, simulation and forecasting of non-linear difference and differential equation systems (Asimul and Apredic) were developed in 1973/74 and Escona in 1990. The non-linear differential equation programs allow the estimation, simulation or forecasting of models subject to boundary point conditions and, if required, inequality constraints on control variables and thus can handle systems which incorporate targeting, present value, rational expectations, optimal control and game theory specifications.

Throughout development of the programs in Wysea, particular attention has been given to numerical precision within the whole system; thus some algorithms are used for precision rather than speed. Most real number calculations are in real(8) but in order to maintain precision at this level some crucial operations are in real(16). In general, modified second order Newton or Generic algorithms are used for maximisation and this is aided by the partial differentiation procedure mentioned above.

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C.R. Wymer (1996), The role of continuous time disequilibrium models in macro-economics presented at the *SEMECON Conference on Dynamic Disequilibrium Modelling, University of Munich, Germany, 30 August–3 September 1993*; published in: *Dynamic Disequilibrium Modelling*, W.A. Barnett, G. Gandolfo and C. Hillinger, eds, Cambridge University Press, Cambridge, pp. 67–123.

C.R. Wymer (1997), Structural non-linear continuous time models in econometrics, *Macro-Economic Dynamics* **1**, Cambridge University Press, 518–548.

C.R. Wymer, *WYSEA User Guide and Reference.*

3. Econometric programming libraries

The software packages described in this section of the Compendium are essentially library tools that can be used in conjunction with computer programming languages in order to produce an executable econometric software package. They generally require the use of one of the standard programming languages, such as C/C+, Visual Basic, or some other similar development language.

The concept of a "library" of routines actually originates in the 1950s, at the beginning of the era of stored program computers. Those who began programming for the EDSAC, EDVAC, and other early machines of this type at the Universities of Cambridge, Pennsylvania and elsewhere quickly realized that once a certain set of fundamental operations had been programmed that could be utilized as components of some other package, it made sense to document these routines and make them generally available. Originally, such libraries took the form of decks of punched cards, or rolls of paper tape, but as online storage facilities came into being, these collections of standard routines, "libraries" that is, began to be made available online at individual computing centers. Over time, many have become generally distributed and widely used and a number are quite well known to programmers generally, as described in the papers by Nerlove and Stokes in this volume.

The libraries described here are of course specifically econometric in orientation and, if anything, represent a new development in econometric software. In past years, program libraries were "statically" linked, indicating that the included routines were linked into, or combined with, an overall program at the time of its original production. Today, in the context of Windows and other operating systems, "dynamic" linking has become common: routines that are dynamically linked are linked with a given program at the time that one or more users actually execute that program. Among the implications of this process is that a modern computer could have a number of dynamically linkable routines available, ready for selection at a moment's notice. Such routines could perform standard operations, or operations that might be performed only occasionally.

BACC

URL: www.cirano.qc.ca/bacc

The principal authors of BACC (Bayesian Analysis, Computation, and Communication) are John Geweke and William McCausland. A continuing goal of the BACC project is to make tools for Bayesian econometrics as accessible to practitioners as are tools for classical econometrics. BACC orginated in 1996 as stand-alone software for Unix and DOS, developed by John Geweke and Siddharta Chib. Users executed commands for posterior simulation and related tasks at the Unix or DOS command line. These commands operated on special input and control files provided by the user, and generated output files, including posterior simulation files. By 1998, BACC supported univariate regression (where residuals are normal, autoregressive or finite mixtures of normals), seemingly unrelated regressions, probit regression and finite state Markov chains. In 1999, BACC was reworked as a dynamically linked (or shared object) library, enabling the use of the software within Gauss for Unix. Since then, BACC has expanded its support to several new mathematical applications (Matlab, SPlus, and R) and the Windows and Linux operating systems. Several models have been added, and further model development is a priority.

The BACC software provides its users with tools for Bayesian Analysis, Computation and Communications. It implements these tools as extensions to popular mathematical applications such as Matlab, S-PLUS, R, and Gauss, running under Windows, Linux or Unix. From the user's perspective, there is a seamless integration of special-purpose BACC commands for posterior simulation and related tasks with powerful built-in commands for matrix computation, graphics, program ow control, and I/O. Nineteen models are currently available, and many others are planned. BACC is designed to be extendible, not only by the developers of BACC, but also by others who wish to implement their own models and thus make them available to BACC users.

