Dynare

Reference Manual, version 4.4.3

Stéphane Adjemian
Houtan Bastani
Frédéric Karamé
Michel Juillard
Junior Maih
Ferhat Mihoubi
George Perendia
Johannes Pfeifer
Marco Ratto
Sébastien Villemot

Table of Contents

1 Introduction

1.1 What is Dynare ?

Dynare is a software platform for handling a wide class of economic models, in particular dynamic stochastic general equilibrium (DSGE) and overlapping generations (OLG) models. The models solved by Dynare include those relying on the *rational expectations* hypothesis, wherein agents form their expectations about the future in a way consistent with the model. But Dynare is also able to handle models where expectations are formed differently: on one extreme, models where agents perfectly anticipate the future; on the other extreme, models where agents have limited rationality or imperfect knowledge of the state of the economy and, hence, form their expectations through a learning process. In terms of types of agents, models solved by Dynare can incorporate consumers, productive firms, governments, monetary authorities, investors and financial intermediaries. Some degree of heterogeneity can be achieved by including several distinct classes of agents in each of the aforementioned agent categories.

Dynare offers a user-friendly and intuitive way of describing these models. It is able to perform simulations of the model given a calibration of the model parameters and is also able to estimate these parameters given a dataset. In practice, the user will write a text file containing the list of model variables, the dynamic equations linking these variables together, the computing tasks to be performed and the desired graphical or numerical outputs.

A large panel of applied mathematics and computer science techniques are internally employed by Dynare: multivariate nonlinear solving and optimization, matrix factorizations, local functional approximation, Kalman filters and smoothers, MCMC techniques for Bayesian estimation, graph algorithms, optimal control, . . .

Various public bodies (central banks, ministries of economy and finance, international organisations) and some private financial institutions use Dynare for performing policy analysis exercises and as a support tool for forecasting exercises. In the academic world, Dynare is used for research and teaching purposes in postgraduate macroeconomics courses.

Dynare is a free software, which means that it can be downloaded free of charge, that its source code is freely available, and that it can be used for both non-profit and for-profit purposes. Most of the source files are covered by the GNU General Public Licence (GPL) version 3 or later (there are some exceptions to this, see the file `license.txt` in Dynare distribution). It is available for the Windows, Mac and Linux platforms and is fully documented through a user guide and a reference manual. Part of Dynare is programmed in C++, while the rest is written using the MATLAB programming language. The latter implies that commercially-available MATLAB software is required in order to run Dynare. However, as an alternative to MATLAB, Dynare is also able to run on top of GNU Octave (basically a free clone of MATLAB): this possibility is particularly interesting for students or institutions who cannot afford, or do not want to pay for, MATLAB and are willing to bear the concomitant performance loss.

The development of Dynare is mainly done at Cepremap by a core team of researchers who devote part of their time to software development. Currently the development team of Dynare is composed of Stéphane Adjemian (Université du Maine, Gains and Cepremap), Houtan Bastani (Cepremap), Michel Juillard (Banque de France), Frédéric Karamé (Université du Maine, Gains and Cepremap), Junior Maih (Norges Bank), Ferhat Mihoubi (Université Paris-Est Créteil, Epee and Cepremap), George Perendia, Johannes Pfeifer (University of Mannheim), Marco Ratto (JRC) and Sébastien Villemot (Cepremap). Increasingly, the developer base is expanding, as tools developed by researchers outside of Cepremap are integrated into Dynare. Financial support is provided by Cepremap, Banque de France and DSGE-net (an international research network for DSGE modeling). The Dynare project also received funding through the Seventh Framework Programme for Research (FP7) of the European Commission's Socio-economic Sciences and Humanities (SSH) Program from October 2008 to September 2011 under grant agreement SSH-CT-2009-225149.

Interaction between developers and users of Dynare is central to the project. A web forum is available for users who have questions about the usage of Dynare or who want to report bugs. Training sessions are given through the Dynare Summer School, which is organized every year and is attended by about 40 people. Finally, priorities in terms of future developments and features to be added are decided in cooperation with the institutions providing financial support.

1.2 Documentation sources

The present document is the reference manual for Dynare. It documents all commands and features in a systematic fashion.

New users should rather begin with Dynare User Guide (*Mancini (2007)*), distributed with Dynare and also available from the official Dynare web site.

Other useful sources of information include the Dynare wiki and the Dynare forums.

1.3 Citing Dynare in your research

If you would like to refer to Dynare in a research article, the recommended way is to cite the present manual, as follows:

> Stéphane Adjemian, Houtan Bastani, Michel Juillard, Frédéric Karamé, Ferhat Mihoubi, George Perendia, Johannes Pfeifer, Marco Ratto and Sébastien Villemot (2011), "Dynare: Reference Manual, Version 4," *Dynare Working Papers*, 1, CEPREMAP

Note that citing the Dynare Reference Manual in your research is a good way to help the Dynare project.

If you want to give a URL, use the address of the Dynare website: `http://www.dynare.org`.

2 Installation and configuration

2.1 Software requirements

Packaged versions of Dynare are available for Windows XP/Vista/7/8, Debian GNU/Linux, Ubuntu and Mac OS X Leopard/Snow Leopard. Dynare should work on other systems, but some compilation steps are necessary in that case.

In order to run Dynare, you need one of the following:

- MATLAB version 7.3 (R2006b) or above;
- GNU Octave version 3.6 or above.

Packages of GNU Octave can be downloaded on the Dynare website.

The following optional extensions are also useful to benefit from extra features, but are in no way required:

- If under MATLAB: the optimization toolbox, the statistics toolbox, the control system toolbox;
- If under GNU Octave, the following Octave-Forge packages: optim, io, java, statistics, control.

If you plan to use the `use_dll` option of the `model` command, you will need to install the necessary requirements for compiling MEX files on your machine. If you are using MATLAB under Windows, install a C++ compiler on your machine and configure it with MATLAB: see instructions on the Dynare wiki. Users of Octave under Linux should install the package for MEX file compilation (under Debian or Ubuntu, it is called `liboctave-dev`). If you are using Octave or MATLAB under Mac OS X, you should install the latest version of XCode: see instructions on the Dynare wiki. Mac OS X Octave users will also need to install gnuplot if they want graphing capabilities. Users of MATLAB under Linux and Mac OS X, and users of Octave under Windows, normally need to do nothing, since a working compilation environment is available by default.

2.2 Installation of Dynare

After installation, Dynare can be used in any directory on your computer. It is best practice to keep your model files in directories different from the one containing the Dynare toolbox. That way you can upgrade Dynare and discard the previous version without having to worry about your own files.

2.2.1 On Windows

Execute the automated installer called `dynare-4.`*x*`.`*y*`-win.exe` (where 4.*x*.*y* is the version number), and follow the instructions. The default installation directory is `c:\dynare\4.`*x*`.`*y*.

After installation, this directory will contain several sub-directories, among which are `matlab`, `mex` and `doc`.

The installer will also add an entry in your Start Menu with a shortcut to the documentation files and uninstaller.

Note that you can have several versions of Dynare coexisting (for example in `c:\dynare`), as long as you correctly adjust your path settings (see Section 2.3.3 [Some words of warning], page 5).

2.2.2 On Debian GNU/Linux and Ubuntu

Please refer to the Dynare Wiki for detailed instructions.

Dynare will be installed under `/usr/share/dynare` and `/usr/lib/dynare`. Documentation will be under `/usr/share/doc/dynare`.

2.2.3 On Mac OS X

Execute the automated installer called `dynare-4.x.y.pkg` (where 4.*x*.*y* is the version number), and follow the instructions. The default installation directory is `/Applications/Dynare/4.x.y`.

Please refer to the Dynare Wiki for detailed instructions.

After installation, this directory will contain several sub-directories, among which are `matlab`, `mex` and `doc`.

Note that you can have several versions of Dynare coexisting (for example in `/Applications/Dynare`), as long as you correctly adjust your path settings (see Section 2.3.3 [Some words of warning], page 5).

2.2.4 For other systems

You need to download Dynare source code from the Dynare website and unpack it somewhere.

Then you will need to recompile the pre-processor and the dynamic loadable libraries. Please refer to README.md.

2.3 Configuration

2.3.1 For MATLAB

You need to add the `matlab` subdirectory of your Dynare installation to MATLAB path. You have two options for doing that:

- Using the `addpath` command in the MATLAB command window:

  Under Windows, assuming that you have installed Dynare in the standard location, and replacing `4.x.y` with the correct version number, type:

  ```
  addpath c:\dynare\4.x.y\matlab
  ```

  Under Debian GNU/Linux or Ubuntu, type:

  ```
  addpath /usr/share/dynare/matlab
  ```

  Under Mac OS X, assuming that you have installed Dynare in the standard location, and replacing `4.x.y` with the correct version number, type:

  ```
  addpath /Applications/Dynare/4.x.y/matlab
  ```

  MATLAB will not remember this setting next time you run it, and you will have to do it again.

- Via the menu entries:

  Select the “Set Path” entry in the “File” menu, then click on “Add Folder...”, and select the `matlab` subdirectory of your Dynare installation. Note that you *should not* use “Add with Subfolders...”. Apply the settings by clicking on “Save”. Note that MATLAB will remember this setting next time you run it.

2.3.2 For GNU Octave

You need to add the `matlab` subdirectory of your Dynare installation to Octave path, using the `addpath` at the Octave command prompt.

Under Windows, assuming that you have installed Dynare in the standard location, and replacing “4.*x*.*y*” with the correct version number, type:

```
addpath c:\dynare\4.x.y\matlab
```

Under Debian GNU/Linux or Ubuntu, there is no need to use the `addpath` command; the packaging does it for you.

Under Mac OS X, assuming that you have installed Dynare in the standard location, and replacing “4.*x*.*y*” with the correct version number, type:

```
addpath /Applications/Dynare/4.x.y/matlab
```

If you don't want to type this command every time you run Octave, you can put it in a file called `.octaverc` in your home directory (under Windows this will generally be `c:\Documents and Settings\USERNAME\` while under Mac OS X it is `/Users/USERNAME/`). This file is run by Octave at every startup.

2.3.3 Some words of warning

You should be very careful about the content of your MATLAB or Octave path. You can display its content by simply typing `path` in the command window.

The path should normally contain system directories of MATLAB or Octave, and some subdirectories of your Dynare installation. You have to manually add the `matlab` subdirectory, and Dynare will automatically add a few other subdirectories at runtime (depending on your configuration). You must verify that there is no directory coming from another version of Dynare than the one you are planning to use.

You have to be aware that adding other directories to your path can potentially create problems if any of your M-files have the same name as a Dynare file. Your file would then override the Dynare file, making Dynare unusable.

3 Running Dynare

In order to give instructions to Dynare, the user has to write a *model file* whose filename extension must be `.mod`. This file contains the description of the model and the computing tasks required by the user. Its contents is described in Chapter 4 [The Model file], page 10.

3.1 Dynare invocation

Once the model file is written, Dynare is invoked using the `dynare` command at the MATLAB or Octave prompt (with the filename of the `.mod` given as argument).

In practice, the handling of the model file is done in two steps: in the first one, the model and the processing instructions written by the user in a *model file* are interpreted and the proper MATLAB or GNU Octave instructions are generated; in the second step, the program actually runs the computations. Both steps are triggered automatically by the `dynare` command.

`dynare` ***`FILENAME`***[*.mod*] [***`OPTIONS`***...] [MATLAB/Octave command]

Description

This command launches Dynare and executes the instructions included in ***`FILENAME`***`.mod`. This user-supplied file contains the model and the processing instructions, as described in Chapter 4 [The Model file], page 10.

`dynare` begins by launching the preprocessor on the `.mod` file. By default (unless `use_dll` option has been given to `model`), the preprocessor creates three intermediary files:

`FILENAME``.m`
: Contains variable declarations, and computing tasks

`FILENAME``_dynamic.m`
: Contains the dynamic model equations. Note that Dynare might introduce auxiliary equations and variables (see Section 4.6 [Auxiliary variables], page 21). Outputs are the residuals of the dynamic model equations in the order the equations were declared and the Jacobian of the dynamic model equations. For higher order approximations also the Hessian and the third-order derivatives are provided. When computing the Jacobian of the dynamic model, the order of the endogenous variables in the columns is stored in `M_.lead_lag_incidence`. The rows of this matrix represent time periods: the first row denotes a lagged (time t-1) variable, the second row a contemporaneous (time t) variable, and the third row a leaded (time t+1) variable. The columns of the matrix represent the endogenous variables in their order of declaration. A zero in the matrix means that this endogenous does not appear in the model in this time period. The value in the `M_.lead_lag_incidence` matrix corresponds to the column of that variable in the Jacobian of the dynamic model. Example: Let the second declared variable be `c` and the `(3,2)` entry of `M_.lead_lag_incidence` be `15`. Then the `15`th column of the Jacobian is the derivative with respect to `y(+1)`.

`FILENAME``_static.m`
: Contains the long run static model equations. Note that Dynare might introduce auxiliary equations and variables (see Section 4.6 [Auxiliary variables], page 21). Outputs are the residuals of the static model equations in the order the equations were declared and the Jacobian of the static equations. Entry `(i,j)` of the Jacobian represents the derivative of the `i`th static model equation with respect to the `j`th model variable in declaration order.

These files may be looked at to understand errors reported at the simulation stage.

`dynare` will then run the computing tasks by executing ***`FILENAME`***`.m`.

A few words of warning is warranted here: the filename of the `.mod` file should be chosen in such a way that the generated `.m` files described above do not conflict with `.m` files provided by MATLAB/Octave or by Dynare. Not respecting this rule could cause crashes or unexpected behaviour. In particular, it means that the `.mod` file cannot be given the name of a MATLAB/Octave or Dynare command. Under Octave, it also means that the `.mod` file cannot be named `test.mod`.

Options

`noclearall`
: By default, `dynare` will issue a `clear all` command to MATLAB or Octave, thereby deleting all workspace variables; this options instructs `dynare` not to clear the workspace

`debug`
: Instructs the preprocessor to write some debugging information about the scanning and parsing of the `.mod` file

`notmpterms`
: Instructs the preprocessor to omit temporary terms in the static and dynamic files; this generally decreases performance, but is used for debugging purposes since it makes the static and dynamic files more readable

`savemacro[=`*`FILENAME`*`]`
: Instructs `dynare` to save the intermediary file which is obtained after macro-processing (see Section 4.20 [Macro-processing language], page 98); the saved output will go in the file specified, or if no file is specified in *`FILENAME`*`-macroexp.mod`

`onlymacro`
: Instructs the preprocessor to only perform the macro-processing step, and stop just after. Mainly useful for debugging purposes or for using the macro-processor independently of the rest of Dynare toolbox.

`nolinemacro`
: Instructs the macro-preprocessor to omit line numbering information in the intermediary `.mod` file created after the macro-processing step. Useful in conjunction with `savemacro` when one wants that to reuse the intermediary `.mod` file, without having it cluttered by line numbering directives.

`nolog`
: Instructs Dynare to no create a logfile of this run in *`FILENAME`*`.log`. The default is to create the logfile.

`nowarn`
: Suppresses all warnings.

`warn_uninit`
: Display a warning for each variable or parameter which is not initialized. See Section 4.4 [Parameter initialization], page 18, or [load_params_and_steady_state], page 105 for initialization of parameters. See Section 4.7 [Initial and terminal conditions], page 22, or [load_params_and_steady_state], page 105 for initialization of endogenous and exogenous variables.

`console`
: Activate console mode. In addition to the behavior of `nodisplay`, Dynare will not use graphical waitbars for long computations.

`nograph`
: Activate the `nograph` option (see [nograph], page 41), so that Dynare will not produce any graph

`nointeractive`
: Instructs Dynare to not request user input

`cygwin` Tells Dynare that your MATLAB is configured for compiling MEX files with Cygwin (see Section 2.1 [Software requirements], page 3). This option is only available under Windows, and is used in conjunction with `use_dll`.

`msvc` Tells Dynare that your MATLAB is configured for compiling MEX files with Microsoft Visual C++ (see Section 2.1 [Software requirements], page 3). This option is only available under Windows, and is used in conjunction with `use_dll`.

`parallel[=`*`CLUSTER_NAME`*`]`
Tells Dynare to perform computations in parallel. If *CLUSTER_NAME* is passed, Dynare will use the specified cluster to perform parallel computations. Otherwise, Dynare will use the first cluster specified in the configuration file. See Chapter 5 [The Configuration File], page 106, for more information about the configuration file.

`conffile=`*`FILENAME`*
Specifies the location of the configuration file if it differs from the default. See Chapter 5 [The Configuration File], page 106, for more information about the configuration file and its default location.

`parallel_slave_open_mode`
Instructs Dynare to leave the connection to the slave node open after computation is complete, closing this connection only when Dynare finishes processing.

`parallel_test`
Tests the parallel setup specified in the configuration file without executing the `.mod` file. See Chapter 5 [The Configuration File], page 106, for more information about the configuration file.

`-D`*`MACRO_VARIABLE`*`=`*`MACRO_EXPRESSION`*
Defines a macro-variable from the command line (the same effect as using the Macro directive `@#define` in a model file, see Section 4.20 [Macro-processing language], page 98).

`nostrict` Allows Dynare to issue a warning and continue processing when
1. there are more endogenous variables than equations
2. an undeclared symbol is assigned in `initval` or `endval`

Output

Depending on the computing tasks requested in the `.mod` file, executing the `dynare` command will leave variables containing results in the workspace available for further processing. More details are given under the relevant computing tasks.

The `M_`, `oo_`, and `options_` structures are saved in a file called *`FILENAME`*`_results.mat`. If they exist, `estim_params_`, `bayestopt_`, `dataset_`, and `estimation_info` are saved in the same file.

Example

```
dynare ramst
dynare ramst.mod savemacro
```

The output of Dynare is left into three main variables in the MATLAB/Octave workspace:

`M_` [MATLAB/Octave variable]
Structure containing various information about the model.

`options_` [MATLAB/Octave variable]
Structure contains the values of the various options used by Dynare during the computation.

`oo_` [MATLAB/Octave variable]

Structure containing the various results of the computations.

3.2 Dynare hooks

It is possible to call pre and post Dynare preprocessor hooks written as MATLAB scripts. The script *`MODFILENAME`*`/hooks/priorprocessing.m` is executed before the call to Dynare's preprocessor, and can be used to programmatically transform the mod file that will be read by the preprocessor. The script *`MODFILENAME`*`/hooks/postprocessing.m` is executed just after the call to Dynare's preprocessor, and can be used to programmatically transform the files generated by Dynare's preprocessor before actual computations start. The pre and/or post dynare preprocessor hooks are executed if and only if the aforementioned scripts are detected in the same folder as the the model file, *`FILENAME`*`.mod`.

3.3 Understanding Preprocessor Error Messages

If the preprocessor runs into an error while processing your `.mod` file, it will issue an error. Due to the way that a parser works, sometimes these errors can be misleading. Here, we aim to demystify these error messages.

The preprocessor issues error messages of the form:

1. `ERROR: <<file.mod>>: line A, col B: <<error message>>`
2. `ERROR: <<file.mod>>: line A, cols B-C: <<error message>>`
3. `ERROR: <<file.mod>>: line A, col B - line C, col D: <<error message>>`

The first two errors occur on a single line, with error two spanning multiple columns. Error three spans multiple rows.

Often, the line and column numbers are precise, leading you directly to the offending syntax. Infrequently however, because of the way the parser works, this is not the case. The most common example of misleading line and column numbers (and error message for that matter) is the case of a missing semicolon, as seen in the following example:

```
varexo a, b
parameters c, ...;
```

In this case, the parser doesn't know a semicolon is missing at the end of the `varexo` command until it begins parsing the second line and bumps into the `parameters` command. This is because we allow commands to span multiple lines and, hence, the parser cannot know that the second line will not have a semicolon on it until it gets there. Once the parser begins parsing the second line, it realizes that it has encountered a keyword, `parameters`, which it did not expect. Hence, it throws an error of the form: `ERROR: <<file.mod>>: line 2, cols 0-9: syntax error, unexpected PARAMETERS`. In this case, you would simply place a semicolon at the end of line one and the parser would continue processing.

4 The Model file

4.1 Conventions

A model file contains a list of commands and of blocks. Each command and each element of a block is terminated by a semicolon (`;`). Blocks are terminated by `end;`.

Most Dynare commands have arguments and several accept options, indicated in parentheses after the command keyword. Several options are separated by commas.

In the description of Dynare commands, the following conventions are observed:

- optional arguments or options are indicated between square brackets: '`[]`';
- repreated arguments are indicated by ellipses: "…";
- mutually exclusive arguments are separated by vertical bars: '`|`';
- *INTEGER* indicates an integer number;
- *DOUBLE* indicates a double precision number. The following syntaxes are valid: `1.1e3`, `1.1E3`, `1.1d3`, `1.1D3`. In some places, infinite values `Inf` and `-Inf` are also allowed;
- *NUMERICAL_VECTOR* indicates a vector of numbers separated by spaces, enclosed by square brackets;
- *EXPRESSION* indicates a mathematical expression valid outside the model description (see Section 4.3 [Expressions], page 14);
- *MODEL_EXPRESSION* indicates a mathematical expression valid in the model description (see Section 4.3 [Expressions], page 14 and Section 4.5 [Model declaration], page 18);
- *MACRO_EXPRESSION* designates an expression of the macro-processor (see Section 4.20.1 [Macro expressions], page 98);
- *VARIABLE_NAME* indicates a variable name starting with an alphabetical character and can't contain: '`()+-*/^=!;:@#.`' or accentuated characters;
- *PARAMETER_NAME* indicates a parameter name starting with an alphabetical character and can't contain: '`()+-*/^=!;:@#.`' or accentuated characters;
- *LATEX_NAME* indicates a valid LaTeX expression in math mode (not including the dollar signs);
- *FUNCTION_NAME* indicates a valid MATLAB function name;
- *FILENAME* indicates a filename valid in the underlying operating system; it is necessary to put it between quotes when specifying the extension or if the filename contains a non-alphanumeric character;

4.2 Variable declarations

Declarations of variables and parameters are made with the following commands:

`var` *VARIABLE_NAME* [*$LATEX_NAME$*] [(*long_name*=*QUOTED_STRING*)]. . .; [Command]

`var` (*deflator* = *MODEL_EXPRESSION*) *VARIABLE_NAME* [*$LATEX_NAME$*] [(*long_name*=*QUOTED_STRING*)]. . .; [Command]

`var` (*log_deflator* = *MODEL_EXPRESSION*) *VARIABLE_NAME* [*$LATEX_NAME$*] [(*long_name*=*QUOTED_STRING*)]. . .; [Command]

Description

This required command declares the endogenous variables in the model. See Section 4.1 [Conventions], page 10, for the syntax of *VARIABLE_NAME* and *MODEL_EXPRESSION*. Optionally it is possible to give a LaTeX name to the variable or, if it is nonstationary, provide information regarding its deflator.

`var` commands can appear several times in the file and Dynare will concatenate them.

Options

If the model is nonstationary and is to be written as such in the `model` block, Dynare will need the trend deflator for the appropriate endogenous variables in order to stationarize the model. The trend deflator must be provided alongside the variables that follow this trend.

`deflator = MODEL_EXPRESSION`
: The expression used to detrend an endogenous variable. All trend variables, endogenous variables and parameters referenced in *MODEL_EXPRESSION* must already have been declared by the `trend_var`, `log_trend_var`, `var` and `parameters` commands. The deflator is assumed to be multiplicative; for an additive deflator, use `log_deflator`.

`log_deflator = MODEL_EXPRESSION`
: Same as `deflator`, except that the deflator is assumed to be additive instead of multiplicative (or, to put it otherwise, the declared variable is equal to the log of a variable with a multiplicative trend).

`long_name = QUOTED_STRING`
: This is the long version of the variable name. Its value is stored in `M_.endo_names_long`. Default: *VARIABLE_NAME*

Example

```
var c gnp q1 q2;
var(deflator=A) i b;
var c $C$ (long_name='Consumption');
```

`varexo` *VARIABLE_NAME* [*$LATEX_NAME$*] [(*long_name*=*QUOTED_STRING*)]. . . ; [Command]

Description

This optional command declares the exogenous variables in the model. See Section 4.1 [Conventions], page 10, for the syntax of *VARIABLE_NAME*. Optionally it is possible to give a LaTeX name to the variable.

Exogenous variables are required if the user wants to be able to apply shocks to her model.

`varexo` commands can appear several times in the file and Dynare will concatenate them.

Options

`long_name = QUOTED_STRING`
: Like [long_name], page 11 but value stored in `M_.exo_names_long`.

Example

```
varexo m gov;
```

`varexo_det` *VARIABLE_NAME* [*$LATEX_NAME$*] [Command]
[(*long_name*=*QUOTED_STRING*)]. . . ;

Description

This optional command declares exogenous deterministic variables in a stochastic model. See Section 4.1 [Conventions], page 10, for the syntax of *VARIABLE_NAME*. Optionally it is possible to give a LaTeX name to the variable.

It is possible to mix deterministic and stochastic shocks to build models where agents know from the start of the simulation about future exogenous changes. In that case `stoch_simul` will compute the rational expectation solution adding future information to the state space (nothing is shown in the output of `stoch_simul`) and `forecast` will compute a simulation conditional on initial conditions and future information.

`varexo_det` commands can appear several times in the file and Dynare will concatenate them.

Options

`long_name = ` *`QUOTED_STRING`*
: Like [long_name], page 11 but value stored in `M_.exo_det_names_long`.

Example

```
varexo m gov;
varexo_det tau;
```

`parameters` *PARAMETER_NAME* [*$LATEX_NAME$*] [(*long_name*=*QUOTED_STRING*)]. . . ; [Command]

Description

This command declares parameters used in the model, in variable initialization or in shocks declarations. See Section 4.1 [Conventions], page 10, for the syntax of *PARAMETER_NAME*. Optionally it is possible to give a LaTeX name to the parameter.

The parameters must subsequently be assigned values (see Section 4.4 [Parameter initialization], page 18).

`parameters` commands can appear several times in the file and Dynare will concatenate them.

Options

`long_name = ` *`QUOTED_STRING`*
: Like [long_name], page 11 but value stored in `M_.param_names_long`.

Example

```
parameters alpha, bet;
```

`change_type` (*var* | *varexo* | *varexo_det* | *parameters*) *VARIABLE_NAME* | *PARAMETER_NAME*. . . ; [Command]

Description

Changes the types of the specified variables/parameters to another type: endogenous, exogenous, exogenous deterministic or parameter.

It is important to understand that this command has a global effect on the `.mod` file: the type change is effective after, but also before, the `change_type` command. This command is typically used when flipping some variables for steady state calibration: typically a separate model file is used for calibration, which includes the list of variable declarations with the macro-processor, and flips some variable.

Example

```
var y, w;
parameters alpha, bet;
...
change_type(var) alpha, bet;
change_type(parameters) y, w;
```

Here, in the whole model file, `alpha` and `beta` will be endogenous and `y` and `w` will be parameters.

`predetermined_variables` *VARIABLE_NAME. . . ;* [Command]

Description

In Dynare, the default convention is that the timing of a variable reflects when this variable is decided. The typical example is for capital stock: since the capital stock used at current period is actually decided at the previous period, then the capital stock entering the production function is `k(-1)`, and the law of motion of capital must be written:

```
k = i + (1-delta)*k(-1)
```

Put another way, for stock variables, the default in Dynare is to use a “stock at the end of the period” concept, instead of a “stock at the beginning of the period” convention.

The `predetermined_variables` is used to change that convention. The endogenous variables declared as predetermined variables are supposed to be decided one period ahead of all other endogenous variables. For stock variables, they are supposed to follow a “stock at the beginning of the period” convention.

Note that Dynare internally always uses the “stock at the end of the period” concept, even when the model has been entered using the `predetermined_variables`-command. Thus, when plotting, computing or simulating variables, Dynare will follow the convention to use variables that are decided in the current period. For example, when generating impulse response functions for capital, Dynare will plot `k`, which is the capital stock decided upon by investment today (and which will be used in tomorrow’s production function). This is the reason that capital is shown to be moving on impact, because it is `k` and not the predetermined `k(-1)` that is displayed. It is important to remember that this also affects simulated time series and output from smoother routines for predetermined variables. Compared to non-predetermined variables they might otherwise appear to be falsely shifted to the future by one period.

Example

The following two program snippets are strictly equivalent.

Using default Dynare timing convention:

```
var y, k, i;
...
model;
y = k(-1)^alpha;
k = i + (1-delta)*k(-1);
...
end;
```

Using the alternative timing convention:

```
var y, k, i;
predetermined_variables k;
...
model;
y = k^alpha;
k(+1) = i + (1-delta)*k;
...
end;
```

`trend_var` (*growth_factor* = *MODEL_EXPRESSION*) *VARIABLE_NAME* [*$LATEX_NAME$*]. . . ; [Command]

Description

This optional command declares the trend variables in the model. See Section 4.1 [Conventions], page 10, for the syntax of *MODEL_EXPRESSION* and *VARIABLE_NAME*. Optionally it is possible to give a LaTeX name to the variable.

The variable is assumed to have a multiplicative growth trend. For an additive growth trend, use `log_trend_var` instead.

Trend variables are required if the user wants to be able to write a nonstationary model in the `model` block. The `trend_var` command must appear before the `var` command that references the trend variable.

`trend_var` commands can appear several times in the file and Dynare will concatenate them.

If the model is nonstationary and is to be written as such in the `model` block, Dynare will need the growth factor of every trend variable in order to stationarize the model. The growth factor must be provided within the declaration of the trend variable, using the `growth_factor` keyword. All endogenous variables and parameters referenced in *MODEL_EXPRESSION* must already have been declared by the `var` and `parameters` commands.

Example

```
trend_var (growth_factor=gA) A;
```

`log_trend_var` (*log_growth_factor* = *MODEL_EXPRESSION*) *VARIABLE_NAME* [*$LATEX_NAME$*]. . . ; [Command]

Description

Same as `trend_var`, except that the variable is supposed to have an additive trend (or, to put it otherwise, to be equal to the log of a variable with a multiplicative trend).

4.3 Expressions

Dynare distinguishes between two types of mathematical expressions: those that are used to describe the model, and those that are used outside the model block (*e.g.* for initializing parameters or variables, or as command options). In this manual, those two types of expressions are respectively denoted by *MODEL_EXPRESSION* and *EXPRESSION*.

Unlike MATLAB or Octave expressions, Dynare expressions are necessarily scalar ones: they cannot contain matrices or evaluate to matrices[1].

Expressions can be constructed using integers (*INTEGER*), floating point numbers (*DOUBLE*), parameter names (*PARAMETER_NAME*), variable names (*VARIABLE_NAME*), operators and functions.

The following special constants are also accepted in some contexts:

`inf` [Constant]

Represents infinity.

`nan` [Constant]

“Not a number”: represents an undefined or unrepresentable value.

[1] Note that arbitrary MATLAB or Octave expressions can be put in a `.mod` file, but those expressions have to be on separate lines, generally at the end of the file for post-processing purposes. They are not interpreted by Dynare, and are simply passed on unmodified to MATLAB or Octave. Those constructions are not addresses in this section.

4.3.1 Parameters and variables

Parameters and variables can be introduced in expressions by simply typing their names. The semantics of parameters and variables is quite different whether they are used inside or outside the model block.

4.3.1.1 Inside the model

Parameters used inside the model refer to the value given through parameter initialization (see Section 4.4 [Parameter initialization], page 18) or `homotopy_setup` when doing a simulation, or are the estimated variables when doing an estimation.

Variables used in a *MODEL_EXPRESSION* denote *current period* values when neither a lead or a lag is given. A lead or a lag can be given by enclosing an integer between parenthesis just after the variable name: a positive integer means a lead, a negative one means a lag. Leads or lags of more than one period are allowed. For example, if `c` is an endogenous variable, then `c(+1)` is the variable one period ahead, and `c(-2)` is the variable two periods before.

When specifying the leads and lags of endogenous variables, it is important to respect the following convention: in Dynare, the timing of a variable reflects when that variable is decided. A control variable — which by definition is decided in the current period — must have no lead. A predetermined variable — which by definition has been decided in a previous period — must have a lag. A consequence of this is that all stock variables must use the “stock at the end of the period” convention. Please refer to *Mancini-Griffoli (2007)* for more details and concrete examples.

Leads and lags are primarily used for endogenous variables, but can be used for exogenous variables. They have no effect on parameters and are forbidden for local model variables (see Section 4.5 [Model declaration], page 18).

4.3.1.2 Outside the model

When used in an expression outside the model block, a parameter or a variable simply refers to the last value given to that variable. More precisely, for a parameter it refers to the value given in the corresponding parameter initialization (see Section 4.4 [Parameter initialization], page 18); for an endogenous or exogenous variable, it refers to the value given in the most recent `initval` or `endval` block.

4.3.2 Operators

The following operators are allowed in both *MODEL_EXPRESSION* and *EXPRESSION*:

- binary arithmetic operators: `+`, `-`, `*`, `/`, `^`
- unary arithmetic operators: `+`, `-`
- binary comparison operators (which evaluate to either `0` or `1`): `<`, `>`, `<=`, `>=`, `==`, `!=`

  Note that these operators are differentiable everywhere except on a line of the 2-dimensional real plane. However for facilitating convergence of Newton-type methods, Dynare assumes that, at the points of non-differentiability, the partial derivatives of these operators with respect to both arguments is equal to 0 (since this is the value of the partial derivatives everywhere else).

The following special operators are accepted in *MODEL_EXPRESSION* (but not in *EXPRESSION*):

`STEADY_STATE (`*`MODEL_EXPRESSION`*`)` [Operator]

This operator is used to take the value of the enclosed expression at the steady state. A typical usage is in the Taylor rule, where you may want to use the value of GDP at steady state to compute the output gap.

`EXPECTATION (`*`INTEGER`*`) (`*`MODEL_EXPRESSION`*`)` [Operator]

This operator is used to take the expectation of some expression using a different information set than the information available at current period. For example, `EXPECTATION(-1)(x(+1))` is equal to the expected value of variable `x` at next period, using the information set available at the previous period. See Section 4.6 [Auxiliary variables], page 21, for an explanation of how this operator is handled internally and how this affects the output.

4.3.3 Functions

4.3.3.1 Built-in Functions

The following standard functions are supported internally for both *MODEL_EXPRESSION* and *EXPRESSION*:

`exp` (*x*) [Function]
Natural exponential.

`log` (*x*) [Function]
`ln` (*x*) [Function]
Natural logarithm.

`log10` (*x*) [Function]
Base 10 logarithm.

`sqrt` (*x*) [Function]
Square root.

`abs` (*x*) [Function]
Absolute value.

Note that this function is not differentiable at $x = 0$. However, for facilitating convergence of Newton-type methods, Dynare assumes that the derivative at $x = 0$ is equal to 0 (this assumption comes from the observation that the derivative of $abs(x)$ is equal to $sign(x)$ for $x \neq 0$ and from the convention for the derivative of $sign(x)$ at $x = 0$).

`sign` (*x*) [Function]
Signum function.

Note that this function is not differentiable at $x = 0$. However, for facilitating convergence of Newton-type methods, Dynare assumes that the derivative at $x = 0$ is equal to 0 (this assumption comes from the observation that both the right- and left-derivatives at this point exist and are equal to 0).

`sin` (*x*) [Function]
`cos` (*x*) [Function]
`tan` (*x*) [Function]
`asin` (*x*) [Function]
`acos` (*x*) [Function]
`atan` (*x*) [Function]
Trigonometric functions.

`max` (*a*, *b*) [Function]
`min` (*a*, *b*) [Function]
Maximum and minimum of two reals.

Note that these functions are differentiable everywhere except on a line of the 2-dimensional real plane defined by $a = b$. However for facilitating convergence of Newton-type methods, Dynare assumes that, at the points of non-differentiability, the partial derivative of these functions with respect to the first (resp. the second) argument is equal to 1 (resp. to 0) (*i.e.* the derivatives at the kink are equal to the derivatives observed on the half-plane where the function is equal to its first argument).

`normcdf` (*x*) [Function]
`normcdf` (*x*, *mu*, *sigma*) [Function]

Gaussian cumulative density function, with mean *mu* and standard deviation *sigma*. Note that `normcdf(x)` is equivalent to `normcdf(x,0,1)`.

`normpdf` (*x*) [Function]
`normpdf` (*x*, *mu*, *sigma*) [Function]

Gaussian probability density function, with mean *mu* and standard deviation *sigma*. Note that `normpdf(x)` is equivalent to `normpdf(x,0,1)`.

`erf` (*x*) [Function]

Gauss error function.

4.3.3.2 External Functions

Any other user-defined (or built-in) MATLAB or Octave function may be used in both a *MODEL_EXPRESSION* and an *EXPRESSION*, provided that this function has a scalar argument as a return value.

To use an external function in a *MODEL_EXPRESSION*, one must declare the function using the `external_function` statement. This is not necessary for external functions used in an *EXPRESSION*.

`external_function` (*OPTIONS...*); [Command]

Description

This command declares the external functions used in the model block. It is required for every unique function used in the model block.

`external_function` commands can appear several times in the file and must come before the model block.

Options

`name = NAME`
: The name of the function, which must also be the name of the M-/MEX file implementing it. This option is mandatory.

`nargs = INTEGER`
: The number of arguments of the function. If this option is not provided, Dynare assumes `nargs = 1`.

`first_deriv_provided [= NAME]`
: If *NAME* is provided, this tells Dynare that the Jacobian is provided as the only output of the M-/MEX file given as the option argument. If *NAME* is not provided, this tells Dynare that the M-/MEX file specified by the argument passed to `name` returns the Jacobian as its second output argument.

`second_deriv_provided [= NAME]`
: If *NAME* is provided, this tells Dynare that the Hessian is provided as the only output of the M-/MEX file given as the option argument. If *NAME* is not provided, this tells Dynare that the M-/MEX file specified by the argument passed to `name` returns the Hessian as its third output argument. NB: This option can only be used if the `first_deriv_provided` option is used in the same `external_function` command.

Example

```
external_function(name = funcname);
external_function(name = otherfuncname, nargs = 2,
                  first_deriv_provided, second_deriv_provided);
external_function(name = yetotherfuncname, nargs = 3,
                  first_deriv_provided = funcname_deriv);
```

4.3.4 A few words of warning in stochastic context

The use of the following functions and operators is strongly discouraged in a stochastic context: `max`, `min`, `abs`, `sign`, `<`, `>`, `<=`, `>=`, `==`, `!=`.

The reason is that the local approximation used by `stoch_simul` or `estimation` will by nature ignore the non-linearities introduced by these functions if the steady state is away from the kink. And, if the steady state is exactly at the kink, then the approximation will be bogus because the derivative of these functions at the kink is bogus (as explained in the respective documentations of these functions and operators).

Note that `extended_path` is not affected by this problem, because it does not rely on a local approximation of the model.

4.4 Parameter initialization

When using Dynare for computing simulations, it is necessary to calibrate the parameters of the model. This is done through parameter initialization.