J. Geweke (1999), Using Simulation Methods for Bayesian Econometric Models: Inference, *Development, and Communication, Econometric Reviews* **18**, 1–126.

J. Geweke and W. McCausland (2000), Embedding Bayesian Tools in Mathematical Software, *Proceedings of the International Society for Bayesian Analysis* (*ISBA*)*: 165–173*, 1.

G. Koop (1999), Bayesian Analysis, Computation and Communication Software, *Journal of Applied Econometrics* **14**, 677–689.

W. McCausland (forthcoming) Using the BACC Software for Bayesian Inference, *Journal of Computational Economics* **2**.

MLE++

URL: www.magma.ca/∼cahill/

MLE++ is a C++ class library for maximum likelihood estimation developed by Ian Cahill. To be used it requires a specific C++ compiler. The first version was completed in 1997 for the Borland C++ Builder product, which was supplied with each unit purchased. The library was ported to be compatible with the Microsoft Visual C++ 6.0 compiler in 2001, and the Borland version was discontinued. A new version is currently being developed, and should be released within a year. It will run on Microsoft Visual C++ Net.

MLE++ is designed as a tool for general maximum likelihood estimation, and can be applied to the estimation of many nonlinear models. As a class library it extends the C++ language by providing vectors and matrices as data types, and classes that manage data files and support the use of named variables in estimation routines. To develop a new model estimation routine, the user derives a class from an abstract base called Model. A number of algorithms for maximization without constraints are provided as part of the class Model. These can be called to maximize the log-likelihood function, as specified by a user for a particular model. Algorithms for numerical gradients are also provided, and will be called if the user does not specify the analytical gradients. There are a number of choices for methods to calculate the covariance matrix.

MLE++ also includes 25 packaged nonlinear models used on cross-sectional data. The models are implemented using the general maximum likelihood estimation tools in order to serve a dual purpose: they are practical model estimation routines for popular models, and they are also documented examples showing how to implement new models. The packaged models include binary logit and probit, Tobit models and their generalizations, truncated regression, sample selection, treatment effects, endogenous switching regression, bivariate probit, multinomial logit, conditional logit, poisson regression, Weibull and exponential survival models (including heterogeneity and time-varying covariates), the lognormal survival model, the loglogistic survival model (including time-varying covariates), and Meyer's semiparametric survival model (including time-varying covariates and heterogeneity).

Data can be imported from ASCII files in various forms, and written to an ASCII file with space delimiters.

I.G. Cahill (2001), *MLE++*$^{\mathrm{TM}}$ *Maximum Likelihood Estimation in C++ User's Manual, Version 2.0*, Cahill Software.

I.G. Cahill (2001), *MLE++*$^{\mathrm{TM}}$ *Maximum Likelihood Estimation in C++ With Microsoft Visual C++ 6.0, Version 2.0*, Cahill Software.

B.D. Meyer (1990). Unemployment Insurance and Unemployment Spells, *Econometrica* **58**, 757–782.

MODLER

URL: www.modler.com

MODLER is described in the section on Independent Econometric Software Packages and references are given there. However, in addition to the package itself, related library routines have been made available since the 1980s that permit access to MODLER facilities in the form of callable subroutines and functions. The original set of library routines was written in 1987 in C and Fortran by Len Schmirl, then at Townsend Greenspan and Company, for the purpose of linking other Townsend Greenspan software to MODLER data banks. Subsequently, these routines were collected into libraries that have since been made available generally to MODLER users and others, including Haver Analytics, Data Resources and other data vendors, who have used the Fortran library in particular to create and maintain MODLER data banks that they have distributed. Another example is the use of the Fortran library by economists at United Bank of Switzerland (UBS) in London (then Phillips and Drew) to create small programs, called FITOUT and FITIN, to permit data to be transferred between MODLER and MicroFit. A variety of such applications have been developed during the past 20 years.

This facility was extended in 1996, with the first release of the Windows version of MODLER. By design, most MODLER facilities are contained in a Dynamic Link Library (DLL) that is called from a Visual Basic "front end." As a consequence, these facilities can also be accessed from other Windows programs resident on the same machine – or, in principle, another machine connected via a network. To date, MODLER users who have taken advantage of this capability have tended to make use of it simply to read and write MODLER data banks. In the future, much more could be done.