The syntax is the following:

`PARAMETER_NAME` `=` *`EXPRESSION`*`;`

Here is an example of calibration:

```
parameters alpha, bet;

beta = 0.99;
alpha = 0.36;
A = 1-alpha*beta;
```

Internally, the parameter values are stored in `M_.params`:

`M_.params` [MATLAB/Octave variable]

Contains the values of model parameters. The parameters are in the order that was used in the `parameters` command.

4.5 Model declaration

The model is declared inside a `model` block:

`model` *;* [Block]
`model (`*`OPTIONS`*...`)`*;* [Block]

Description

The equations of the model are written in a block delimited by `model` and `end` keywords.

There must be as many equations as there are endogenous variables in the model, except when computing the unconstrained optimal policy with `ramsey_policy` or `discretionary_policy`.

The syntax of equations must follow the conventions for *MODEL_EXPRESSION* as described in Section 4.3 [Expressions], page 14. Each equation must be terminated by a semicolon (‘`;`’). A normal equation looks like:

`MODEL_EXPRESSION` `=` *`MODEL_EXPRESSION`*`;`

When the equations are written in homogenous form, it is possible to omit the ‘`=0`’ part and write only the left hand side of the equation. A homogenous equation looks like:

MODEL_EXPRESSION;

Inside the model block, Dynare allows the creation of *model-local variables*, which constitute a simple way to share a common expression between several equations. The syntax consists of a pound sign (`#`) followed by the name of the new model local variable (which must **not** be declared as in Section 4.2 [Variable declarations], page 10), an equal sign, and the expression for which this new variable will stand. Later on, every time this variable appears in the model, Dynare will substitute it by the expression assigned to the variable. Note that the scope of this variable is restricted to the model block; it cannot be used outside. A model local variable declaration looks like:

```
# VARIABLE_NAME = MODEL_EXPRESSION;
```

Options

`linear` Declares the model as being linear. It spares oneself from having to declare initial values for computing the steady state of a stationary linear model. This options can't be used with non-linear models, it will NOT trigger linearization of the model.

`use_dll` Instructs the preprocessor to create dynamic loadable libraries (DLL) containing the model equations and derivatives, instead of writing those in M-files. You need a working compilation environment, *i.e.* a working `mex` command (see Section 2.1 [Software requirements], page 3 for more details). Using this option can result in faster simulations or estimations, at the expense of some initial compilation time.[2]

`block` Perform the block decomposition of the model, and exploit it in computations (steady-state, deterministic simulation, stochastic simulation with first order approximation and estimation). See Dynare wiki for details on the algorithms used in deterministic simulation and steady-state computation.

`bytecode` Instead of M-files, use a bytecode representation of the model, *i.e.* a binary file containing a compact representation of all the equations.

`cutoff =` *DOUBLE*
Threshold under which a jacobian element is considered as null during the model normalization. Only available with option `block`. Default: `1e-15`

`mfs =` *INTEGER*
Controls the handling of minimum feedback set of endogenous variables. Only available with option `block`. Possible values:

`0` All the endogenous variables are considered as feedback variables (Default).

`1` The endogenous variables assigned to equation naturally normalized (*i.e.* of the form $x = f(Y)$ where x does not appear in Y) are potentially recursive variables. All the other variables are forced to belong to the set of feedback variables.

`2` In addition of variables with `mfs = 1` the endogenous variables related to linear equations which could be normalized are potential recursive variables. All the other variables are forced to belong to the set of feedback variables.

`3` In addition of variables with `mfs = 2` the endogenous variables related to non-linear equations which could be normalized are potential recursive variables. All the other variables are forced to belong to the set of feedback variables.

[2] In particular, for big models, the compilation step can be very time-consuming, and use of this option may be counter-productive in those cases.

`no_static`
: Don't create the static model file. This can be useful for models which don't have a steady state.

`differentiate_forward_vars`
`differentiate_forward_vars = ( VARIABLE_NAME [VARIABLE_NAME ...] )`
: Tells Dynare to create a new auxiliary variable for each endogenous variable that appears with a lead, such that the new variable is the time differentiate of the original one. More precisely, if the model contains `x(+1)`, then a variable `AUX_DIFF_VAR` will be created such that `AUX_DIFF_VAR=x-x(-1)`, and `x(+1)` will be replaced with `x+AUX_DIFF_VAR(+1)`.

  The transformation is applied to all endogenous variables with a lead if the option is given without a list of variables. If there is a list, the transformation is restricted to endogenous with a lead that also appear in the list.

  This option can useful for some deterministic simulations where convergence is hard to obtain. Bad values for terminal conditions in the case of very persistent dynamics or permanent shocks can hinder correct solutions or any convergence. The new differentiated variables have obvious zero terminal conditions (if the terminal condition is a steady state) and this in many cases helps convergence of simulations.

`parallel_local_files = ( FILENAME [, FILENAME]... )`
: Declares a list of extra files that should be transferred to slave nodes when doing a parallel computation (see Section 5.2 [Parallel Configuration], page 107).

Example 1: elementary RBC model

```
var c k;
varexo x;
parameters aa alph bet delt gam;

model;
c =  - k + aa*x*k(-1)^alph + (1-delt)*k(-1);
c^(-gam) = (aa*alph*x(+1)*k^(alph-1) + 1 - delt)*c(+1)^(-gam)/(1+bet);
end;
```

Example 2: use of model local variables

The following program:

```
model;
# gamma = 1 - 1/sigma;
u1 = c1^gamma/gamma;
u2 = c2^gamma/gamma;
end;
```

. . . is formally equivalent to:

```
model;
u1 = c1^(1-1/sigma)/(1-1/sigma);
u2 = c2^(1-1/sigma)/(1-1/sigma);
end;
```

Example 3: a linear model

```
model(linear);
x = a*x(-1)+b*y(+1)+e_x;
y = d*y(-1)+e_y;
end;
```

Dynare has the ability to output the list of model equations to a LaTeX file, using the `write_latex_dynamic_model` command. The static model can also be written with the `write_latex_static_model` command.

`write_latex_dynamic_model` *;* [Command]

Description

This command creates a LaTeX file containing the (dynamic) model.

If your `.mod` file is *`FILENAME`*`.mod`, then Dynare will create a file called *`FILENAME`*`_dynamic.tex`, containing the list of all the dynamic model equations.

If LaTeX names were given for variables and parameters (see Section 4.2 [Variable declarations], page 10), then those will be used; otherwise, the plain text names will be used.

Time subscripts (`t`, `t+1`, `t-1`, . . .) will be appended to the variable names, as LaTeX subscripts.

Note that the model written in the TeX file will differ from the model declared by the user in the following dimensions:

- the timing convention of predetermined variables (see [predetermined_variables], page 13) will have been changed to the default Dynare timing convention; in other words, variables declared as predetermined will be lagged on period back,
- the expectation operators (see [expectation], page 15) will have been removed, replaced by auxiliary variables and new equations as explained in the documentation of the operator,
- endogenous variables with leads or lags greater or equal than two will have been removed, replaced by new auxiliary variables and equations,
- for a stochastic model, exogenous variables with leads or lags will also have been replaced by new auxiliary variables and equations.

Compiling the TeX file requires the following LaTeX packages: `geometry`, `fullpage`, `breqn`.

`write_latex_static_model` *;* [Command]

Description

This command creates a LaTeX file containing the static model.

If your `.mod` file is *`FILENAME`*`.mod`, then Dynare will create a file called *`FILENAME`*`_static.tex`, containing the list of all the equations of the steady state model.

If LaTeX names were given for variables and parameters (see Section 4.2 [Variable declarations], page 10), then those will be used; otherwise, the plain text names will be used.

Note that the model written in the TeX file will differ from the model declared by the user in the some dimensions (see [write_latex_dynamic_model], page 21 for details).

Also note that this command will not output the contents of the optional `steady_state_model` block (see [steady_state_model], page 34); it will rather output a static version (*i.e.* without leads and lags) of the dynamic model declared in the `model` block.

Compiling the TeX file requires the following LaTeX packages: `geometry`, `fullpage`, `breqn`.

4.6 Auxiliary variables

The model which is solved internally by Dynare is not exactly the model declared by the user. In some cases, Dynare will introduce auxiliary endogenous variables—along with corresponding auxiliary equations—which will appear in the final output.

The main transformation concerns leads and lags. Dynare will perform a transformation of the model so that there is only one lead and one lag on endogenous variables and, in the case of a stochastic model, no leads/lags on exogenous variables.

This transformation is achieved by the creation of auxiliary variables and corresponding equations. For example, if `x(+2)` exists in the model, Dynare will create one auxiliary variable `AUX_ENDO_LEAD = x(+1)`, and replace `x(+2)` by `AUX_ENDO_LEAD(+1)`.

A similar transformation is done for lags greater than 2 on endogenous (auxiliary variables will have a name beginning with `AUX_ENDO_LAG`), and for exogenous with leads and lags (auxiliary variables will have a name beginning with `AUX_EXO_LEAD` or `AUX_EXO_LAG` respectively).

Another transformation is done for the `EXPECTATION` operator. For each occurrence of this operator, Dynare creates an auxiliary variable defined by a new equation, and replaces the expectation operator by a reference to the new auxiliary variable. For example, the expression `EXPECTATION(-1)(x(+1))` is replaced by `AUX_EXPECT_LAG_1(-1)`, and the new auxiliary variable is declared as `AUX_EXPECT_LAG_1 = x(+2)`.

Auxiliary variables are also introduced by the preprocessor for the `ramsey_policy` command. In this case, they are used to represent the Lagrange multipliers when first order conditions of the Ramsey problem are computed. The new variables take the form `MULT_`*i*, where *i* represents the constraint with which the multiplier is associated (counted from the order of declaration in the model block).

The last type of auxiliary variables is introduced by the `differentiate_forward_vars` option of the `model` block. The new variables take the form `AUX_DIFF_FWRD_`*i*, and are equal to `x-x(-1)` for some endogenous variable `x`.

Once created, all auxiliary variables are included in the set of endogenous variables. The output of decision rules (see below) is such that auxiliary variable names are replaced by the original variables they refer to.

The number of endogenous variables before the creation of auxiliary variables is stored in `M_.orig_endo_nbr`, and the number of endogenous variables after the creation of auxiliary variables is stored in `M_.endo_nbr`.

See Dynare Wiki for more technical details on auxiliary variables.

4.7 Initial and terminal conditions

For most simulation exercises, it is necessary to provide initial (and possibly terminal) conditions. It is also necessary to provide initial guess values for non-linear solvers. This section describes the statements used for those purposes.

In many contexts (deterministic or stochastic), it is necessary to compute the steady state of a non-linear model: `initval` then specifies numerical initial values for the non-linear solver. The command `resid` can be used to compute the equation residuals for the given initial values.

Used in perfect foresight mode, the types of forward-looking models for which Dynare was designed require both initial and terminal conditions. Most often these initial and terminal conditions are static equilibria, but not necessarily.

One typical application is to consider an economy at the equilibrium, trigger a shock in first period, and study the trajectory of return at the initial equilibrium. To do that, one needs `initval` and `shocks` (see Section 4.8 [Shocks on exogenous variables], page 27.

Another one is to study, how an economy, starting from arbitrary initial conditions converges toward equilibrium. To do that, one needs `initval` and `endval`.

For models with lags on more than one period, the command `histval` permits to specify different historical initial values for periods before the beginning of the simulation.

`initval` *;* [Block]
`initval (`*OPTIONS...*`);` [Block]

Description

The `initval` block serves two purposes: declaring the initial (and possibly terminal) conditions in a simulation exercise, and providing guess values for non-linear solvers.

This block is terminated by `end;`, and contains lines of the form:

```
VARIABLE_NAME = EXPRESSION;
```

In a deterministic (i.e. perfect foresight) model

First, it provides the initial conditions for all the endogenous and exogenous variables at all the periods preceeding the first simulation period (unless some of these initial values are modified by `histval`).

Second, in the absence of an `endval` block, it sets the terminal conditions for all the periods succeeding the last simulation period.

Third, in the absence of an `endval` block, it provides initial guess values at all simulation dates for the non-linear solver implemented in `simul`.

For this last reason, it necessary to provide values for all the endogenous variables in an `initval` block (even though, theoretically, initial conditions are only necessary for lagged variables). If some variables, endogenous or exogenous, are not mentioned in the `initval` block, a zero value is assumed.

Note that if the `initval` block is immediately followed by a `steady` command, its semantics is changed. The `steady` command will compute the steady state of the model for all the endogenous variables, assuming that exogenous variables are kept constant to the value declared in the `initval` block, and using the values declared for the endogenous as initial guess values for the non-linear solver. An `initval` block followed by `steady` is formally equivalent to an `initval` block with the same values for the exogenous, and with the associated steady state values for the endogenous.

In a stochastic model

The main purpose of `initval` is to provide initial guess values for the non-linear solver in the steady state computation. Note that if the `initval` block is not followed by `steady`, the steady state computation will still be triggered by subsequent commands (`stoch_simul`, `estimation`...).

It is not necessary to declare `0` as initial value for exogenous stochastic variables, since it is the only possible value.

This steady state will be used as the initial condition at all the periods preceeding the first simulation period for the two possible types of simulations in stochastic mode:

- in `stoch_simul`, if the `periods` options is specified
- in `forecast` (in this case, note that it is still possible to modify some of these initial values with `histval`)

Options

`all_values_required`

Issues an error and stops processing the `.mod` file if there is at least one endogenous or exogenous variable that has not been set in the `initval` block.

Example

```
initval;
c = 1.2;
k = 12;
x = 1;
```

```
end;

steady;
```

endval ; [Block]
endval (*OPTIONS...*); [Block]

Description

This block is terminated by `end;`, and contains lines of the form:

```
VARIABLE_NAME = EXPRESSION;
```

The `endval` block makes only sense in a deterministic model, and serves two purposes.

First, it sets the terminal conditions for all the periods succeeding the last simulation period.

Second, it provides initial guess values at all the simulation dates for the non-linear solver implemented in `simul`.

For this last reason, it necessary to provide values for all the endogenous variables in an `endval` block (even though, theoretically, terminal conditions are only necessary for forward variables). If some variables, endogenous or exogenous, are not mentioned in the `endval` block, the value assumed is that of the last `initval` block or `steady` command.

Note that if the `endval` block is immediately followed by a `steady` command, its semantics is changed. The `steady` command will compute the steady state of the model for all the endogenous variables, assuming that exogenous variables are kept constant to the value declared in the `endval` block, and using the values declared for the endogenous as initial guess values for the non-linear solver. An `endval` block followed by `steady` is formally equivalent to an `endval` block with the same values for the exogenous, and with the associated steady state values for the endogenous.

Options

`all_values_required`
    See [all_values_required], page 23.

Example

```
var c k;
varexo x;
...
initval;
c = 1.2;
k = 12;
x = 1;
end;

steady;

endval;
c = 2;
k = 20;
x = 2;
end;

steady;
```

The initial equilibrium is computed by `steady` for `x=1`, and the terminal one, for `x=2`.

Example

```
var c k;
varexo x;
...
model;
c + k - aa*x*k(-1)^alph - (1-delt)*k(-1);
c^(-gam) - (1+bet)^(-1)*(aa*alph*x(+1)*k^(alph-1) + 1 - delt)*c(+1)^(-gam);
end;

initval;
c = 1.2;
k = 12;
x = 1;
end;

endval;
c = 2;
k = 20;
x = 1.1;
end;
simul(periods=200);
```

In this example, the problem is finding the optimal path for consumption and capital for the periods t=1 to T=200, given the path of the exogenous technology level `x`. Setting `x=1.1` in the `endval`-block without a `shocks`-block implies that technology jumps to this new level in t=1 and stays there forever. Because the law of motion for capital is backward-looking, we also need an initial condition for `k` at time 0, specified in the `initval`-block. Similarly, because the Euler equation is forward-looking, we need a terminal condition for `c` at t=201, which is specified in the `endval`-block. Specifying `c` in the `initval`-block and `k` in the `endval`-block has no impact on the results: due to the optimization problem in the first period being to choose `c,k` at t=1 given predetermined capital stock `k` inherited from t=0 as well as the current and future values for technology, the value for `c` at time t=0 plays no role. The same applies to the choice of `c,k` at time t=200, which does not depend on `k` at t=201. As the Euler equation shows, that choice only depends on current capital as well as future consumption `c` and technology `x`, but not on future capital `k`. The intuitive reason is that those variables are the consequence of optimization problems taking place in at periods t=0 and t=201, respectively, which are not considered. Thus, when specifying those values in the `initval` and `endval`-blocks, Dynare takes them as given and basically assumes that there were realizations of exogenous variables and states (basically initial/terminal conditions at the unspecified time periods t<0 and t>201) that make those choices equilibrium values.

This also suggest another way of looking at the use of `steady` after `initval` and `endval`. Instead of saying that the implicit unspecified conditions before and after the simulation range have to fit the initial/terminal conditions of the endogenous variables in those blocks, `steady` specifies that those conditions at t<0 and t>201 are equal to being at the steady state given the exogenous variables in the `initval` and `endval`-blocks and sets the endogenous variables at t=0 and t=201 to the corresponding steady state equilibrium values.

The fact that `c` at t=0 and `k` at t=201 specified in `initval` and `endval` are taken as given has an important implication for plotting the simulated vector for the endogenous variables: this vector will also contain the initial and terminal conditions and thus is 202 periods long in the example. When you specify arbitrary values for the initial and terminal conditions for forward- and backward-looking variables, respectively, these values can be very far away from the endogenously determined values at t=1 and t=200. While the values at t=0 and t=201 are unrelated to the dynamics for 0<t<201, they may result in strange-looking large jumps. In the example above, consumption will display a large jump from t=0 to t=1 and capital will jump from t=200 to t=201.

`histval ;` [Block]

Description

In a deterministic perfect foresight context

In models with lags on more than one period, the `histval` block permits to specify different historical initial values for different periods.

This block is terminated by `end;`, and contains lines of the form:

```
VARIABLE_NAME(INTEGER) = EXPRESSION;
```

EXPRESSION is any valid expression returning a numerical value and can contain already initialized variable names.

By convention in Dynare, period 1 is the first period of the simulation. Going backward in time, the first period before the start of the simulation is period `0`, then period `-1`, and so on.

If your lagged variables are linked by identities, be careful to satisfy these identities when you set historical initial values.

Variables not initialized in the `histval` block are assumed to have a value of zero at period 0 and before. Note that this behavior differs from the case where there is no `histval` block, where all variables are initialized at their steady state value at period 0 and before (except when a `steady` command doesn't follow an `initval` block).

In a stochastic simulation context

In the context of stochastic simulations, `histval` allows setting the starting point of those simulations in the state space (it does not affect the starting point for impulse response functions). As for the case of perfect foresight simulations, all not explicitly specified variables are set to 0. Moreover, as only states enter the recursive policy functions, all values specified for control variables will be ignored.

Example

```
var x y;
varexo e;

model;
x = y(-1)^alpha*y(-2)^(1-alpha)+e;
...
end;

initval;
x = 1;
y = 1;
e = 0.5;
end;

steady;

histval;
y(0) = 1.1;
```

```
y(-1) = 0.9;
end;
```

`resid` *;* [Command]

This command will display the residuals of the static equations of the model, using the values given for the endogenous in the last `initval` or `endval` block (or the steady state file if you provided one, see Section 4.10 [Steady state], page 30).

`initval_file` (*filename* = *FILENAME*)*;* [Command]

Description

In a deterministic setup, this command is used to specify a path for all endogenous and exogenous variables. The length of these paths must be equal to the number of simulation periods, plus the number of leads and the number of lags of the model (for example, with 50 simulation periods, in a model with 2 lags and 1 lead, the paths must have a length of 53). Note that these paths cover two different things:

- the constraints of the problem, which are given by the path for exogenous and the initial and terminal values for endogenous
- the initial guess for the non-linear solver, which is given by the path for endogenous variables for the simulation periods (excluding initial and terminal conditions)

The command accepts three file formats:

- M-file (extension `.m`): for each endogenous and exogenous variable, the file must contain a row vector of the same name.
- MAT-file (extension `.mat`): same as for M-files.
- Excel file (extension `.xls` or `.xlsx`): for each endogenous and exogenous, the file must contain a column of the same name (supported under Octave if the io and java packages from Octave-Forge are installed, along with a Java Runtime Environment).