4. Econometric and mathematical programming languages

The software packages described in this section of the Compendium provide the user with the capability to program mathematical and statistical operations that are econometric in nature. Some of these packages have been created specifically for use by economists and econometricians. Others have a more general application that includes use by economists and econometricians. These programming languages and their use are also described, as a type, in the articles by Herbert, Nerlove, and Stokes elsewhere in this volume.

Econometric programming languages can be used in order to create specific econometric software packages that perform particular operations or types of operations. The next section of this compendium provides a number of examples of such packages, created using the software described in this section. These languages can also be used individually by economists and econometricians to create locally developed packages used only by the author of that package, or perhaps also by colleagues.

In all cases, the packages described in this section are themselves written in a standard programming language (or languages) and operate using a standard computer operating system. Examples of the former are C/C+, FORTRAN, Pascal, and Visual Basic. Examples of the latter are Linux, Windows, and Unix.

GAUSS

URL: www.aptech.com

Lee Edlefsen and Sam Jones designed the GAUSS matrix programming language in the early to mid 1980's. GAUSS became generally available in June 1985. Currently GAUSS is available on Windows, Linux, Solaris, HPUX and AIX. The power of GAUSS can also be added to applications written in C, C++, Java or other development environments that support the C language API through the GAUSS Engine, a dynamically linked library for compiling and executing GAUSS programs from another application. Data can be passed back and forth between the GAUSS Engine workspace and the application.

GAUSS is a full featured matrix programming language with emphasis on statistical and mathematical applications. In addition to the language, Aptech Systems distributes applications written in GAUSS. The most popular applications are MAXLIK (Maximum Likelihood) and CML (Constrained Maximum Likelihood) for the estimation and inference of statistical models.

LINDO/LINGO

URL: www.lindo.com

The principal authors of LINDO/LINGO are Kevin Cunningham and Linus Schrage. LINDO was originally written in FORTRAN for the DEC 20 computer in 1977. When a Fortran compiler became available on the IBM PC in 1982, LINDO was ported to the IBM PC. The extensive matrix and set handling capabilities of LINGO were added in 1987. The latest versions are written in C/C++ and run mainly on Windows, Linux, and Solaris operating systems.

LINGO is essentially a linear, quadratic, integer, and global solver for large scale optimization problems. It consists of a modeling language front end that is sometimes used for solving econometric and statistical problems with nonstandard objectives. These include problems with minimum average absolute deviation regression, maximum absolute regression, and constrained regression. Some special features of LINGO include: a) a recently added global optimization capability that is of particular interest when the criterion is nonconvex in the parameters, for example, as in some maximum likelihood estimation problems; b) a quasi-random number generation feature for generating low discrepancy multi-dimensional uniform random numbers. Many of the features of LINGO are also available in spreadsheet add-in solver called What'sBest. The underlying solver engine is callable directly from programs written in C/C++, Visual Basic, Fortran, Matlab, Delphi/Pascal, Ox, and Java.

L. Schrage (2003), *Optimization Modeling with LINGO*, LINDO Systems Press, Chicago.

OX

URL: www.nuff.ox.ac.uk/Users/Doornik/ and www.oxmetrics.net

Ox is written by Jurgen Doornik. Development of Ox started in April 1994, based on an earlier failed attempt called ECL. The first release was in 1996, when it was available on its own, but also given as a add-on to PcGive. The object-oriented features of Ox were modelled on C++. A major design aim for Ox was to avoid the complexity of C++, see Doornik (2002). As a consequence, several aspects are more like Java and C#, which both did not exist yet at the time (although the Java project had already started).

Ox is an object-oriented matrix programming system. At its core is a powerful matrix language, which is complemented by a comprehensive statistical library. Among the special features of Ox are its speed, well-designed syntax and editor, and graphical facilities. Ox can read and write many data formats, including spreadsheets and GiveWin files; Ox can run many Gauss? programs directly; if necessary, existing C or FORTRAN code can be added to Ox in the form of dynamic link libraries (see, e.g. SsfPack, Koopman, Shephard and Doornik, 1999); there is sufficient flexibility in the Ox system to allow it to be fully integrated in applications requiring an econometric or statistical engine; Ox is available on Windows, Linux, and several Unix platforms.

There are many functions integral to Ox, including numerical optimization (unconstrained, quadratic programming and constrained maximization) and differentiation, solving non-linear equations, probability (density, quantile, cumulative density and random generation of many probability functions), ARMA, econometrics (e.g. VAR and cointegration), and Monte Carlo simulation. Many additional packages are available for downloading. Some of these are comprehensive econometric systems, which can also be used interactively.