Warning

The extension must be omitted in the command argument. Dynare will automatically figure out the extension and select the appropriate file type.

4.8 Shocks on exogenous variables

In a deterministic context, when one wants to study the transition of one equilibrium position to another, it is equivalent to analyze the consequences of a permanent shock and this in done in Dynare through the proper use of `initval` and `endval`.

Another typical experiment is to study the effects of a temporary shock after which the system goes back to the original equilibrium (if the model is stable. . .). A temporary shock is a temporary change of value of one or several exogenous variables in the model. Temporary shocks are specified with the command `shocks`.

In a stochastic framework, the exogenous variables take random values in each period. In Dynare, these random values follow a normal distribution with zero mean, but it belongs to the user to specify the variability of these shocks. The non-zero elements of the matrix of variance-covariance of the shocks can be entered with the `shocks` command. Or, the entire matrix can be directly entered with `Sigma_e` (this use is however deprecated).

If the variance of an exogenous variable is set to zero, this variable will appear in the report on policy and transition functions, but isn't used in the computation of moments and of Impulse Response Functions. Setting a variance to zero is an easy way of removing an exogenous shock.

shocks *;* [Block]

In deterministic context

For deterministic simulations, the `shocks` block specifies temporary changes in the value of exogenous variables. For permanent shocks, use an `endval` block.

The block should contain one or more occurrences of the following group of three lines:

```
var VARIABLE_NAME;
periods INTEGER[:INTEGER] [[,] INTEGER[:INTEGER]]...;
values DOUBLE | (EXPRESSION)  [[,] DOUBLE | (EXPRESSION) ]...;
```

It is possible to specify shocks which last several periods and which can vary over time. The `periods` keyword accepts a list of several dates or date ranges, which must be matched by as many shock values in the `values` keyword. Note that a range in the `periods` keyword can be matched by only one value in the `values` keyword. If `values` represents a scalar, the same value applies to the whole range. If `values` represents a vector, it must have as many elements as there are periods in the range.

Note that shock values are not restricted to numerical constants: arbitrary expressions are also allowed, but you have to enclose them inside parentheses.

Here is an example:

```
shocks;
var e;
periods 1;
values 0.5;
var u;
periods 4:5;
values 0;
var v;
periods 4:5 6 7:9;
values 1 1.1 0.9;
var w;
periods 1 2;
values (1+p) (exp(z));
end;
```

A second example with a vector of values:

```
xx = [1.2; 1.3; 1];

shocks;
var e;
periods 1:3;
values (xx);
end;
```

In stochastic context

For stochastic simulations, the `shocks` block specifies the non zero elements of the covariance matrix of the shocks of exogenous variables.

You can use the following types of entries in the block:

`var` *VARIABLE_NAME*`; stderr` *EXPRESSION*`;`
: Specifies the standard error of a variable.

`var` *VARIABLE_NAME* `=` *EXPRESSION*`;`
: Specifies the variance error of a variable.

`var` *VARIABLE_NAME*, *VARIABLE_NAME* = *EXPRESSION*;
: Specifies the covariance of two variables.

`corr` *VARIABLE_NAME*, *VARIABLE_NAME* = *EXPRESSION*;
: Specifies the correlation of two variables.

In an estimation context, it is also possible to specify variances and covariances on endogenous variables: in that case, these values are interpreted as the calibration of the measurement errors on these variables. This requires the `var_obs`-command to be specified before the `shocks`-block.

Here is an example:

```
shocks;
var e = 0.000081;
var u; stderr 0.009;
corr e, u = 0.8;
var v, w = 2;
end;
```

Mixing deterministic and stochastic shocks

It is possible to mix deterministic and stochastic shocks to build models where agents know from the start of the simulation about future exogenous changes. In that case `stoch_simul` will compute the rational expectation solution adding future information to the state space (nothing is shown in the output of `stoch_simul`) and `forecast` will compute a simulation conditional on initial conditions and future information.

Here is an example:

```
varexo_det tau;
varexo e;

...

shocks;
var e; stderr 0.01;
var tau;
periods 1:9;
values -0.15;
end;

stoch_simul(irf=0);

forecast;
```

`mshocks` *;* [Block]

The purpose of this block is similar to that of the `shocks` block for deterministic shocks, except that the numeric values given will be interpreted in a multiplicative way. For example, if a value of `1.05` is given as shock value for some exogenous at some date, it means 5% above its steady state value (as given by the last `initval` or `endval` block).

The syntax is the same than `shocks` in a deterministic context.

This command is only meaningful in two situations:

- on exogenous variables with a non-zero steady state, in a deterministic setup,
- on deterministic exogenous variables with a non-zero steady state, in a stochastic setup.

`Sigma_e` [Special variable]

Warning

The use of this special variable is deprecated and is strongly discouraged. You should use a `shocks` block instead.

Description

This special variable specifies directly the covariance matrix of the stochastic shocks, as an upper (or lower) triangular matrix. Dynare builds the corresponding symmetric matrix. Each row of the triangular matrix, except the last one, must be terminated by a semi-colon `;`. For a given element, an arbitrary *EXPRESSION* is allowed (instead of a simple constant), but in that case you need to enclose the expression in parentheses. *The order of the covariances in the matrix is the same as the one used in the* `varexo` *declaration.*

Example

```
varexo u, e;
...
Sigma_e = [ 0.81 (phi*0.9*0.009);
            0.000081];
```

This sets the variance of `u` to 0.81, the variance of `e` to 0.000081, and the correlation between `e` and `u` to `phi`.

4.9 Other general declarations

`dsample` *`INTEGER` [`INTEGER`];* [Command]

Reduces the number of periods considered in subsequent output commands.

`periods` *`INTEGER`;* [Command]

Description

This command is now deprecated (but will still work for older model files). It is not necessary when no simulation is performed and is replaced by an option `periods` in `simul` and `stoch_simul`.

This command sets the number of periods in the simulation. The periods are numbered from `1` to *INTEGER*. In perfect foresight simulations, it is assumed that all future events are perfectly known at the beginning of period `1`.

Example

```
periods 100;
```

4.10 Steady state

There are two ways of computing the steady state (*i.e.* the static equilibrium) of a model. The first way is to let Dynare compute the steady state using a nonlinear Newton-type solver; this should work for most models, and is relatively simple to use. The second way is to give more guidance to Dynare, using your knowledge of the model, by providing it with a "steady state file".

4.10.1 Finding the steady state with Dynare nonlinear solver

`steady` *;* [Command]
`steady` *(`OPTIONS...`);* [Command]

Description

This command computes the steady state of a model using a nonlinear Newton-type solver and displays it. When a steady state file is used `steady` displays the steady state and checks that it is a solution of the static model.

More precisely, it computes the equilibrium value of the endogenous variables for the value of the exogenous variables specified in the previous `initval` or `endval` block.

`steady` uses an iterative procedure and takes as initial guess the value of the endogenous variables set in the previous `initval` or `endval` block.

For complicated models, finding good numerical initial values for the endogenous variables is the trickiest part of finding the equilibrium of that model. Often, it is better to start with a smaller model and add new variables one by one.

Options

`maxit = INTEGER`
: Determines the maximum number of iterations used in the non-linear solver. The default value of `maxit` is 10. The `maxit` option is shared with the `simul` command. So a change in `maxit` in a `steady` command will also be considered in the following `simul` commands.

`solve_algo = INTEGER`
: Determines the non-linear solver to use. Possible values for the option are:

  `0` Use `fsolve` (under MATLAB, only available if you have the Optimization Toolbox; always available under Octave)

  `1` Use Dynare's own nonlinear equation solver (a Newton-like algorithm with line-search)

  `2` Splits the model into recursive blocks and solves each block in turn using the same solver as value `1`

  `3` Use Chris Sims' solver

  `4` Same as value `2`, except that it does not try to adapt the search direction when the Jacobian is nearly singular

  `5` Newton algorithm with a sparse Gaussian elimination (SPE) (requires `bytecode` option, see Section 4.5 [Model declaration], page 18)

  `6` Newton algorithm with a sparse LU solver at each iteration (requires `bytecode` and/or `block` option, see Section 4.5 [Model declaration], page 18)

  `7` Newton algorithm with a Generalized Minimal Residual (GMRES) solver at each iteration (requires `bytecode` and/or `block` option, see Section 4.5 [Model declaration], page 18; not available under Octave)

  `8` Newton algorithm with a Stabilized Bi-Conjugate Gradient (BICGSTAB) solver at each iteration (requires `bytecode` and/or `block` option, see Section 4.5 [Model declaration], page 18)

  Default value is `2`.

`homotopy_mode = INTEGER`
: Use a homotopy (or divide-and-conquer) technique to solve for the steady state. If you use this option, you must specify a `homotopy_setup` block. This option can take three possible values:

  `1` In this mode, all the parameters are changed simultaneously, and the distance between the boundaries for each parameter is divided in as many intervals as there are steps (as defined by `homotopy_steps` option); the problem is solves as many times as there are steps.

`2` Same as mode `1`, except that only one parameter is changed at a time; the problem is solved as many times as steps times number of parameters.

`3` Dynare tries first the most extreme values. If it fails to compute the steady state, the interval between initial and desired values is divided by two for all parameters. Every time that it is impossible to find a steady state, the previous interval is divided by two. When it succeeds to find a steady state, the previous interval is multiplied by two. In that last case `homotopy_steps` contains the maximum number of computations attempted before giving up.

`homotopy_steps = ` *`INTEGER`*
Defines the number of steps when performing a homotopy. See `homotopy_mode` option for more details.

`homotopy_force_continue = ` *`INTEGER`*
This option controls what happens when homotopy fails.

`0` `steady` fails with an error message

`1` `steady` keeps the values of the last homotopy step that was successful and continues. BE CAREFUL: parameters and/or exogenous variables are NOT at the value expected by the user

Default is `0`.

`nocheck` Don't check the steady state values when they are provided explicitly either by a steady state file or a `steady_state_model` block. This is useful for models with unit roots as, in this case, the steady state is not unique or doesn't exist.

`markowitz = ` *`DOUBLE`*
Value of the Markowitz criterion, used to select the pivot. Only used when `solve_algo = 5`. Default: `0.5`.

Example

See Section 4.7 [Initial and terminal conditions], page 22.

After computation, the steady state is available in the following variable:

`oo_.steady_state` [MATLAB/Octave variable]

Contains the computed steady state.

Endogenous variables are ordered in order of declaration used in `var` command (which is also the order used in `M_.endo_names`).

`homotopy_setup` *;* [Block]

Description

This block is used to declare initial and final values when using a homotopy method. It is used in conjunction with the option `homotopy_mode` of the `steady` command.

The idea of homotopy (also called divide-and-conquer by some authors) is to subdivide the problem of finding the steady state into smaller problems. It assumes that you know how to compute the steady state for a given set of parameters, and it helps you finding the steady state for another set of parameters, by incrementally moving from one to another set of parameters.

The purpose of the `homotopy_setup` block is to declare the final (and possibly also the initial) values for the parameters or exogenous that will be changed during the homotopy. It should contain lines of the form:

    VARIABLE_NAME, EXPRESSION, EXPRESSION;

This syntax specifies the initial and final values of a given parameter/exogenous.

There is an alternative syntax:

    VARIABLE_NAME, EXPRESSION;

Here only the final value is specified for a given parameter/exogenous; the initial value is taken from the preceeding `initval` block.

A necessary condition for a successful homotopy is that Dynare must be able to solve the steady state for the initial parameters/exogenous without additional help (using the guess values given in the `initval` block).

If the homotopy fails, a possible solution is to increase the number of steps (given in `homotopy_steps` option of `steady`).

Example

In the following example, Dynare will first compute the steady state for the initial values (`gam=0.5` and `x=1`), and then subdivide the problem into 50 smaller problems to find the steady state for the final values (`gam=2` and `x=2`).

```
var c k;
varexo x;

parameters alph gam delt bet aa;
alph=0.5;
delt=0.02;
aa=0.5;
bet=0.05;

model;
c + k - aa*x*k(-1)^alph - (1-delt)*k(-1);
c^(-gam) - (1+bet)^(-1)*(aa*alph*x(+1)*k^(alph-1) + 1 - delt)*c(+1)^(-gam);
end;

initval;
x = 1;
k = ((delt+bet)/(aa*x*alph))^(1/(alph-1));
c = aa*x*k^alph-delt*k;
end;

homotopy_setup;
gam, 0.5, 2;
x, 2;
end;

steady(homotopy_mode = 1, homotopy_steps = 50);
```

4.10.2 Using a steady state file

If you know how to compute the steady state for your model, you can provide a MATLAB/Octave function doing the computation instead of using `steady`. Again, there are two options for doing that:

- The easiest way is to write a `steady_state_model` block, which is described below in more details. See also `fs2000.mod` in the `examples` directory for an example.

  The steady state file generated by Dynare will be called *`FILENAME`*`_steadystate2.m`.
- You can write the corresponding MATLAB function by hand. If your MOD-file is called *`FILENAME`*`.mod`, the steady state file must be called *`FILENAME`*`_steadystate.m`. See `NK_baseline_steadystate.m` in the `examples` directory for an example. This option gives a bit more flexibility, at the expense of a heavier programming burden and a lesser efficiency.

Note that both files allow to update parameters in each call of the function. This allows for example to calibrate a model to a labor supply of 0.2 in steady state by setting the labor disutility parameter to a corresponding value (see `NK_baseline_steadystate.m` in the `examples` directory). They can also be used in estimation where some parameter may be a function of an estimated parameter and needs to be updated for every parameter draw. For example, one might want to set the capital utilization cost parameter as a function of the discount rate to ensure that capacity utilization is 1 in steady state. Treating both parameters as independent or not updating one as a function of the other would lead to wrong results. But this also means that care is required. Do not accidentally overwrite your parameters with new values as it will lead to wrong results.

`steady_state_model` *;* [Block]

Description

When the analytical solution of the model is known, this command can be used to help Dynare find the steady state in a more efficient and reliable way, especially during estimation where the steady state has to be recomputed for every point in the parameter space.

Each line of this block consists of a variable (either an endogenous, a temporary variable or a parameter) which is assigned an expression (which can contain parameters, exogenous at the steady state, or any endogenous or temporary variable already declared above). Each line therefore looks like:

```
VARIABLE_NAME = EXPRESSION;
```

Note that it is also possible to assign several variables at the same time, if the main function in the right hand side is a MATLAB/Octave function returning several arguments:

```
[ VARIABLE_NAME, VARIABLE_NAME... ] = EXPRESSION;
```

Dynare will automatically generate a steady state file (of the form *`FILENAME`*`_steadystate2.m`) using the information provided in this block.

Steady state file for deterministic models

`steady_state_model` block works also with deterministic models. An `initval` block and, when necessary, an `endval` block, is used to set the value of the exogenous variables. Each `initval` or `endval` block must be followed by `steady` to execute the function created by `steady_state_model` and set the initial, respectively terminal, steady state.

Example

```
var m P c e W R k d n l gy_obs gp_obs y dA;
varexo e_a e_m;

parameters alp bet gam mst rho psi del;

...
// parameter calibration, (dynamic) model declaration, shock calibration...
...
```

```
steady_state_model;
  dA = exp(gam);
  gst = 1/dA; // A temporary variable
  m = mst;

  // Three other temporary variables
  khst = ( (1-gst*bet*(1-del)) / (alp*gst^alp*bet) )^(1/(alp-1));
  xist = ( ((khst*gst)^alp - (1-gst*(1-del))*khst)/mst )^(-1);
  nust = psi*mst^2/( (1-alp)*(1-psi)*bet*gst^alp*khst^alp );

  n  = xist/(nust+xist);
  P  = xist + nust;
  k  = khst*n;

  l  = psi*mst*n/( (1-psi)*(1-n) );
  c  = mst/P;
  d  = l - mst + 1;
  y  = k^alp*n^(1-alp)*gst^alp;
  R  = mst/bet;

  // You can use MATLAB functions which return several arguments
  [W, e] = my_function(l, n);

  gp_obs = m/dA;
  gy_obs = dA;
end;

steady;
```

4.10.3 Replace some equations during steady state computations

When there is no steady state file, Dynare computes the steady state by solving the static model, *i.e.* the model from the `.mod` file from which leads and lags have been removed.

In some specific cases, one may want to have more control over the way this static model is created. Dynare therefore offers the possibility to explicitly give the form of equations that should be in the static model.

More precisely, if an equation is prepended by a `[static]` tag, then it will appear in the static model used for steady state computation, but that equation will not be used for other computations. For every equation tagged in this way, you must tag another equation with `[dynamic]`: that equation will not be used for steady state computation, but will be used for other computations.

This functionality can be useful on models with a unit root, where there is an infinity of steady states. An equation (tagged `[dynamic]`) would give the law of motion of the nonstationary variable (like a random walk). To pin down one specific steady state, an equation tagged `[static]` would affect a constant value to the nonstationary variable.

Example

This is a trivial example with two endogenous variables. The second equation takes a different form in the static model.

```
var c k;
varexo x;

...
```

```
model;
c + k - aa*x*k(-1)^alph - (1-delt)*k(-1);
[dynamic] c^(-gam) - (1+bet)^(-1)*(aa*alph*x(+1)*k^(alph-1) + 1 - delt)*c(+1)^(-gam);
[static] k = ((delt+bet)/(x*aa*alph))^(1/(alph-1));
end;
```

4.11 Getting information about the model

`check` *;* [Command]
`check` (*solve_algo* = *INTEGER*) *;* [Command]

Description

Computes the eigenvalues of the model linearized around the values specified by the last `initval`, `endval` or `steady` statement. Generally, the eigenvalues are only meaningful if the linearization is done around a steady state of the model. It is a device for local analysis in the neighborhood of this steady state.

A necessary condition for the uniqueness of a stable equilibrium in the neighborhood of the steady state is that there are as many eigenvalues larger than one in modulus as there are forward looking variables in the system. An additional rank condition requires that the square submatrix of the right Schur vectors corresponding to the forward looking variables (jumpers) and to the explosive eigenvalues must have full rank.

Options

`solve_algo = INTEGER`
: See [solve_algo], page 31, for the possible values and their meaning.

`qz_zero_threshold = DOUBLE`
: Value used to test if a generalized eigenvalue is 0/0 in the generalized Schur decomposition (in which case the model does not admit a unique solution). Default: `1e-6`.

Output

`check` returns the eigenvalues in the global variable `oo_.dr.eigval`.

`oo_.dr.eigval` [MATLAB/Octave variable]
Contains the eigenvalues of the model, as computed by the `check` command.

`model_diagnostics` *;* [Command]
This command performs various sanity checks on the model, and prints a message if a problem is detected (missing variables at current period, invalid steady state, singular Jacobian of static model).

`model_info` *;* [Command]
`model_info` (*OPTIONS...*)*;* [Command]

Description

This command provides information about:

- the normalization of the model: an endogenous variable is attributed to each equation of the model;
- the block structure of the model: for each block model_info indicates its type, the equations number and endogenous variables belonging to this block.

This command can only be used in conjunction with the `block` option of the `model` block.

There are five different types of blocks depending on the simulation method used:

'`EVALUATE FORWARD`'
: In this case the block contains only equations where endogenous variable attributed to the equation appears currently on the left hand side and where no forward looking endogenous variables appear. The block has the form: $y_{j,t} = f_j(y_t, y_{t-1}, \ldots, y_{t-k})$.

'`EVALUATE BACKWARD`'
: The block contains only equations where endogenous variable attributed to the equation appears currently on the left hand side and where no backward looking endogenous variables appear. The block has the form: $y_{j,t} = f_j(y_t, y_{t+1}, \ldots, y_{t+k})$.

'`SOLVE FORWARD` *x*'
: The block contains only equations where endogenous variable attributed to the equation does not appear currently on the left hand side and where no forward looking endogenous variables appear. The block has the form: $g_j(y_{j,t}, y_t, y_{t-1}, \ldots, y_{t-k}) = 0$. x is equal to '`SIMPLE`' if the block has only one equation. If several equation appears in the block, x is equal to '`COMPLETE`'.

'`SOLVE FORWARD` *x*'
: The block contains only equations where endogenous variable attributed to the equation does not appear currently on the left hand side and where no backward looking endogenous variables appear. The block has the form: $g_j(y_{j,t}, y_t, y_{t+1}, \ldots, y_{t+k}) = 0$. x is equal to '`SIMPLE`' if the block has only one equation. If several equation appears in the block, x is equal to '`COMPLETE`'.

'`SOLVE TWO BOUNDARIES` *x*'
: The block contains equations depending on both forward and backward variables. The block looks like: $g_j(y_{j,t}, y_t, y_{t-1}, \ldots, y_{t-k}, y_t, y_{t+1}, \ldots, y_{t+k}) = 0$. x is equal to '`SIMPLE`' if the block has only one equation. If several equation appears in the block, x is equal to '`COMPLETE`'.

Options

`'static'`
: Prints out the block decomposition of the static model. Without 'static' option model_info displays the block decomposition of the dynamic model.

`'incidence'`
: Displays the gross incidence matrix and the reordered incidence matrix of the block decomposed model.

`print_bytecode_dynamic_model` *;* [Command]

Prints the equations and the Jacobian matrix of the dynamic model stored in the bytecode binary format file. Can only be used in conjunction with the `bytecode` option of the `model` block.

`print_bytecode_static_model` *;* [Command]

Prints the equations and the Jacobian matrix of the static model stored in the bytecode binary format file. Can only be used in conjunction with the `bytecode` option of the `model` block.

4.12 Deterministic simulation

When the framework is deterministic, Dynare can be used for models with the assumption of perfect foresight. Typically, the system is supposed to be in a state of equilibrium before a period '`1`' when the news of a contemporaneous or of a future shock is learned by the agents in the model. The purpose of the simulation is to describe the reaction in anticipation of, then in reaction to the shock, until the system returns to the old or to a new state of equilibrium. In most models, this return to equilibrium is only an asymptotic phenomenon, which one must approximate by an horizon of simulation far enough in the future. Another exercise for which Dynare is well suited is to study the transition path to a new equilibrium following a permanent shock. For deterministic simulations, the numerical problem consists of solving a nonlinar system of simultaneous equations in `n` endogenous variables in `T` periods. Dynare offers several algorithms for solving this problem, which can be chosen via the `stack_solve_algo`-option. By default (`stack_solve_algo=0`), Dynare uses a Newton-type method to solve the simultaneous equation system. Because the resulting Jacobian is in the order of `n` by `T` and hence will be very large for long simulations with many variables, Dynare makes use of the sparse matrix capacities of MATLAB/Octave. A slower but potentially less memory consuming alternative (`stack_solve_algo=6`) is based on a Newton-type algorithm first proposed by *Laffargue (1990)* and *Boucekkine (1995)*, which uses relaxation techniques. Thereby, the algorithm avoids ever storing the full Jacobian. The details of the algorithm can be found in *Juillard (1996)*. The third type of algorithms makes use of block decomposition techniques (divide-and-conquer methods) that exploit the structure of the model. The principle is to identify recursive and simultaneous blocks in the model structure and use this information to aid the solution process. These solution algorithms can provide a significant speed-up on large models.

`simul` *;* [Command]
`simul (`*OPTIONS...*`);` [Command]

Description

Triggers the computation of a deterministic simulation of the model for the number of periods set in the option `periods`.

Options

`periods = ` *INTEGER*

Number of periods of the simulation

`maxit = ` *INTEGER*

Determines the maximum number of iterations used in the non-linear solver. The default value of `maxit` is 10. The `maxit` option is shared with the `steady` command. So a change in `maxit` in a `simul` command will also be considered in the following `steady` commands.

`stack_solve_algo = ` *INTEGER*

Algorithm used for computing the solution. Possible values are:

`0` Newton method to solve simultaneously all the equations for every period, using sparse matrices (Default).

`1` Use a Newton algorithm with a sparse LU solver at each iteration (requires `bytecode` and/or `block` option, see Section 4.5 [Model declaration], page 18).

`2` Use a Newton algorithm with a Generalized Minimal Residual (GMRES) solver at each iteration (requires `bytecode` and/or `block` option, see Section 4.5 [Model declaration], page 18; not available under Octave)

`3` Use a Newton algorithm with a Stabilized Bi-Conjugate Gradient (BICGSTAB) solver at each iteration (requires `bytecode` and/or `block` option, see Section 4.5 [Model declaration], page 18).

`4` Use a Newton algorithm with a optimal path length at each iteration (requires `bytecode` and/or `block` option, see Section 4.5 [Model declaration], page 18).

`5` Use a Newton algorithm with a sparse Gaussian elimination (SPE) solver at each iteration (requires `bytecode` option, see Section 4.5 [Model declaration], page 18).

`6` Use the historical algorithm proposed in *Juillard (1996)*: it is slower than `stack_solve_algo=0`, but may be less memory consuming on big models (not available with `bytecode` and/or `block` options).

`markowitz = DOUBLE`
Value of the Markowitz criterion, used to select the pivot. Only used when `stack_solve_algo = 5`. Default: `0.5`.

`minimal_solving_periods = INTEGER`
Specify the minimal number of periods where the model has to be solved, before using a constant set of operations for the remaining periods. Only used when `stack_solve_algo = 5`. Default: `1`.

`datafile = FILENAME`
If the variables of the model are not constant over time, their initial values, stored in a text file, could be loaded, using that option, as initial values before a deterministic simulation.

Output

The simulated endogenous variables are available in global matrix `oo_.endo_simul`.

`oo_.endo_simul` [MATLAB/Octave variable]

This variable stores the result of a deterministic simulation (computed by `simul`) or of a stochastic simulation (computed by `stoch_simul` with the `periods` option or by `extended_path`).

The variables are arranged row by row, in order of declaration (as in `M_.endo_names`). Note that this variable also contains initial and terminal conditions, so it has more columns than the value of `periods` option.

`oo_.exo_simul` [MATLAB/Octave variable]

This variable stores the path of exogenous variables during a simulation (computed by `simul`, `stoch_simul` or `extended_path`).

The variables are arranged in columns, in order of declaration (as in `M_.endo_names`). Periods are in rows. Note that this convention regarding columns and rows is the opposite of the convention for `oo_.endo_simul`!

4.13 Stochastic solution and simulation

In a stochastic context, Dynare computes one or several simulations corresponding to a random draw of the shocks.

The main algorithm for solving stochastic models relies on a Taylor approximation, up to third order, of the expectation functions (see *Judd (1996)*, *Collard and Juillard (2001a)*, *Collard and Juillard (2001b)*, and *Schmitt-Grohé and Urı́be (2004)*). The details of the Dynare implementation of the first order solution are given in *Villemot (2011)*. Such a solution is computed using the `stoch_simul` command.

As an alternative, it is possible to compute a simulation to a stochastic model using the *extended path* method presented by *Fair and Taylor (1983)*. This method is especially useful when there are strong nonlinearities or binding constraints. Such a solution is computed using the `extended_path` command.

4.13.1 Computing the stochastic solution

`stoch_simul [VARIABLE_NAME...];` [Command]
`stoch_simul (OPTIONS...) [VARIABLE_NAME...];` [Command]

Description

`stoch_simul` solves a stochastic (*i.e.* rational expectations) model, using perturbation techniques.

More precisely, `stoch_simul` computes a Taylor approximation of the decision and transition functions for the model. Using this, it computes impulse response functions and various descriptive statistics (moments, variance decomposition, correlation and autocorrelation coefficients). For correlated shocks, the variance decomposition is computed as in the VAR literature through a Cholesky decomposition of the covariance matrix of the exogenous variables. When the shocks are correlated, the variance decomposition depends upon the order of the variables in the `varexo` command.

The Taylor approximation is computed around the steady state (see Section 4.10 [Steady state], page 30).

The IRFs are computed as the difference between the trajectory of a variable following a shock at the beginning of period 1 and its steady state value. More details on the computation of IRFs can be found on the DynareWiki.

Variance decomposition, correlation, autocorrelation are only displayed for variables with strictly positive variance. Impulse response functions are only plotted for variables with response larger than 10^{-10}.

Variance decomposition is computed relative to the sum of the contribution of each shock. Normally, this is of course equal to aggregate variance, but if a model generates very large variances, it may happen that, due to numerical error, the two differ by a significant amount. Dynare issues a warning if the maximum relative difference between the sum of the contribution of each shock and aggregate variance is larger than 0.01%.

The covariance matrix of the shocks is specified with the `shocks` command (see Section 4.8 [Shocks on exogenous variables], page 27).

When a list of *VARIABLE_NAME* is specified, results are displayed only for these variables.

The `stoch_simul` command with a first order approximation can benefit from the block decomposition of the model (see [block], page 19).

Options

`ar = INTEGER`
: Order of autocorrelation coefficients to compute and to print. Default: `5`.

`drop = INTEGER`
: Number of points (burnin) dropped at the beginning of simulation before computing the summary statistics. Note that this option does not affect the simulated series stored in *oo_.endo_simul* and the workspace. Here, no periods are dropped. Default: `100`.

`hp_filter = DOUBLE`
: Uses HP filter with λ = *DOUBLE* before computing moments. Default: no filter.

`hp_ngrid = INTEGER`
: Number of points in the grid for the discrete Inverse Fast Fourier Transform used in the HP filter computation. It may be necessary to increase it for highly autocorrelated processes. Default: `512`.

`irf = INTEGER`
: Number of periods on which to compute the IRFs. Setting `irf=0`, suppresses the plotting of IRFs. Default: `40`.

`irf_shocks = ( VARIABLE_NAME [[,] VARIABLE_NAME ...] )`
: The exogenous variables for which to compute IRFs. Default: all.

`relative_irf`
: Requests the computation of normalized IRFs in percentage of the standard error of each shock.

`irf_plot_threshold = DOUBLE`
: Threshold size for plotting IRFs. All IRFs for a particular variable with a maximum absolute deviation from the steady state smaller than this value are not displayed. Default: `1e-10`.

`nocorr`
: Don't print the correlation matrix (printing them is the default).

`nofunctions`
: Don't print the coefficients of the approximated solution (printing them is the default).

`nomoments`
: Don't print moments of the endogenous variables (printing them is the default).

`nograph`
: Do not create graphs (which implies that they are not saved to the disk nor displayed). If this option is not used, graphs will be saved to disk (to the format specified by `graph_format` option, except if `graph_format=none`) and displayed to screen (unless `nodisplay` option is used).

`nodisplay`
: Do not display the graphs, but still save them to disk (unless `nograph` is used).

`graph_format = FORMAT`
`graph_format = ( FORMAT, FORMAT... )`
: Specify the file format(s) for graphs saved to disk. Possible values are `eps` (the default), `pdf`, `fig` and `none` (under Octave, only `eps` and `none` are available). If the file format is set equal to `none`, the graphs are displayed but not saved to the disk.

`noprint`
: Don't print anything. Useful for loops.

`print`
: Print results (opposite of `noprint`).

`order = INTEGER`
: Order of Taylor approximation. Acceptable values are `1`, `2` and `3`. Note that for third order, `k_order_solver` option is implied and only empirical moments are available (you must provide a value for `periods` option). Default: `2` (except after an `estimation` command, in which case the default is the value used for the estimation).

`k_order_solver`
: Use a k-order solver (implemented in C++) instead of the default Dynare solver. This option is not yet compatible with the `bytecode` option (see Section 4.5 [Model declaration], page 18. Default: disabled for order 1 and 2, enabled otherwise

`periods = INTEGER`
: If different from zero, empirical moments will be computed instead of theoretical moments. The value of the option specifies the number of periods to use in the simulations. Values of the `initval` block, possibly recomputed by `steady`, will be used as starting point for the simulation. The simulated endogenous variables are

made available to the user in a vector for each variable and in the global matrix `oo_.endo_simul` (see [oo_.endo_simul], page 39). The simulated exogenous variables are made available in `oo_.exo_simul` (see [oo_.exo_simul], page 39). Default: `0`.

`qz_criterium = DOUBLE`
: Value used to split stable from unstable eigenvalues in reordering the Generalized Schur decomposition used for solving 1^st order problems. Default: `1.000001` (except when estimating with `lik_init` option equal to `1`: the default is `0.999999` in that case; see Section 4.14 [Estimation], page 48).

`qz_zero_threshold = DOUBLE`
: See [qz_zero_threshold], page 36.

`replic = INTEGER`
: Number of simulated series used to compute the IRFs. Default: `1` if `order`=`1`, and `50` otherwise.

`simul_replic = INTEGER`
: Number of series to simulate when empirical moments are requested (*i.e.* `periods` > 0). Note that if this option is greater than `1`, the additional series will not be used for computing the empirical moments but will simply be saved in binary form to the file `FILENAME_simul`. Default: `1`.

`solve_algo = INTEGER`
: See [solve_algo], page 31, for the possible values and their meaning.

`aim_solver`
: Use the Anderson-Moore Algorithm (AIM) to compute the decision rules, instead of using Dynare's default method based on a generalized Schur decomposition. This option is only valid for first order approximation. See AIM website for more details on the algorithm.

`conditional_variance_decomposition = INTEGER`
: See below.

`conditional_variance_decomposition = [INTEGER1:INTEGER2]`
: See below.

`conditional_variance_decomposition = [INTEGER1 INTEGER2 ...]`
: Computes a conditional variance decomposition for the specified period(s). The periods must be strictly positive. Conditional variances are given by $var(y_{t+k}|t)$. For period 1, the conditional variance decomposition provides the decomposition of the effects of shocks upon impact. The results are stored in `oo_.conditional_variance_decomposition` (see [oo_.conditional_variance_decomposition], page 45). The variance decomposition is only conducted, if theoretical moments are requested, i.e. using the `periods=0`-option. In case of `order=2`, Dynare provides a second-order accurate approximation to the true second moments based on the linear terms of the second-order solution (see *Kim, Kim, Schaumburg and Sims (2008)*). Note that the unconditional variance decomposition (i.e. at horizon infinity) is automatically conducted if theoretical moments are requested (see [oo_.variance_decomposition], page 45)

`pruning`
: Discard higher order terms when iteratively computing simulations of the solution. At second order, Dynare uses the algorithm of *Kim, Kim, Schaumburg and Sims (2008)*, while at third order its generalization by *Andreasen, Fernández-Villaverde and Rubio-Ramírez (2013)* is used.

`partial_information`
: Computes the solution of the model under partial information, along the lines of *Pearlman, Currie and Levine (1986)*. Agents are supposed to observe only some

variables of the economy. The set of observed variables is declared using the `varobs` command. Note that if `varobs` is not present or contains all endogenous variables, then this is the full information case and this option has no effect. More references can be found at `http://www.dynare.org/DynareWiki/PartialInformation`.

`sylvester = OPTION`
: Determines the algorithm used to solve the Sylvester equation for block decomposed model. Possible values for *OPTION* are:

  `default` Uses the default solver for Sylvester equations (`gensylv`) based on Ondra Kamenik's algorithm (see the Dynare Website for more information).

  `fixed_point`
  Uses a fixed point algorithm to solve the Sylvester equation (`gensylv_fp`). This method is faster than the `default` one for large scale models.

  Default value is `default`

`sylvester_fixed_point_tol = DOUBLE`
: It is the convergence criterion used in the fixed point Sylvester solver. Its default value is 1e-12.

`dr = OPTION`
: Determines the method used to compute the decision rule. Possible values for *OPTION* are:

  `default` Uses the default method to compute the decision rule based on the generalized Schur decomposition (see *Villemot (2011)* for more information).

  `cycle_reduction`
  Uses the cycle reduction algorithm to solve the polynomial equation for retrieving the coefficients associated to the endogenous variables in the decision rule. This method is faster than the `default` one for large scale models.

  `logarithmic_reduction`
  Uses the logarithmic reduction algorithm to solve the polynomial equation for retrieving the coefficients associated to the endogenous variables in the decision rule. This method is in general slower than the `cycle_reduction`.

  Default value is `default`

`dr_cycle_reduction_tol = DOUBLE`
: The convergence criterion used in the cycle reduction algorithm. Its default value is 1e-7.

`dr_logarithmic_reduction_tol = DOUBLE`
: The convergence criterion used in the logarithmic reduction algorithm. Its default value is 1e-12.

`dr_logarithmic_reduction_maxiter = INTEGER`
: The maximum number of iterations used in the logarithmic reduction algorithm. Its default value is 100.

`loglinear`
: See [loglinear], page 53. Note that ALL variables are log-transformed by using the Jacobian transformation, not only selected ones. Thus, you have to make sure that your variables have strictly positive steady states. `stoch_simul` will display the

moments, decision rules, and impulse responses for the log-linearized variables. The decision rules saved in `oo_.dr` and the simulated variables will also be the ones for the log-linear variables.

Output

This command sets `oo_.dr`, `oo_.mean`, `oo_.var` and `oo_.autocorr`, which are described below.

If option `periods` is present, sets `oo_.endo_simul` (see [oo_.endo_simul], page 39), and also saves the simulated variables in MATLAB/Octave vectors of the global workspace with the same name as the endogenous variables.

If options `irf` is different from zero, sets `oo_.irfs` (see below) and also saves the IRFs in MATLAB/Octave vectors of the global workspace (this latter way of accessing the IRFs is deprecated and will disappear in a future version).

Example 1

```
shocks;
var e;
stderr 0.0348;
end;

stoch_simul;
```

Performs the simulation of the 2nd order approximation of a model with a single stochastic shock `e`, with a standard error of 0.0348.

Example 2

```
stoch_simul(irf=60) y k;
```

Performs the simulation of a model and displays impulse response functions on 60 periods for variables `y` and `k`.

`oo_.mean` [MATLAB/Octave variable]

After a run of `stoch_simul`, contains the mean of the endogenous variables. Contains theoretical mean if the `periods` option is not present, and empirical mean otherwise. The variables are arranged in declaration order.

`oo_.var` [MATLAB/Octave variable]

After a run of `stoch_simul`, contains the variance-covariance of the endogenous variables. Contains theoretical variance if the `periods` option is not present (or an approximation thereof for `order=2`), and empirical variance otherwise. The variables are arranged in declaration order.

`oo_.autocorr` [MATLAB/Octave variable]

After a run of `stoch_simul`, contains a cell array of the autocorrelation matrices of the endogenous variables. The element number of the matrix in the cell array corresponds to the order of autocorrelation. The option `ar` specifies the number of autocorrelation matrices available. Contains theoretical autocorrelations if the `periods` option is not present (or an approximation thereof for `order=2`), and empirical autocorrelations otherwise. The field is only created if stationary variables are present.

The element `oo_.autocorr{i}(k,l)` is equal to the correlation between y_t^k and y_{t-i}^l, where y^k (resp. y^l) is the k-th (resp. l-th) endogenous variable in the declaration order.

Note that if theoretical moments have been requested, `oo_.autocorr{i}` is the same than `oo_.gamma_y{i+1}`.