Ox comes in two versions: Ox Professional and Ox Console. Ox Professional interfaces with GiveWin for its graphical output, and allows for several packages to be run interactively via GiveWin through the OxPack module. Ox Console lacks the interfaces of GiveWin, and instead is supplied with the freely available OxEdit text-editor. Ox Console is freely available for academic research and teaching.

F. Cribari-Neto and S.G. Zarkos (2003), Econometric and statistical computing using Ox, *Computational Economics* **21**, 277–295.

J.A. Doornik (2001), *Object-Oriented Matrix Programming using Ox*, 4th Ed., Timberlake Consultants Press, London.

J.A. Doornik (2002), Object-oriented programming in econometrics and statistics using Ox: A comparison with C++, Java and C#, in: *Programming Languages and Systems in Computational Economics and Finance*, S.S. Nielsen, ed., Kluwer Academic Publishers, Dordrecht.

J.A. Doornik, D.F. Hendry and N. Shephard (2002), Computationally-intensive econometrics using a distributed matrix-programming language, *Philosophical Transactions of the Royal Society of London* **Series A 360**, 1245–1266.

J.A. Doornik and M. Ooms (2001), *Introduction to Ox*, Timberlake Consultants Press, London.

5. Applications of econometric and mathematical programming languages

The software packages described in this section of the Compendium are each created as applications of and using a high level econometric or mathematical-statistical programming language of the type represented in the previous section of this compendium. Some of the applications packages described here have been created specifically for use by economists and econometricians. Others have a more general application that includes use by economists and econometricians. The programming languages these applications use are Gauss, Mathematica, or Ox.

Because the packages described are themselves written in the proprietary econometric and mathematical programming language of which they are applications, in each case they require either the developers' prior use of one of these programming languages or that the user's computer have a resident copy of one of these languages, or that both of these requirements are met.

ARFIMA package for Ox

URL: www.nuff.ox.ac.uk/Users/Doornik/ and www.oxmetrics.net

The Arfima package, developed by Jurgen Doornik and Marius Ooms, provides an Ox class for estimation and forecasting of ARFIMA(p,d,q) and ARMA(p,q) models. The available estimation methods are exact maximum likelihood (EML), modified profile likelihood (MPL), and nonlinear least squares (NLS). The mean of the process the ARFIMA process can be a (nonlinear) function of regressors. This makes it straightforward to model (nonlinear) deterministic trends and additive outliers. Missing observations can easily be estimated. Regressors can also be used to model the innovations of the process. This allows ARFIMA distributed lag modelling, an extension of autoregressive distributed lag (ARDL) modelling. Innovative outliers can be estimated. A simulation class is also provided.

J.A. Doornik and M. Ooms (1999), *A Package for Estimating, Forecasting and Simulating ARFIMA Models*, Mimeo, Nuffield College, Oxford.

J.A. Doornik and M. Ooms (2003), Computational Aspects of Maximum Likelihood Estimation of Autoregressive Fractionally Integrated Moving Average Models, *Computational Statistics and Data Analysis* **42**, 333–348.

M. Ooms and J.A. Doornik (1999), *Inference and Forecasting for Fractional Autoregressive Integrated Moving Average Models, with an application to US and UK*, inflation Econometric Institute Report EI-9947/A, Erasmus University Rotterdam.

CML – Constrained maximum likelihood

URL: www.aptech.com

CML was developed in 1995 in the GAUSS programming language by Ron Schoenberg at Aptech Systems. It implements the sequential quadratic programming method to solve the maximum likelihood problem with general constraints on parameters, linear and nonlinear equality, and linear and nonlinear inequality (Han, 1977; Jamshidian and Bentler, 1993).

Its features include the calculation of the approximate covariance matrix of the parameters for models with constraints on parameters (Hartmann and Hartwig, 1995), Bayesian weighted likelihood bootstrap (Newton and Raftery, 1994), likelihood profile and profile t trace (Bates and Watts, 1988), bootstrap, confidence limits by inversion of the Wald statistic, and confidence limits by inversion of the likelihood ratio statistic and quasi-maximum likelihood (QML) inference.

D.M. Bates and D.G. Watts (1988), *Nonlinear Regression Analysis and Its Applications*, John Wiley & Sons, New York.

S.P. Han (1977), A globally convergent method for nonlinear programming, *Journal of Optimization Theory and Applications* **22**, 297–309.