`oo_.gamma_y` [MATLAB/Octave variable]

After a run of `stoch_simul`, if theoretical moments have been requested (*i.e.* if the `periods` option is not present), this variable contains a cell array with the following values (where `ar` is the value of the option of the same name):

`oo_.gamma{1}`
: Variance/co-variance matrix.

`oo_.gamma{i+1} (for i=1:ar)`
: Autocorrelation function. see [oo_.autocorr], page 44 for more details. Beware, this is the *autocorrelation* function, not the *autocovariance* function.

`oo_.gamma{nar+2}`
: Unconditional variance decomposition see [oo_.variance_decomposition], page 45

`oo_.gamma{nar+3}`
: If a second order approximation has been requested, contains the vector of the mean correction terms.

In case of `order=2`, the theoretical second moments are a second order accurate approximation of the true second moments, see `conditional_variance_decomposition`.

`oo_.variance_decomposition` [MATLAB/Octave variable]

After a run of `stoch_simul` when requesting theoretical moments (`periods=0`), contains a matrix with the result of the unconditional variance decomposition (i.e. at horizon infinity). The first dimension corresponds to the endogenous variables (in the order of declaration) and the second dimension corresponds to exogenous variables (in the order of declaration). Numbers are in percent and sum up to 100 across columns.

`oo_.conditional_variance_decomposition` [MATLAB/Octave variable]

After a run of `stoch_simul` with the `conditional_variance_decomposition` option, contains a three-dimensional array with the result of the decomposition. The first dimension corresponds to forecast horizons (as declared with the option), the second dimension corresponds to endogenous variables (in the order of declaration), the third dimension corresponds to exogenous variables (in the order of declaration).

`oo_.irfs` [MATLAB/Octave variable]

After a run of `stoch_simul` with option `irf` different from zero, contains the impulse responses, with the following naming convention: *`VARIABLE_NAME_SHOCK_NAME`*.

For example, `oo_.irfs.gnp_ea` contains the effect on `gnp` of a one standard deviation shock on `ea`.

The approximated solution of a model takes the form of a set of decision rules or transition equations expressing the current value of the endogenous variables of the model as function of the previous state of the model and shocks observed at the beginning of the period. The decision rules are stored in the structure `oo_.dr` which is described below.

`extended_path ;` [Command]
`extended_path (`*`OPTIONS...`*`) ;` [Command]

Description

`extended_path` solves a stochastic (*i.e.* rational expectations) model, using the *extended path* method presented by *Fair and Taylor (1983)*. Time series for the endogenous variables are generated by assuming that the agents believe that there will no more shocks in the following periods.

This function first computes a random path for the exogenous variables (stored in `oo_.exo_simul`, see [oo_.exo_simul], page 39) and then computes the corresponding path for endogenous variables, taking the steady state as starting point. The result of the simulation is stored in `oo_.endo_simul` (see [oo_.endo_simul], page 39). Note that this simulation approach does not solve for the policy and transition equations but for paths for the endogenous variables.

Options

`periods = INTEGER`
: The number of periods for which the simulation is to be computed. No default value, mandatory option.

`solver_periods = INTEGER`
: The number of periods used to compute the solution of the perfect foresight at every iteration of the algorithm. Default: `200`.

`order = INTEGER`
: If `order` is greater than 0 Dynare uses a gaussian quadrature to take into account the effects of future uncertainty. If `order`=*S* then the time series for the endogenous variables are generated by assuming that the agents believe that there will no more shocks after period *t*+*S*. This is an experimental feature and can be quite slow. Default: `0`.

`hybrid`
: Use the constant of the second order perturbation reduced form to correct the paths generated by the (stochastic) extended path algorithm.

4.13.2 Typology and ordering of variables

Dynare distinguishes four types of endogenous variables:

Purely backward (or purely predetermined) variables
: Those that appear only at current and past period in the model, but not at future period (*i.e.* at t and $t-1$ but not $t+1$). The number of such variables is equal to `M_.npred`.

Purely forward variables
: Those that appear only at current and future period in the model, but not at past period (*i.e.* at t and $t+1$ but not $t-1$). The number of such variables is stored in `M_.nfwrd`.

Mixed variables
: Those that appear at current, past and future period in the model (*i.e.* at t, $t+1$ and $t-1$). The number of such variables is stored in `M_.nboth`.

Static variables
: Those that appear only at current, not past and future period in the model (*i.e.* only at t, not at $t+1$ or $t-1$). The number of such variables is stored in `M_.nstatic`.

Note that all endogenous variables fall into one of these four categories, since after the creation of auxiliary variables (see Section 4.6 [Auxiliary variables], page 21), all endogenous have at most one lead and one lag. We therefore have the following identity:

```
M_.npred + M_.both + M_.nfwrd + M_.nstatic = M_.endo_nbr
```

Internally, Dynare uses two orderings of the endogenous variables: the order of declaration (which is reflected in `M_.endo_names`), and an order based on the four types described above, which we will call the DR-order ("DR" stands for decision rules). Most of the time, the declaration order is used, but for elements of the decision rules, the DR-order is used.

The DR-order is the following: static variables appear first, then purely backward variables, then mixed variables, and finally purely forward variables. Inside each category, variables are arranged according to the declaration order.

Variable `oo_.dr.order_var` maps DR-order to declaration order, and variable `oo_.dr.inv_order_var` contains the inverse map. In other words, the k-th variable in the DR-order corresponds to the endogenous variable numbered `oo_.dr_order_var(k)` in declaration order. Conversely, k-th declared variable is numbered `oo_.dr.inv_order_var(k)` in DR-order.

Finally, the state variables of the model are the purely backward variables and the mixed variables. They are ordered in DR-order when they appear in decision rules elements. There are `M_.nspred = M_.npred + M_.nboth` such variables. Similarly, one has `M_.nsfwrd = M_.nfwrd + M_.nboth`, and `M_.ndynamic = M_.nfwrd+M_.nboth+M_.npred`.

4.13.3 First order approximation

The approximation has the stylized form:

$$y_t = y^s + Ay^h_{t-1} + Bu_t$$

where y^s is the steady state value of y and $y^h_t = y_t - y^s$.

The coefficients of the decision rules are stored as follows:

- y^s is stored in `oo_.dr.ys`. The vector rows correspond to all endogenous in the declaration order.
- A is stored in `oo_.dr.ghx`. The matrix rows correspond to all endogenous in DR-order. The matrix columns correspond to state variables in DR-order.
- B is stored `oo_.dr.ghu`. The matrix rows correspond to all endogenous in DR-order. The matrix columns correspond to exogenous variables in declaration order.

Of course, the shown form of the approximation is only stylized, because it neglects the required different ordering in y^s and y^h_t. The precise form of the approximation that shows the way Dynare deals with differences between declaration and DR-order, is

$$y_t(oo\_.dr.order\_var) = y^s(oo\_.dr.order\_var) + A \cdot y_{t-1}(oo\_.dr.order\_var(k2)) - y^s(oo\_.dr.order\_var(k2)) + B \cdot u_t$$

where $k2$ selects the state variables, y_t and y^s are in declaration order and the coefficient matrices are in DR-order. Effectively, all variables on the right hand side are brought into DR order for computations and then assigned to y_t in declaration order.

4.13.4 Second order approximation

The approximation has the form:

$$y_t = y^s + 0.5\Delta^2 + Ay^h_{t-1} + Bu_t + 0.5C(y^h_{t-1} \otimes y^h_{t-1}) + 0.5D(u_t \otimes u_t) + E(y^h_{t-1} \otimes u_t)$$

where y^s is the steady state value of y, $y^h_t = y_t - y^s$, and Δ^2 is the shift effect of the variance of future shocks. For the reordering required due to differences in declaration and DR order, see the first order approximation.

The coefficients of the decision rules are stored in the variables described for first order approximation, plus the following variables:

- Δ^2 is stored in `oo_.dr.ghs2`. The vector rows correspond to all endogenous in DR-order.
- C is stored in `oo_.dr.ghxx`. The matrix rows correspond to all endogenous in DR-order. The matrix columns correspond to the Kronecker product of the vector of state variables in DR-order.
- D is stored in `oo_.dr.ghuu`. The matrix rows correspond to all endogenous in DR-order. The matrix columns correspond to the Kronecker product of exogenous variables in declaration order.
- E is stored in `oo_.dr.ghxu`. The matrix rows correspond to all endogenous in DR-order. The matrix columns correspond to the Kronecker product of the vector of state variables (in DR-order) by the vector of exogenous variables (in declaration order).

4.13.5 Third order approximation

The approximation has the form:

$$y_t = y^s + G_0 + G_1 z_t + G_2(z_t \otimes z_t) + G_3(z_t \otimes z_t \otimes z_t)$$

where y^s is the steady state value of y, and z_t is a vector consisting of the deviation from the steady state of the state variables (in DR-order) at date $t-1$ followed by the exogenous variables at date t (in declaration order). The vector z_t is therefore of size n_z = `M_.nspred + M_.exo_nbr`.

The coefficients of the decision rules are stored as follows:

- y^s is stored in `oo_.dr.ys`. The vector rows correspond to all endogenous in the declaration order.
- G_0 is stored in `oo_.dr.g_0`. The vector rows correspond to all endogenous in DR-order.
- G_1 is stored in `oo_.dr.g_1`. The matrix rows correspond to all endogenous in DR-order. The matrix columns correspond to state variables in DR-order, followed by exogenous in declaration order.
- G_2 is stored in `oo_.dr.g_2`. The matrix rows correspond to all endogenous in DR-order. The matrix columns correspond to the Kronecker product of state variables (in DR-order), followed by exogenous (in declaration order). Note that the Kronecker product is stored in a folded way, *i.e.* symmetric elements are stored only once, which implies that the matrix has $n_z(n_z+1)/2$ columns. More precisely, each column of this matrix corresponds to a pair (i_1, i_2) where each index represents an element of z_t and is therefore between 1 and n_z. Only non-decreasing pairs are stored, *i.e.* those for which $i_1 \leq i_2$. The columns are arranged in the lexicographical order of non-decreasing pairs. Also note that for those pairs where $i_1 \neq i_2$, since the element is stored only once but appears two times in the unfolded G_2 matrix, it must be multiplied by 2 when computing the decision rules.
- G_3 is stored in `oo_.dr.g_3`. The matrix rows correspond to all endogenous in DR-order. The matrix columns correspond to the third Kronecker power of state variables (in DR-order), followed by exogenous (in declaration order). Note that the third Kronecker power is stored in a folded way, *i.e.* symmetric elements are stored only once, which implies that the matrix has $n_z(n_z+1)(n_z+2)/6$ columns. More precisely, each column of this matrix corresponds to a tuple (i_1, i_2, i_3) where each index represents an element of z_t and is therefore between 1 and n_z. Only non-decreasing tuples are stored, *i.e.* those for which $i_1 \leq i_2 \leq i_3$. The columns are arranged in the lexicographical order of non-decreasing tuples. Also note that for tuples that have three distinct indices (*i.e.* $i_1 \neq i_2$ and $i_1 \neq i_3$ and $i_2 \neq i_3$, since these elements are stored only once but appears six times in the unfolded G_3 matrix, they must be multiplied by 6 when computing the decision rules. Similarly, for those tuples that have two equal indices (*i.e.* of the form (a, a, b) or (a, b, a) or (b, a, a)), since these elements are stored only once but appears three times in the unfolded G_3 matrix, they must be multiplied by 3 when computing the decision rules.

4.14 Estimation

Provided that you have observations on some endogenous variables, it is possible to use Dynare to estimate some or all parameters. Both maximum likelihood (as in *Ireland (2004)*) and Bayesian techniques (as in *Rabanal and Rubio-Ramirez (2003)*, *Schorfheide (2000)* or *Smets and Wouters (2003)*) are available. Using Bayesian methods, it is possible to estimate DSGE models, VAR models, or a combination of the two techniques called DSGE-VAR.

Note that in order to avoid stochastic singularity, you must have at least as many shocks or measurement errors in your model as you have observed variables.

The estimation using a first order approximation can benefit from the block decomposition of the model (see [block], page 19).

`varobs` *VARIABLE_NAME...;* [Command]

Description

This command lists the name of observed endogenous variables for the estimation procedure. These variables must be available in the data file (see [estimation_cmd], page 52).

Alternatively, this command is also used in conjunction with the `partial_information` option of `stoch_simul`, for declaring the set of observed variables when solving the model under partial information.

Only one instance of `varobs` is allowed in a model file. If one needs to declare observed variables in a loop, the macro-processor can be used as shown in the second example below.

Simple example

```
varobs C y rr;
```

Example with a loop

```
varobs
@#for co in countries
  GDP_@{co}
@#endfor
;
```

`observation_trends` *;* [Block]

Description

This block specifies *linear* trends for observed variables as functions of model parameters.

Each line inside of the block should be of the form:

```
VARIABLE_NAME(EXPRESSION);
```

In most cases, variables shouldn't be centered when `observation_trends` is used.

Example

```
observation_trends;
Y (eta);
P (mu/eta);
end;
```

`estimated_params` *;* [Block]

Description

This block lists all parameters to be estimated and specifies bounds and priors as necessary.

Each line corresponds to an estimated parameter.

In a maximum likelihood estimation, each line follows this syntax:

```
stderr VARIABLE_NAME | corr VARIABLE_NAME_1, VARIABLE_NAME_2 | PARAMETER_NAME
, INITIAL_VALUE [, LOWER_BOUND, UPPER_BOUND ];
```

In a Bayesian estimation, each line follows this syntax:

```
stderr VARIABLE_NAME | corr VARIABLE_NAME_1, VARIABLE_NAME_2 |
PARAMETER_NAME | DSGE_PRIOR_WEIGHT
[, INITIAL_VALUE [, LOWER_BOUND, UPPER_BOUND]], PRIOR_SHAPE,
PRIOR_MEAN, PRIOR_STANDARD_ERROR [, PRIOR_3RD_PARAMETER [,
PRIOR_4TH_PARAMETER [, SCALE_PARAMETER ] ] ];
```

The first part of the line consists of one of the three following alternatives:

`stderr` *`VARIABLE_NAME`*
: Indicates that the standard error of the exogenous variable *VARIABLE_NAME*, or of the observation error/measurement errors associated with endogenous observed variable *VARIABLE_NAME*, is to be estimated

`corr` *`VARIABLE_NAME1, VARIABLE_NAME2`*
: Indicates that the correlation between the exogenous variables *VARIABLE_NAME1* and *VARIABLE_NAME2*, or the correlation of the observation errors/measurement errors associated with endogenous observed variables *VARIABLE_NAME1* and *VARIABLE_NAME2*, is to be estimated. Note that correlations set by previous `shocks`-blocks or `estimation`-commands are kept at their value set prior to estimation if they are not estimated again subsequently. Thus, the treatment is the same as in the case of deep parameters set during model calibration and not estimated.

`PARAMETER_NAME`
: The name of a model parameter to be estimated

`DSGE_PRIOR_WEIGHT`
: . . .

The rest of the line consists of the following fields, some of them being optional:

`INITIAL_VALUE`
: Specifies a starting value for the posterior mode optimizer or the maximum likelihood estimation. If unset, defaults to the prior mean.

`LOWER_BOUND`
: Specifies a lower bound for the parameter value in maximum likelihood estimation

`UPPER_BOUND`
: Specifies an upper bound for the parameter value in maximum likelihood estimation

`PRIOR_SHAPE`
: A keyword specifying the shape of the prior density. The possible values are: `beta_pdf`, `gamma_pdf`, `normal_pdf`, `uniform_pdf`, `inv_gamma_pdf`, `inv_gamma1_pdf`, `inv_gamma2_pdf`. Note that `inv_gamma_pdf` is equivalent to `inv_gamma1_pdf`

`PRIOR_MEAN`
: The mean of the prior distribution

`PRIOR_STANDARD_ERROR`
: The standard error of the prior distribution

`PRIOR_3RD_PARAMETER`
: A third parameter of the prior used for generalized beta distribution, generalized gamma and for the uniform distribution. Default: `0`

`PRIOR_4TH_PARAMETER`
: A fourth parameter of the prior used for generalized beta distribution and for the uniform distribution. Default: `1`

`SCALE_PARAMETER`
: A parameter specific scale parameter for the jumping distribution's covariance matrix of the Metropolis-Hasting algorithm

Note that *INITIAL_VALUE*, *LOWER_BOUND*, *UPPER_BOUND*, *PRIOR_MEAN*, *PRIOR_STANDARD_ERROR*, *PRIOR_3RD_PARAMETER*, *PRIOR_4TH_PARAMETER* and *SCALE_PARAMETER* can be any valid *EXPRESSION*. Some of them can be empty, in which Dynare will select a default value depending on the context and the prior shape.

As one uses options more towards the end of the list, all previous options must be filled: for example, if you want to specify *SCALE_PARAMETER*, you must specify

PRIOR_3RD_PARAMETER and *PRIOR_4TH_PARAMETER*. Use empty values, if these parameters don't apply.

Example

The following line:

```
corr eps_1, eps_2, 0.5,  ,  , beta_pdf, 0, 0.3, -1, 1;
```

sets a generalized beta prior for the correlation between `eps_1` and `eps_2` with mean 0 and variance 0.3. By setting *PRIOR_3RD_PARAMETER* to -1 and *PRIOR_4TH_PARAMETER* to 1 the standard beta distribution with support [0,1] is changed to a generalized beta with support [-1,1]. Note that *LOWER_BOUND* and *UPPER_BOUND* are left empty and thus default to -1 and 1, respectively. The initial value is set to 0.5.

Similarly, the following line:

```
corr eps_1, eps_2, 0.5,  -0.5,  1, beta_pdf, 0, 0.3, -1, 1;
```

sets the same generalized beta distribution as before, but now truncates this distribution to [-0.5,1] through the use of *LOWER_BOUND* and *UPPER_BOUND*. Hence, the prior does not integrate to 1 anymore.

Parameter transformation

Sometimes, it is desirable to estimate a transformation of a parameter appearing in the model, rather than the parameter itself. It is of course possible to replace the original parameter by a function of the estimated parameter everywhere is the model, but it is often unpractical.

In such a case, it is possible to declare the parameter to be estimated in the `parameters` statement and to define the transformation, using a pound sign (#) expression (see Section 4.5 [Model declaration], page 18).

Example

```
parameters bet;

model;
# sig = 1/bet;
c = sig*c(+1)*mpk;
end;

estimated_params;
bet, normal_pdf, 1, 0.05;
end;
```

`estimated_params_init` *;* [Block]

`estimated_params_init` (*OPTIONS*...)*;* [Block]

This block declares numerical initial values for the optimizer when these ones are different from the prior mean. It should be specified after the `estimated_params`-block as otherwise the specified starting values are overwritten by the latter.

Each line has the following syntax:

```
stderr VARIABLE_NAME | corr VARIABLE_NAME_1, VARIABLE_NAME_2 | PARAMETER_NAME
, INITIAL_VALUE;
```

Options

`use_calibration`

For not specifically initialized parameters, use the deep parameters and the elements of the covariance matrix specified in the `shocks` block from calibration as starting values for estimation. For components of the `shocks` block that were not explicitly specified during calibration or which violate the prior, the prior mean is used.

See [estimated_params], page 49, for the meaning and syntax of the various components.

`estimated_params_bounds` *;* [Block]

This block declares lower and upper bounds for parameters in maximum likelihood estimation.

Each line has the following syntax:

```
stderr VARIABLE_NAME | corr VARIABLE_NAME_1, VARIABLE_NAME_2 | PARAMETER_NAME
, LOWER_BOUND, UPPER_BOUND;
```

See [estimated_params], page 49, for the meaning and syntax of the various components.

`estimation` [*VARIABLE_NAME...*]; [Command]
`estimation` (*OPTIONS...*) [*VARIABLE_NAME...*]; [Command]

Description

This command runs Bayesian or maximum likelihood estimation.