W.M. Hartmann and R.E. Hartwig (1995), *Computing the Moore-Penrose Inverse for the Covariance Matrix in Constrained Nonlinear Estimation*, SAS Institute, Inc., Cary, NC.

M. Jamshidian and P.M. Bentler (1993), A modified Newton method for constrained estimation in covariance structure analysis, *Computational Statistics & Data Analysis* **15**, 133–146.

M.A. Newton and A.E. Raftery (1994), Approximate Bayesian inference with the weighted likelihood bootstrap, *J.R. Statist. Soc. B* **56**, 3–48.

DPD for Ox

URL: www.nuff.ox.ac.uk/Users/Doornik/ and www.oxmetrics.net

The DPD (Dynamic Panel Data) package for Ox is developed by Manuel Arellano, Stephen Bond and Jurgen Doornik. DPD98, an earlier GAUSS package by Arellano and Bond, is still available at www.ifs.org.uk/econometindex.shtml .

DPD is for estimating dynamic panel data models, but also implements some of the static panel data estimators. DPD is designed to handle unbalanced panels. DPD is a class written in Ox, and is used by writing small Ox programs which create and use an object of the DPD class. The package can also be used interactively, which requires Ox Professional, together with GiveWin 2.00 or newer.

G@RCH

URL: www.core.ucl.ac.be/∼laurent/ and www.nuff.ox.ac.uk/Users/Doornik/

G@RCH, by Sebastien Laurent and Jean-Philipe Peters, is an Ox package dedicated to the estimation and forecast of various univariate ARCH-type models in the conditional variance and an AR(FI)MA specification in the conditional mean. These ARCH processes include ARCH, GARCH, EGARCH, GJR, APARCH, IGARCH, FIGARCH, FIEGARCH, FIAPARCH and HYGARCH. These models can be estimated by Approximate (Quasi-) Maximum Likelihood under four assumptions:

normal, Student-t, GED or skewed Student-t errors. Moreover, "in-mean" ARCH-type models are available and explanatory variables can enter the mean and/or the variance equations. One-step-ahead (density) forecasts of both the conditional mean and variance are available as well as some miss-specification tests and several graphical features.

Two versions of G@RCH are available. The 'Light' version requires some experience with the program, its structure and the Ox language. The light version is aimed at advanced users, and those who only have access to Ox Console. The 'Full' version provides the same features as the light version, but also offers a user-friendly interface and some graphical features. This version needs to be launched from OxPack, and requires Ox Professional.

S. Laurent and J.P. Peters (2002), G@RCH 2.2: an Ox Package for Estimating and Forecasting Various ARCH Models, *Journal of Economic Surveys* **16**, 447–485.

GaussX

URL: www.econotron.com

The principal author of Gaussx is Jon Breslaw. The program, which began as an extension of TSP, was ported to the newly released matrix programming language Gauss in 1988. The interactive menu component was written first in Gauss, but then replaced with a C interface in 1994. The initial PC release was for DOS, and the first Windows release was in 1994. The programming language has always been open source, written in Gauss. It is currently available for Windows, Unix and Linux.

Gaussx incorporates a full featured set of professional, state of the art, econometric routines that run under Gauss. These tools can be used within Gaussx, both in research and in teaching. Alternatively, since the Gauss source is included, individual econometric routines can be extracted and integrated in stand-alone Gauss programs.

Gaussx is a command file driven program, where a command file is executed, the results displayed, and an output file created. This replicates the classic edit/execute/view sequence. It is an open source program, and thus allows the user to include her own code, written in Gauss, where necessary. The concept is similar to Latex: Latex lets you get stuff done in TEX, without knowing TEX; Gaussx lets you get stuff done in Gauss, without knowing Gauss. Both allow you to use the underlying language, when required. The concept provides a very shallow learning curve to leading edge econometric techniques. Thus, a wide range of estimation techniques, tests and models are available as preprogrammed modules, which can first be used either as is, or adapted and used as a template. The most recent developments include fractionally integrated GARCH, cluster analysis, robust estimation, Bayesian estimation, stochastic volatility model estimation, constrained optimization, trust regions, genetic algorithms, EM estimation, DBDC models, Markov switching models, feasible MNP, Gibbs sampling, wavelet denoising and Census X12 smoothing.

Since the entire Gauss language can be used within the Gaussx command files, the program provides a vehicle for econometricians to have a full range of econometric methods at their disposal, with the potential to customize any part of the program or models. Gaussx is used by academics, students and companies in over 40 countries. It is current (last revision 5.0)., and is distributed by Aptech Systems, Inc., who also distribute Gauss.

J. Breslaw (1991), Gaussx: An Integrated Environment for Gauss, *Computer Science in Economics and Management* **4**, 65–74.

D. Nitzsche (1993), Gaussx, *The Economic Journal* **103**(420), 1342–1345.

R.G. Pierse (1996), Gaussx: Version 3.4, *Journal of Applied Econometrics* **11**(6), 687–693.

J. Breslaw (2003), *Gaussx, Version 5.0*, Aptech Systems, Inc, WA.

mathStatica

URL: www.mathStatica.com

The principal authors of mathStatica are Colin Rose and Murray D. Smith. mathStatica is a software package – and add-on to Mathematica – that provides a sophisticated toolset specially designed for doing mathematical statistics. After more than 6 years in development, version 1.0 was released in March 2002, while version 1.2 was released in April 2003.

mathStatica was designed to solve the algebraic/symbolic problems that are of primary interest in mathematical statistics. It does so by building upon the symbolic computational power of Mathematica to create a sophisticated toolset specially designed for doing mathematical statistics. By contrast, packages like SPSS, Systat, SAS, Gauss, JMP and S-Plus provide a numerical/graphical toolset. They can illustrate, they can simulate, and they can find approximate numerical solutions to numerical problems, but they generally cannot find exact symbolic solutions to statistical problems. Features include: a complete suite of functions for manipulating PDFs, automated expectations, probability, density plotting, automated transformations (functions of RVs), symbolic MLE, numerical MLE, automated Pearson curve fitting, Johnson curve fitting, Gram-Charlier expansions, nonparametric kernel density estimation, moment conversion formulae, component-mix and parameter-mix distributions, stable distributions, copulae, random number generation, asymptotics, sufficient statistics, decision theory, order statistics, Fisher Information, h-statistics, k-statistics, polykays, and much more.

It runs on Mac (Classic and OS X), Windows, Linux, SPARC, Solaris, SGI, IBM RISC, DEC Alpha and HP-UX. It requires Mathematica 4 or later.

B.D. McCullough (December, 2002), A Review of Mathematical Statistics with Mathematica, *Journal of the American Statistical Association*, 1202–1203.

M. Quine (2003), Review: Mathematical Statistics with Mathematica, Economic Record, forthcoming.

C. Rose and M.D. Smith (2002), mathStatica: Mathematical Statistics with Mathematica, in: *COMPSTAT 2002: Proceedings in Computational Statistics*, E. Härdle and B. Rönz, eds, Physica-Verlag, Heidelberg, pp. 437–442.

C. Rose and M.D. Smith (2002), *Mathematical Statistics with Mathematica*, Springer-Verlag, New York.

C. Rose and M.D. Smith (2003), *mathStatica, Proceedings of the American Statistical Association 2002*, Statistical Computing Section.

H.D. Vinod (2003), Review of MATHSTATICA, *Journal of Applied Econometrics* (August), 485–491.

MSVAR

URL: www.economics.ox.ac.uk/research/hendry/krolzig

MSVAR (Markov-Switching Vector Autoregressions) is an Ox package written by Hans-Martin Krolzig. MSVAR is designed for the econometric modelling of univariate and multiple time series subject to shifts in regime. It provides the statistical tools for the maximum likelihood estimation (EM algorithm) and evaluation of Markov-Switching Vector Autoregressions and Markov-Switching Vector Equilibrium Correction models as discussed in Krolzig (1997). A variety of model specifications regarding the type of regime switching (including Treshold models and Switching Regressions), the number of regimes, regime-dependence versus invariance of parameters etc. provides the necessary flexibility for empirical research. MSVAR will be of use to econometricians intending to construct and use models of the business cycle and other regime-switching phenomena.

MSVAR can be used by writing a small Ox program. As MSVAR derives from the Modelbase class, it allows the easy use and exchange with other Ox classes such as PcFiml. In conjunction with Ox professional, MSVAR can be used interactively via the user-friendly interface OxPack in combination with GiveWin 2 for data input and graphical and text output.

M.P. Clements and H.-M. Krolzig (2003), Business Cycle Asymmetries: Characterisation and Testing based on Markov-Switching Autoregressions, *Journal of Business and Economic Statistics* **21**, 196–211.