The following information will be displayed by the command:

- results from posterior optimization (also for maximum likelihood)
- marginal log data density
- posterior mean and highest posterior density interval (shortest credible set) from posterior simulation
- Metropolis-Hastings convergence graphs that still need to be documented
- graphs with prior, posterior, and mode
- graphs of smoothed shocks, smoothed observation errors, smoothed and historical variables

Also, during the MCMC (Bayesian estimation with `mh_replic`>0) a (graphical or text) waiting bar is displayed showing the progress of the Monte-Carlo and the *current* value of the acceptance ratio. Note that if the `load_mh_file` option is used (see below) the reported acceptance ratio does not take into account the draws from the previous MCMC. In the literature there is a general agreement for saying that the acceptance ratio should be close to one third or one quarter. If this not the case, you can stop the MCMC (`Ctrl-C`) and change the value of option `mh_jscale` (see below).

Note that by default Dynare generates random numbers using the algorithm `mt199937ar` (*ie* Mersenne Twister method) with a seed set equal to `0`. Consequently the MCMCs in Dynare are deterministic: one will get exactly the same results across different Dynare runs (*ceteris paribus*). For instance, the posterior moments or posterior densities will be exactly the same. This behaviour allows to easily identify the consequences of a change on the model, the priors or the estimation options. But one may also want to check that across multiple runs, with different sequences of proposals, the returned results are almost identical. This should be true if the number of iterations (*ie* the value of `mh_replic`) is important enough to ensure the convergence of the MCMC to its ergodic distribution. In this case the default behaviour of the random number generators in not wanted, and the user should set the seed according to the system clock before the estimation command using the following command:

```
set_dynare_seed('clock');
```

so that the sequence of proposals will be different across different runs.

Algorithms

The Monte Carlo Markov Chain (MCMC) diagnostics are generated by the estimation command if [mh_replic], page 54 is larger than 2000 and if option [nodiagnostic], page 59 is not used. If [mh_nblocks], page 54 is equal to one, the convergence diagnostics of *Geweke (1992,1999)* is computed. It uses a chi square test to compare the means of the first and last draws specified by [geweke_interval], page 63 after discarding the burnin of [mh_drop], page 54. The test is computed using variance estimates under the assumption of no serial correlation as well as using tapering windows specified in [taper_steps], page 63. If [mh_nblocks], page 54 is larger than 1, the convergence diagnostics of *Brooks and Gelman (1998)* are used instead. As described in section 3 of *Brooks and Gelman (1998)* the univariate convergence diagnostics are based on comparing pooled and within MCMC moments (Dynare displays the second and third order moments, and the length of the Highest Probability Density interval covering 80% of the posterior distribution). Due to computational reasons, the multivariate convergence diagnostic does not follow *Brooks and Gelman (1998)* strictly, but rather applies their idea for univariate convergence diagnostics to the range of the posterior likelihood function instead of the individual parameters. The posterior kernel is used to aggregate the parameters into a scalar statistic whose convergence is then checked using the *Brooks and Gelman (1998)* univariate convergence diagnostic.

Options

`datafile` = *FILENAME*
: The datafile: a `.m` file, a `.mat` file, a `.csv` file, or a `.xls`/`.xlsx` file (under Octave, the io from Octave-Forge is required for the `.csv`, `.xls` and `.xlsx` formats; in addition, for the `.xls` and `.xlsx` formats, the java package is required, along with a Java Runtime Environment)

`xls_sheet` = *NAME*
: The name of the sheet with the data in an Excel file

`xls_range` = *RANGE*
: The range with the data in an Excel file

`nobs` = *INTEGER*
: The number of observations to be used. Default: all observations in the file

`nobs` = [*INTEGER1*:*INTEGER2*]
: Runs a recursive estimation and forecast for samples of size ranging of *INTEGER1* to *INTEGER2*. Option `forecast` must also be specified. The forecasts are stored in the `RecursiveForecast` field of the results structure (see [RecursiveForecast], page 66).

`first_obs` = *INTEGER*
: The number of the first observation to be used. Default: `1`

`prefilter` = *INTEGER*
: A value of `1` means that the estimation procedure will demean each data series by its empirical mean. Default: `0`, *i.e.* no prefiltering

`presample` = *INTEGER*
: The number of observations to be skipped before evaluating the likelihood. These first observations are used as a training sample. Default: `0`

`loglinear`
: Computes a log-linear approximation of the model instead of a linear approximation. As always in the context of estimation, the data must correspond to the definition of the variables used in the model (see *Pfeifer 2013* for more details on how to correctly specify observation equations linking model variables and the data). If you specify the loglinear option, Dynare will take the logarithm of both your model variables and of your data as it assumes the data to correspond to the original non-logged model variables. The displayed posterior results like impulse responses, smoothed variables, and moments will be for the logged variables, not the original un-logged ones. Default: computes a linear approximation

`plot_priors` = *INTEGER*
: Control the plotting of priors:

  `0` No prior plot

  `1` Prior density for each estimated parameter is plotted. It is important to check that the actual shape of prior densities matches what you have in mind. Ill-chosen values for the prior standard density can result in absurd prior densities.

  Default value is `1`.

`nograph` See [nograph], page 41.

`nodisplay`
: See [nodisplay], page 41.

`graph_format` = *FORMAT*
`graph_format` = (*FORMAT*, *FORMAT*...)
: See [graph_format], page 41.

`lik_init` = *INTEGER*
: Type of initialization of Kalman filter:

  `1` For stationary models, the initial matrix of variance of the error of forecast is set equal to the unconditional variance of the state variables

  `2` For nonstationary models: a wide prior is used with an initial matrix of variance of the error of forecast diagonal with 10 on the diagonal

  `3` For nonstationary models: use a diffuse filter (use rather the `diffuse_filter` option)

  `4` The filter is initialized with the fixed point of the Riccati equation

  Default value is `1`. For advanced use only.

`lik_algo` = *INTEGER*
: For internal use and testing only.

`conf_sig` = *DOUBLE*
: Confidence interval used for classical forecasting after estimation. See See [conf_sig], page 69.

`mh_conf_sig` = *DOUBLE*
: Confidence/HPD interval used for the computation of prior and posterior statistics like: parameter distributions, prior/posterior moments, conditional variance decomposition, impulse response functions, Bayesian forecasting. Default: `0.9`

`mh_replic` = *INTEGER*
: Number of replications for Metropolis-Hastings algorithm. For the time being, `mh_replic` should be larger than `1200`. Default: `20000`

`sub_draws` = *INTEGER*
: number of draws from the Metropolis iterations that are used to compute posterior distribution of various objects (smoothed variable, smoothed shocks, forecast, moments, IRF). `sub_draws` should be smaller than the total number of Metropolis draws available. Default: `min(1200,0.25*Total number of draws)`

`mh_nblocks` = *INTEGER*
: Number of parallel chains for Metropolis-Hastings algorithm. Default: `2`

`mh_drop` = *DOUBLE*
: The fraction of initially generated parameter vectors to be dropped as a burnin before using posterior simulations. Default: `0.5`

`mh_jscale = DOUBLE`
: The scale parameter of the jumping distribution's covariance matrix (Metropolis-Hastings algorithm). The default value is rarely satisfactory. This option must be tuned to obtain, ideally, an acceptance ratio of 25%-33% in the Metropolis-Hastings algorithm. Basically, the idea is to increase the variance of the jumping distribution if the acceptance ratio is too high, and decrease the same variance if the acceptance ratio is too low. In some situations in may help to consider parameter specific values for this scale parameter, this can be done in the [estimated_params], page 49 block. Default: `0.2`

`mh_init_scale = DOUBLE`
: The scale to be used for drawing the initial value of the Metropolis-Hastings chain. Default: 2*`mh_scale`

`mh_recover`
: Attempts to recover a Metropolis-Hastings simulation that crashed prematurely. Shouldn't be used together with `load_mh_file`

`mh_mode = INTEGER`
: ...

`mode_file = FILENAME`
: Name of the file containing previous value for the mode. When computing the mode, Dynare stores the mode (`xparam1`) and the hessian (`hh`, only if `cova_compute=1`) in a file called `MODEL_FILENAME_mode.mat`

`mode_compute = INTEGER | FUNCTION_NAME`
: Specifies the optimizer for the mode computation:

`0` The mode isn't computed. When `mode_file` option is specified, the mode is simply read from that file.

When `mode_file` option is not specified, Dynare reports the value of the log posterior (log likelihood) evaluated at the initial value of the parameters.

When `mode_file` option is not specified and there is no `estimated_params` block, but the `smoother` option is used, it is a roundabout way to compute the smoothed value of the variables of a model with calibrated parameters.

`1` Uses `fmincon` optimization routine (available under MATLAB if the optimization toolbox is installed; not available under Octave)

`2` Value no longer used

`3` Uses `fminunc` optimization routine (available under MATLAB if the optimization toolbox is installed; available under Octave if the optim package from Octave-Forge is installed)

`4` Uses Chris Sims's `csminwel`

`5` Uses Marco Ratto's `newrat`. This value is not compatible with non linear filters or DSGE-VAR models

`6` Uses a Monte-Carlo based optimization routine (see Dynare wiki for more details)

`7` Uses `fminsearch`, a simplex based optimization routine (available under MATLAB if the optimization toolbox is installed; available under Octave if the optim package from Octave-Forge is installed)

`8` Uses Dynare implementation of the Nelder-Mead simplex based optimization routine (generally more efficient than the MATLAB or Octave implementation available with `mode_compute=7`)

`9` Uses the CMA-ES (Covariance Matrix Adaptation Evolution Strategy) algorithm, an evolutionary algorithm for difficult non-linear non-convex optimization

`10` Uses the simpsa algorithm, based on the combination of the non-linear simplex and simulated annealing algorithms and proposed by *Cardoso, Salcedo and Feyo de Azevedo (1996)*.

`FUNCTION_NAME`
It is also possible to give a *FUNCTION_NAME* to this option, instead of an *INTEGER*. In that case, Dynare takes the return value of that function as the posterior mode.

Default value is `4`.

`mcmc_jumping_covariance = hessian|prior_variance|identity_matrix|`*`FILENAME`*
Tells Dynare which covariance to use for the proposal density of the MCMC sampler. `mcmc_jumping_covariance` can be one of the following:

`hessian` Uses the Hessian matrix computed at the mode.

`prior_variance`
Uses the prior variances. No infinite prior variances are allowed in this case.

`identity_matrix`
Uses an identity matrix.

`FILENAME` Loads an arbitrary user-specified covariance matrix from *`FILENAME`*`.mat`. The covariance matrix must be saved in a variable named `jumping_covariance`, must be square, positive definite, and have the same dimension as the number of estimated parameters.

Note that the covariance matrices are still scaled with [mh_jscale], page 55. Default value is `hessian`.

`mode_check`
Tells Dynare to plot the posterior density for values around the computed mode for each estimated parameter in turn. This is helpful to diagnose problems with the optimizer

`mode_check_neighbourhood_size = `*`DOUBLE`*
Used in conjunction with option `mode_check`, gives the width of the window around the posterior mode to be displayed on the diagnostic plots. This width is expressed in percentage deviation. The `Inf` value is allowed, and will trigger a plot over the entire domain (see also `mode_check_symmetric_plots`). Default: `0.5`.

`mode_check_symmetric_plots = `*`INTEGER`*
Used in conjunction with option `mode_check`, if set to `1`, tells Dynare to ensure that the check plots are symmetric around the posterior mode. A value of `0` allows to have asymmetric plots, which can be useful if the posterior mode is close to a domain boundary, or in conjunction with `mode_check_neighbourhood_size = Inf` when the domain in not the entire real line. Default: `1`.

`mode_check_number_of_points = `*`INTEGER`*
Number of points around the posterior mode where the posterior kernel is evaluated (for each parameter). Default is `20`

`prior_trunc` = *DOUBLE*
: Probability of extreme values of the prior density that is ignored when computing bounds for the parameters. Default: `1e-32`

`load_mh_file`
: Tells Dynare to add to previous Metropolis-Hastings simulations instead of starting from scratch. Shouldn't be used together with `mh_recover`

`optim` = (*NAME*, *VALUE*, ...)
: A list of *NAME* and *VALUE* pairs. Can be used to set options for the optimization routines. The set of available options depends on the selected optimization routine (ie on the value of option [mode_compute], page 55):

  `1, 3, 7` Available options are given in the documentation of the MATLAB optimization toolbox or in Octave's documentation.

  `4` Available options are:

    `'MaxIter'`
    : Maximum number of iterations. Default: `1000`

    `'NumgradAlgorithm'`
    : Possible values are `2`, `3` and `5` respectively corresponding to the two, three and five points formula used to compute the gradient of the objective function (see *Abramowitz and Stegun (1964)*). Values `13` and `15` are more experimental. If perturbations on the right and the left increase the value of the objective function (we minimize this function) then we force the corresponding element of the gradient to be zero. The idea is to temporarily reduce the size of the optimization problem. Default: `2`.

    `'NumgradEpsilon'`
    : Size of the perturbation used to compute numerically the gradient of the objective function. Default: `1e-6`

    `'TolFun'` Stopping criteria. Default: `1e-7`

    `'InitialInverseHessian'`
    : Initial approximation for the inverse of the Hessian matrix of the posterior kernel (or likelihood). Obviously this approximation has to be a square, positive definite and symmetric matrix. Default: `'1e-4*eye(nx)'`, where `nx` is the number of parameters to be estimated.

  `6` Available options are:

    `'NumberOfMh'`
    : Number of MCMC run sequentially. Default: `3`

    `'ncov-mh'`
    : Number of iterations used for updating the covariance matrix of the jumping distribution. Default: `20000`

    `'nscale-mh'`
    : Maximum number of iterations used for adjusting the scale parameter of the jumping distribution. `200000`

    `'nclimb'` Number of iterations in the last MCMC (climbing mode).

`'InitialCovarianceMatrix'`
: Initial covariance matrix of the jumping distribution. Default is `'previous'` if option `mode_file` is used, `'prior'` otherwise.

`'AcceptanceRateTarget'`
: A real number between zero and one. The scale parameter of the jumping distribution is adjusted so that the effective acceptance rate matches the value of option `'AcceptanceRateTarget'`. Default: `1.0/3.0`

`8` Available options are:

`'MaxIter'`
: Maximum number of iterations. Default: `5000`

`'MaxFunEvals'`
: Maximum number of objective function evaluations. No default.

`'MaxFunvEvalFactor'`
: Set `MaxFunvEvals` equal to `MaxFunvEvalFactor` times the number of estimated parameters. Default: `500`.

`'TolFun'` Tolerance parameter (w.r.t the objective function). Default: `1e-4`

`'TolX'` Tolerance parameter (w.r.t the instruments). Default: `1e-4`

`'InitialSimplexSize'`
: Initial size of the simplex, expressed as percentage deviation from the provided initial guess in each direction. Default: `.05`

`9` Available options are:

`'MaxIter'`
: Maximum number of iterations.

`'MaxFunEvals'`
: Maximum number of objective function evaluations. Default: `Inf`.

`'TolFun'` Tolerance parameter (w.r.t the objective function). Default: `1e-7`

`'TolX'` Tolerance parameter (w.r.t the instruments). Default: `1e-7`

`10` Available options are:

`'MaxIter'`
: Maximum number of iterations. Default: `5000`

`'MaxFunvEvals'`
: Maximum number of objective function evaluations. No default.

`'TolFun'` Tolerance parameter (w.r.t the objective function). Default: `1e-4`

`'TolX'` Tolerance parameter (w.r.t the instruments). Default: `1e-4`

`'EndTemperature'`
Terminal condition w.r.t the temperature. When the temperature reaches `EndTemperature`, the temperature is set to zero and the algorithm falls back into a standard simplex algorithm. Default: `.1`

Example 1 To change the defaults of csminwel (`mode_compute=4`):

```
estimation(..., mode_compute=4, optim=('NumgradAlgorithm',3,'TolFun',1e-
5), ...);
```

`nodiagnostic`
Does not compute the convergence diagnostics for Metropolis-Hastings. Default: diagnostics are computed and displayed

`bayesian_irf`
Triggers the computation of the posterior distribution of IRFs. The length of the IRFs are controlled by the `irf` option. Results are stored in `oo_.PosteriorIRF.dsge` (see below for a description of this variable)

`dsge_var = `*`DOUBLE`*
Triggers the estimation of a DSGE-VAR model, where the weight of the DSGE prior of the VAR model is calibrated to the value passed (see *Del Negro and Schorfheide (2004)*). It represents ratio of dummy over actual observations. To assure that the prior is proper, the value must be bigger than $(k + n)/T$, where k is the number of estimated parameters, n is the number of observables, and T is the number of observations. NB: The previous method of declaring `dsge_prior_weight` as a parameter and then calibrating it is now deprecated and will be removed in a future release of Dynare.

`dsge_var` Triggers the estimation of a DSGE-VAR model, where the weight of the DSGE prior of the VAR model will be estimated (as in *Adjemian et alii (2008)*). The prior on the weight of the DSGE prior, `dsge_prior_weight`, must be defined in the `estimated_params` section. NB: The previous method of declaring `dsge_prior_weight` as a parameter and then placing it in `estimated_params` is now deprecated and will be removed in a future release of Dynare.

`dsge_varlag = `*`INTEGER`*
The number of lags used to estimate a DSGE-VAR model. Default: `4`.

`moments_varendo`
Triggers the computation of the posterior distribution of the theoretical moments of the endogenous variables. Results are stored in `oo_.PosteriorTheoreticalMoments` (see [oo_.PosteriorTheoreticalMoments], page 65). The number of lags in the autocorrelation function is controlled by the `ar` option.

`conditional_variance_decomposition = `*`INTEGER`*
See below.

`conditional_variance_decomposition = [`*`INTEGER1`*`:`*`INTEGER2`*`]`
See below.

`conditional_variance_decomposition = [`*`INTEGER1 INTEGER2`*` ...]`
Computes the posterior distribution of the conditional variance decomposition for the specified period(s). The periods must be strictly positive. Conditional variances are given by $var(y_{t+k}|t)$. For period 1, the conditional variance decomposition provides the decomposition

of the effects of shocks upon impact. The results are stored in `oo_.PosteriorTheoreticalMoments.dsge.ConditionalVarianceDecomposition`, but currently there is no displayed output. Note that this option requires the option `moments_varendo` to be specified.

`filtered_vars`
: Triggers the computation of the posterior distribution of filtered endogenous variables/one-step ahead forecasts, i.e. $E_t y_{t+1}$. Results are stored in `oo_.FilteredVariables` (see below for a description of this variable)

`smoother`
: Triggers the computation of the posterior distribution of smoothed endogenous variables and shocks, i.e. the expected value of variables and shocks given the information available in all observations up to the *final* date ($E_T y_t$). Results are stored in `oo_.SmoothedVariables`, `oo_.SmoothedShocks` and `oo_.SmoothedMeasurementErrors`. Also triggers the computation of `oo_.UpdatedVariables`, which contains the estimation of the expected value of variables given the information available at the *current* date ($E_t y_t$). See below for a description of all these variables.

`forecast = INTEGER`
: Computes the posterior distribution of a forecast on *INTEGER* periods after the end of the sample used in estimation. If no Metropolis-Hastings is computed, the result is stored in variable `oo_.forecast` and corresponds to the forecast at the posterior mode. If a Metropolis-Hastings is computed, the distribution of forecasts is stored in variables `oo_.PointForecast` and `oo_.MeanForecast`. See Section 4.15 [Forecasting], page 69, for a description of these variables.