H.-M. Krolzig (1997), Markov-Switching Vector Autoregressions. Modelling, Statistical Inference and Application to Business Cycle Analysis, *Lecture Notes in Economics and Mathematical Systems* **454**, Springer, Berlin.

Time series modelling 3.2 (TSMod32)

URL: http://www.cf.ac.uk/carbs/econ/davidsonje/

Econometric software should ideally combine ease of use and an intuitive interface, with flexibility and user extendibility – requirements that can appear mutually incompatible. TSMod by James Davidson (earlier versions were known as LMMod for Long Memory Modelling) represents one attempt to get the best of both worlds. While TSMod is an Ox program, it runs as a stand-alone GUI application, started from an icon on the desktop and controlled entirely by menus and dialogs, with Ox running transparently in the background.

The program is platform-independent, running under Windows and Linux. In addition to Ox 3.3 Console, the software components needed are the Java Runtime Environment (JRE) and OxJapi, a port to Ox, by Christine Choirat and Rafaello Seri, of the Java Application Programming Interface due to Merten Joost. Graphics capabilities are supplied by GnuPlot, interfaced with Ox using GnuDraw, an extension of the OxDraw package by Charles Bos. All the required components are freeware, as is TSMod – to academic users.

TSMod32 estimates a range of time series models including ARIMA, ARFIMA, several ARCH/GARCH variants, and Markov-switching models. It offers full graphics capabilities, data manipulation, routine diagnostics, forecasting, and the ability to impose and test parameter restrictions. However, its star feature is the facility to code the equation to be estimated (including general dynamic specifications) as an Ox function. This allows nonlinear time series models such as bilinear, SETAR, ESTAR, etc. etc., to be handled very easily. The programming skills and effort called for are far less than would be required to write a free-standing Ox application from scratch. The user-defined equation can be combined with the built-in model features (e.g., have ARCH residuals, or exhibit Markov switching) to provide almost limitless flexibility in model specification.

Estimators include OLS, GMM, time domain MLE for Gaussian, Student-t and skewed-student disturbances, and Whittle estimation for ARFIMA models. Available formats for data input and output including text files, spreadsheets (.xls and .wks) and GiveWin format (.in7). Formats for graphics output include Postscript (.eps, .epc), bitmaps (.png) and GiveWin format (.gwg). The estimation module can also be run without the Java front end, and called from another Ox program. This provides both a straightforward command line operating mode, if preferred, and the ability to (for example) incorporate the code in Monte Carlo simulations.

TSMod is a new project, still very much under development. Planned extensions include more ARCH variants, VAR models with cointegration and fractional cointegration, bootstrap tests, and more self-coding features including test statistics.

J. Davidson (2003), Moment and memory properties of linear conditional heteroscedasticity models, and a new model, *Journal of Business and Economics Statistics*, forthcoming.

6. No longer supported econometric software programs

The packages described in this section are historically significant, but are now no longer supported. In one case, the package has been absorbed into a sibling package.

In other cases, particularly that of EPS and XSIM, the packages have become victims of the merger and acquisition process.

DAMSEL

The original author of DAMSEL is Douglas Bracy. This software is an extension of the PLANETS software, originally created at the Brookings Institution by Bracy during the period 1968–1971, becoming operational on a Digital Equipment Corporation PDP-10 there in 1971. As DAMSEL, the software was adopted by Wharton Econometric Forecasting Associates in 1974 and implemented on a series of IBM 360/370 computers between then and 1985, when it began to be replaced by AREMOS, although it continued to be used to some degree even as late as 1988 or possibly later.

DAMSEL provided support for the maintenance of Wharton's large scale data bases and general analytic facilities, including in particular parameter estimation and single equation model simulations and forecasts, but stopped short of incorporating multi-equation model solution capabilities, which were provided by the SIMPLE model solution software beginning in the early 1980s, and by Brian Brown's "WEFA Batch Solution Program" and other programs prior to that. During the mid 1970s, on a quarterly basis, the Wharton US quarterly model was made available to WEFA clients in the context of Brown's program. Once mounted on the client's mainframe computer, this software could be used either to replicate the Wharton quarterly model forecasts, or to develop alternative forecasts on the basis of and as extensions of these. In principle, of course, independent forecasts could also have been made, but there is no known instance of this. In the late 1970s, online model building and solution support for client and WEFA models was provided in the form of four programs: USER MODELS, SETUP, SOLUTION and TABLES, used respectively to code, edit and maintain models; create, edit, and maintain solution files; solve models; and to create and print tables.

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EPS

The original principal author and designer of EPS is Robert Lacey, with important design contributions by Robert Hall and Edward Green. It was introduced by Data Resources Inc. (DRI) in 1977–1978 and replaced the EPL software originally developed by Robert Hall during the period 1968–1977, which was in turn based on TSP. By the early 1980s, the responsibility for maintaining and updating EPS became a corporate activity. The original installation was on a Burroughs B6700 and then a B7700. EPS was ported to the IBM mainframe environment in the mid-1980s as EPS/VM. A version for the PC, implemented as a DOS package, became operational in or about 1990. With the merger of the WEFA Group and DRI, to form Global Insight in late 2002 or early 2003, EPS has apparently ceased to be a supported product and is currently in a winding down phase.

A fundamental characteristic of EPS was its design to be used in conjunction with large scale multi-frequency databases, both created by DRI and licensed from other organizations worldwide. During the 1970s, DRI data banks in the aggregate grew to contain literally millions of time series pertaining to a number of national economies, as well as sub-national regions and certain super-national aggregates. EPS began its life as software designed to be used in-house by DRI economists and by DRI clients as a mainframe time-sharing package, accessible from a remote telecommunications terminal; for many years it was used in this form (Renfro, 1980).

Generally characterized by a free-format, if slightly stylized, command language, EPS permits its users to access and query data retrieved from data banks and, beyond that, to select series by mnemonic name in the context of a variety of commands, including both display (PRINT, plotting, table-making) and regression commands. The software supports a wide variety of data transformations, incorporating both arithmetic symbols and an array of implicit functions. It also supports such operations as seasonal adjustment, as well as a number of financial functions and operations.

However, if the general sense of the package from a user's perspective has always been its noticeably user-friendly, command-oriented facility to be used interactively for general analytic work, it is nevertheless true that EPS provides broad support for data base management, parameter estimation, and the construction and use of econometric models, albeit mainly small models. Since the late 1970s/early 1980s, EPS has always generically included econometric model solution capabilities, but for large DRI models, such as the US quarterly model, several standalone packages, considered to be more efficient, were successively used by DRI economists. By name, the PC solution packages used include e*model, PC*model, and model 386.

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PcFiml

PcFiml was the multiple-equation counterpart of PcGive. Technical and methodological limitations forced the initial PC-implementation to be a separate program. The first version was PC-FIML 5 (1987, released with PC-GIVE 5), see Hendry, Neale and Srba, 1988. PcGive version numbering was followed subsequently, except for version 7 which never existed. Version 6.01 was the last of the FORTRAN generation, and already incorporated the Johansen (1988) cointegration procedure. Version 8 extended much of the single-equation testing methodology of PcGive to the multiple-equation setting. As of PcGive 10, however, PcFiml is a fully integrated part of PcGive, and ceased to exist as a stand-alone program.

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XSIM

The original principal author of XSIM is Mark Eisner. It originated as a commercial extension of the TROLL package and was developed in the late 1970s, organizationally, by Dynamics Associates for Interactive Data Corporation/Chase Econometric Associates (IDC/CEA); Dynamics Associates subsequently became part of IDC, which in turn was owned by Chase Manhattan Bank. XSIM was designed to operate in a time sharing environment, supporting both economists and other employees of Chase Econometrics and the Interactive Data Corporation and clients of these firms. It was also licensed by IDC/CEA clients during the 1980s for inhouse corporate use on their own IBM and IBM-compatible mainframe computers. When used as a time shared system, it could be accessed from a remote telecommunications terminal using either a voice grade or dedicated line (Renfro, 1980).

Seen as econometric modeling language software, the program was designed as a broadly based system incorporating data base management, parameter estimation, model solution, tabular report generation, and graphics displays. The parameter estimation facilities offered included the standard time-oriented techniques commonly used at the beginning of the 1980s. However, it also included a relatively comprehensive high level programming language that provided support for the development of both macro command facilities and XSIM applications that were capable of creating an intermediate command interface. Such applications, developed in an XSIM framework, included a broad range of both economic and financial applications, each as a type of expert system. For example, one such application was &FORECAST (Fay, 1981), which was intended to provide access to XSIM's model solution facilities without requiring the user to learn the full set of XSIM commands.

XSIM was developed to be used with large scale economic and financial data bases, both those created and maintained by IDC/CEA and those licensed from other organizations worldwide.

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