`tex`
: Requests the printing of results and graphs in TEX tables and graphics that can be later directly included in LATEX files (not yet implemented)

`kalman_algo = INTEGER`

`0`	Automatically use the Multivariate Kalman Filter for stationary models and the Multivariate Diffuse Kalman Filter for non-stationary models
`1`	Use the Multivariate Kalman Filter
`2`	Use the Univariate Kalman Filter
`3`	Use the Multivariate Diffuse Kalman Filter
`4`	Use the Univariate Diffuse Kalman Filter

Default value is `0`. In case of missing observations of single or all series, Dynare treats those missing values as unobserved states and uses the Kalman filter to infer their value (see e.g. *Durbin and Koopman (2012), Ch. 4.10*)

`kalman_tol = DOUBLE`
: Numerical tolerance for determining the singularity of the covariance matrix of the prediction errors during the Kalman filter (minimum allowed reciprocal of the matrix condition number). Default value is `1e-10`

`filter_covariance`
: Saves the series of one step ahead error of forecast covariance matrices.

`filter_step_ahead = [INTEGER1:INTEGER2]`
: See below.

`filter_step_ahead = [INTEGER1 INTEGER2 ...]`
: Triggers the computation k-step ahead filtered values. Stores results in `oo_.FilteredVariablesKStepAhead` and `oo_.FilteredVariablesKStepAheadVariances`.

`filter_decomposition`
: Triggers the computation of the shock decomposition of the above k-step ahead filtered values.

`diffuse_filter`
: Uses the diffuse Kalman filter (as described in *Durbin and Koopman (2012)* and *Koopman and Durbin (2003)*) to estimate models with non-stationary observed variables.

  When `diffuse_filter` is used the `lik_init` option of `estimation` has no effect.

  When there are nonstationary exogenous variables in a model, there is no unique deterministic steady state. For instance, if productivity is a pure random walk:

  $a_t = a_{t-1} + e_t$

  any value of $\bar{a}$ of a is a deterministic steady state for productivity. Consequently, the model admits an infinity of steady states. In this situation, the user must help Dynare in selecting one steady state, except if zero is a trivial model's steady state, which happens when the `linear` option is used in the model declaration. The user can either provide the steady state to Dynare using a `steady_state_model` block (or writing a steady state file) if a closed form solution is available, see [steady_state_model], page 34, or specify some constraints on the steady state, see [equation_tag_for_conditional_steady_state], page 35, so that Dynare computes the steady state conditionally on some predefined levels for the non stationary variables. In both cases, the idea is to use dummy values for the steady state level of the exogenous non stationary variables.

  Note that the nonstationary variables in the model must be integrated processes (their first difference or k-difference must be stationary).

`selected_variables_only`
: Only run the smoother on the variables listed just after the `estimation` command. Default: run the smoother on all the declared endogenous variables.

`cova_compute = INTEGER`
: When `0`, the covariance matrix of estimated parameters is not computed after the computation of posterior mode (or maximum likelihood). This increases speed of computation in large models during development, when this information is not always necessary. Of course, it will break all successive computations that would require this covariance matrix. Otherwise, if this option is equal to `1`, the covariance matrix is computed and stored in variable `hh` of `MODEL_FILENAME_mode.mat`. Default is `1`.

`solve_algo = INTEGER`
: See [solve_algo], page 31.

`order = INTEGER`
: Order of approximation, either `1` or `2`. When equal to `2`, the likelihood is evaluated with a particle filter based on a second order approximation of the model (see *Fernandez-Villaverde and Rubio-Ramirez (2005)*). Default is `1`, ie the likelihood of the linearized model is evaluated using a standard Kalman filter.

`irf = INTEGER`
: See [irf], page 41. Only used if [bayesian_irf], page 59 is passed.

`irf_shocks = ( VARIABLE_NAME [[,] VARIABLE_NAME ...] )`
: See [irf_shocks], page 41. Only used if [bayesian_irf], page 59 is passed. Cannot be used with [dsge_var], page 59.

`irf_plot_threshold = DOUBLE`
: See [irf_plot_threshold], page 41. Only used if [bayesian_irf], page 59 is passed.

`aim_solver`
: See [aim_solver], page 42.

`sylvester = OPTION`
: See [sylvester], page 43.

`sylvester_fixed_point_tol = *DOUBLE*`
: See [sylvester_fixed_point_tol], page 43.

`lyapunov = *OPTION*`
: Determines the algorithm used to solve the Lyapunov equation to initialized the variance-covariance matrix of the Kalman filter using the steady-state value of state variables. Possible values for *OPTION* are:

  `default` Uses the default solver for Lyapunov equations based on Bartels-Stewart algorithm.

  `fixed_point`
  : Uses a fixed point algorithm to solve the Lyapunov equation. This method is faster than the `default` one for large scale models, but it could require a large amount of iterations.

  `doubling` Uses a doubling algorithm to solve the Lyapunov equation (`disclyap_fast`). This method is faster than the two previous one for large scale models.

  `square_root_solver`
  : Uses a square-root solver for Lyapunov equations (`dlyapchol`). This method is fast for large scale models (available under MATLAB if the control system toolbox is installed; available under Octave if the control package from Octave-Forge is installed)

  Default value is `default`

`lyapunov_fixed_point_tol = *DOUBLE*`
: This is the convergence criterion used in the fixed point Lyapunov solver. Its default value is 1e-10.

`lyapunov_doubling_tol = *DOUBLE*`
: This is the convergence criterion used in the doubling algorithm to solve the Lyapunov equation. Its default value is 1e-16.

`analytic_derivation`
: Triggers estimation with analytic gradient. The final hessian is also computed analytically. Only works for stationary models without missing observations.

`ar = *INTEGER*`
: See [ar], page 40. Only useful in conjunction with option `moments_varendo`.

`endogenous_prior`
: Use endogenous priors as in *Christiano, Trabandt and Walentin (2011)*.

`use_univariate_filters_if_singularity_is_detected = *INTEGER*`
: Decide whether Dynare should automatically switch to univariate filter if a singularity is encountered in the likelihood computation (this is the behaviour if the option is equal to `1`). Alternatively, if the option is equal to `0`, Dynare will not automatically change the filter, but rather use a penalty value for the likelihood when such a singularity is encountered. Default: `1`.

`qz_zero_threshold = *DOUBLE*`
: See [qz_zero_threshold], page 36.

`taper_steps = [`*INTEGER1 INTEGER2* `...]`
: Percent tapering used for the spectral window in the *Geweke (1992,1999)* convergence diagnostics (requires [mh_nblocks], page 54=1). The tapering is used to take the serial correlation of the posterior draws into account. Default: `[4 8 15]`.

`geweke_interval = [`*DOUBLE DOUBLE*`]`
: Percentage of MCMC draws at the beginning and end of the MCMC chain taken to compute the *Geweke (1992,1999)* convergence diagnostics (requires [mh_nblocks], page 54=1) after discarding the first [mh_drop], page 54 percent of draws as a burnin. Default: `[0.2 0.5]`.

Note

If no `mh_jscale` parameter is used in estimated_params, the procedure uses `mh_jscale` for all parameters. If `mh_jscale` option isn't set, the procedure uses `0.2` for all parameters.

Output

After running `estimation`, the parameters `M_.params` and the variance matrix `M_.Sigma_e` of the shocks are set to the mode for maximum likelihood estimation or posterior mode computation without Metropolis iterations.

After `estimation` with Metropolis iterations (option `mh_replic` > 0 or option `load_mh_file` set) the parameters `M_.params` and the variance matrix `M_.Sigma_e` of the shocks are set to the posterior mean.

Depending on the options, `estimation` stores results in various fields of the `oo_` structure, described below.

In the following variables, we will adopt the following shortcuts for specific field names:

MOMENT_NAME
: This field can take the following values:

`HPDinf`	Lower bound of a 90% HPD interval[3]
`HPDsup`	Upper bound of a 90% HPD interval
`Mean`	Mean of the posterior distribution
`Median`	Median of the posterior distribution
`Std`	Standard deviation of the posterior distribution
`Variance`	Variance of the posterior distribution
`deciles`	Deciles of the distribution.
`density`	Non parametric estimate of the posterior density. First and second columns are respectively abscissa and ordinate coordinates.

ESTIMATED_OBJECT
: This field can take the following values:

`measurement_errors_corr`	Correlation between two measurement errors
`measurement_errors_std`	Standard deviation of measurement errors
`parameters`	Parameters

[3] See option [conf_sig], page 69 to change the size of the HPD interval

`shocks_corr`
: Correlation between two structural shocks

`shocks_std`
: Standard deviation of structural shocks

`oo_.MarginalDensity.LaplaceApproximation` [MATLAB/Octave variable]

Variable set by the `estimation` command.

`oo_.MarginalDensity.ModifiedHarmonicMean` [MATLAB/Octave variable]

Variable set by the `estimation` command, if it is used with `mh_replic > 0` or `load_mh_file` option.

`oo_.FilteredVariables` [MATLAB/Octave variable]

Variable set by the `estimation` command, if it is used with the `filtered_vars` option.

After an estimation without Metropolis, fields are of the form:

```
oo_.FilteredVariables.VARIABLE_NAME
```

After an estimation with Metropolis, fields are of the form:

```
oo_.FilteredVariables.MOMENT_NAME.VARIABLE_NAME
```

`oo_.FilteredVariablesKStepAhead` [MATLAB/Octave variable]

Variable set by the `estimation` command, if it is used with the `filter_step_ahead` option. The k-steps are stored along the rows while the columns indicate the respective variables. The third dimension of the array provides the observation for which the forecast has been made. For example, if `filter_step_ahead=[1 2 4]` and `nobs=200`, the element (3,5,204) stores the four period ahead filtered value of variable 5 computed at time t=200 for time t=204. The periods at the beginning and end of the sample for which no forecasts can be made, e.g. entries (1,5,1) and (1,5,204) in the example, are set to zero.

`oo_.FilteredVariablesKStepAheadVariances` [MATLAB/Octave variable]

Variable set by the `estimation` command, if it is used with the `filter_step_ahead` option.

`oo_.Filtered_Variables_X_step_ahead` [MATLAB/Octave variable]

Variable set by the `estimation` command, if it is used with the `filter_step_ahead` option in the context of Bayesian estimation. Fields are of the form:

```
oo_.Filtered_Variables_X_step_ahead.VARIABLE_NAME
```

The nth entry stores the k-step ahead filtered variable computed at time n for time n+k.

`oo_.PosteriorIRF.dsge` [MATLAB/Octave variable]

Variable set by the `estimation` command, if it is used with the `bayesian_irf` option. Fields are of the form:

```
oo_.PosteriorIRF.dsge.MOMENT_NAME.VARIABLE_NAME_SHOCK_NAME
```

`oo_.SmoothedMeasurementErrors` [MATLAB/Octave variable]

Variable set by the `estimation` command, if it is used with the `smoother` option. Fields are of the form:

```
oo_.SmoothedMeasurementErrors.VARIABLE_NAME
```

`oo_.SmoothedShocks` [MATLAB/Octave variable]

Variable set by the `estimation` command (if used with the `smoother` option), or by the `calib_smoother` command.

After an estimation without Metropolis, or if computed by `calib_smoother`, fields are of the form:

```
oo_.SmoothedShocks.VARIABLE_NAME
```

After an estimation with Metropolis, fields are of the form:

```
oo_.SmoothedShocks.MOMENT_NAME.VARIABLE_NAME
```

`oo_.SmoothedVariables` [MATLAB/Octave variable]

Variable set by the `estimation` command (if used with the `smoother` option), or by the `calib_smoother` command.

After an estimation without Metropolis, or if computed by `calib_smoother`, fields are of the form:

```
oo_.SmoothedVariables.VARIABLE_NAME
```

After an estimation with Metropolis, fields are of the form:

```
oo_.SmoothedVariables.MOMENT_NAME.VARIABLE_NAME
```

`oo_.UpdatedVariables` [MATLAB/Octave variable]

Variable set by the `estimation` command (if used with the `smoother` option), or by the `calib_smoother` command. Contains the estimation of the expected value of variables given the information available at the *current* date.

After an estimation without Metropolis, or if computed by `calib_smoother`, fields are of the form:

```
oo_.UpdatedVariables.VARIABLE_NAME
```

After an estimation with Metropolis, fields are of the form:

```
oo_.UpdatedVariables.MOMENT_NAME.VARIABLE_NAME
```

`oo_.PosteriorTheoreticalMoments` [MATLAB/Octave variable]

Variable set by the `estimation` command, if it is used with the `moments_varendo` option. Fields are of the form:

```
oo_.PosteriorTheoreticalMoments.dsge.THEORETICAL_MOMENT.ESTIMATED_OBJECT.MOMENT_
NAME.VARIABLE_NAME
```

where *THEORETICAL_MOMENT* is one of the following:

`covariance`
: Variance-covariance of endogenous variables

`correlation`
: Auto- and cross-correlation of endogenous variables. Fields are vectors with correlations from 1 up to order `options_.ar`

`VarianceDecomposition`
: Decomposition of variance (unconditional variance, i.e. at horizon infinity)[4]

`ConditionalVarianceDecomposition`
: Only if the `conditional_variance_decomposition` option has been specified

`oo_.posterior_density` [MATLAB/Octave variable]

Variable set by the `estimation` command, if it is used with `mh_replic > 0` or `load_mh_file` option. Fields are of the form:

```
oo_.posterior_density.PARAMETER_NAME
```

`oo_.posterior_hpdinf` [MATLAB/Octave variable]

Variable set by the `estimation` command, if it is used with `mh_replic > 0` or `load_mh_file` option. Fields are of the form:

```
oo_.posterior_hpdinf.ESTIMATED_OBJECT.VARIABLE_NAME
```

`oo_.posterior_hpdsup` [MATLAB/Octave variable]

Variable set by the `estimation` command, if it is used with `mh_replic > 0` or `load_mh_file` option. Fields are of the form:

```
oo_.posterior_hpdsup.ESTIMATED_OBJECT.VARIABLE_NAME
```

[4] When the shocks are correlated, it is the decomposition of orthogonalized shocks via Cholesky decomposition according to the order of declaration of shocks (see Section 4.2 [Variable declarations], page 10)

`oo_.posterior_mean` [MATLAB/Octave variable]

Variable set by the `estimation` command, if it is used with `mh_replic > 0` or `load_mh_file` option. Fields are of the form:

```
oo_.posterior_mean.ESTIMATED_OBJECT.VARIABLE_NAME
```

`oo_.posterior_mode` [MATLAB/Octave variable]

Variable set by the `estimation` command, if it is used with `mh_replic > 0` or `load_mh_file` option. Fields are of the form:

```
oo_.posterior_mode.ESTIMATED_OBJECT.VARIABLE_NAME
```

`oo_.posterior_std` [MATLAB/Octave variable]

Variable set by the `estimation` command, if it is used with `mh_replic > 0` or `load_mh_file` option. Fields are of the form:

```
oo_.posterior_std.ESTIMATED_OBJECT.VARIABLE_NAME
```

Here are some examples of generated variables:

```
oo_.posterior_mode.parameters.alp
oo_.posterior_mean.shocks_std.ex
oo_.posterior_hpdsup.measurement_errors_corr.gdp_conso
```

`oo_.RecursiveForecast` [MATLAB/Octave variable]

Variable set by the `forecast` option of the `estimation` command when used with the nobs = [*INTEGER1*:*INTEGER2*] option (see [nobs], page 53).

Fields are of the form:

```
oo_.RecursiveForecast.FORECAST_OBJECT.VARIABLE_NAME
```

where *FORECAST_OBJECT* is one of the following[5]:

`Mean` Mean of the posterior forecast distribution

`HPDinf/HPDsup`
Upper/lower bound of the 90% HPD interval taking into account only parameter uncertainty

`HPDTotalinf/HPDTotalsup`
Upper/lower bound of the 90% HPD interval taking into account both parameter and future shock uncertainty

VARIABLE_NAME contains a matrix of the following size: number of time periods for which forecasts are requested using the nobs = [*INTEGER1*:*INTEGER2*] option times the number of forecast horizons requested by the `forecast` option. I.e., the row indicates the period at which the forecast is performed and the column the respective k-step ahead forecast. The starting periods are sorted in ascending order, not in declaration order.

`oo_.convergence.geweke` [MATLAB/Octave variable]

Variable set by the convergence diagnostics of the `estimation` command when used with [mh_nblocks], page 54=1 option (see [mh_nblocks], page 54).

Fields are of the form:

```
oo_.convergence.geweke.VARIABLE_NAME.DIAGNOSTIC_OBJECT
```

where *DIAGNOSTIC_OBJECT* is one of the following:

`posteriormean`
Mean of the posterior parameter distribution

[5] See [forecast], page 60 for more information

`posteriorstd`
: Standard deviation of the posterior parameter distribution

`nse_iid`
: Numerical standard error (NSE) under the assumption of iid draws

`rne_iid`
: Relative numerical efficiency (RNE) under the assumption of iid draws

`nse_x`
: Numerical standard error (NSE) when using an x% taper

`rne_x`
: Relative numerical efficiency (RNE) when using an x% taper

`pooled_mean`
: Mean of the parameter when pooling the beginning and end parts of the chain specified in [geweke_interval], page 63 and weighting them with their relative precision. It is a vector containing the results under the iid assumption followed by the ones using the [taper_steps], page 63 (see [taper_steps], page 63).

`pooled_nse`
: NSE of the parameter when pooling the beginning and end parts of the chain and weighting them with their relative precision. See `pooled_mean`

`prob_chi2_test`
: p-value of a chi squared test for equality of means in the beginning and the end of the MCMC chain. See `pooled_mean`. A value above 0.05 indicates that the null hypothesis of equal means and thus convergence cannot be rejected at the 5 percent level. Differing values along the [taper_steps], page 63 signal the presence of significant autocorrelation in draws. In this case, the estimates using a higher tapering are usually more reliable.

`model_comparison` *FILENAME*[(*DOUBLE*)]...; [Command]
`model_comparison` (*marginal_density = laplace | modifiedharmonicmean*) *FILENAME*[(*DOUBLE*)]...; [Command]

Description

This command computes odds ratios and estimate a posterior density over a collection of models (see e.g. *Koop (2003), Ch. 1*). The priors over models can be specified as the *DOUBLE* values, otherwise a uniform prior over all models is assumed. In contrast to frequentist econometrics, the models to be compared do not need to be nested. However, as the computation of posterior odds ratios is a Bayesian technique, the comparison of models estimated with maximum likelihood is not supported.

Example

```
model_comparison my_model(0.7) alt_model(0.3);
```

This example attributes a 70% prior over `my_model` and 30% prior over `alt_model`.

`shock_decomposition` [*VARIABLE_NAME*]...; [Command]
`shock_decomposition` (*OPTIONS*...) [*VARIABLE_NAME*]...; [Command]

Description

This command computes and displays shock decomposition according to the model for a given sample.

Note that this command must come after either `estimation` (in case of an estimated model) or `stoch_simul` (in case of a calibrated model).

Options

`parameter_set = PARAMETER_SET`
: Specify the parameter set to use for running the smoother. The *PARAMETER_SET* can take one of the following five values: `calibration`, `prior_mode`, `prior_mean`, `posterior_mode`, `posterior_mean`, `posterior_median`. Default value: `posterior_mean` if Metropolis has been run, else `posterior_mode`.

`datafile = FILENAME`
: See [datafile], page 53. Useful when computing the shock decomposition on a calibrated model.

The results are stored in the field `oo_.shock_decomposition`, which is a three dimensional array. The first dimension contains the endogenous variables for which the shock decomposition has been requested. The second dimension stores in the first `M_.exo_nbr` columns the contribution of the respective shocks. Column `M_.exo_nbr+1` stores the contribution of the initial conditions, while column `M_.exo_nbr+2` stores the smoothed value of the respective endogenous variable. The third dimension stores the time periods.

`unit_root_vars` *VARIABLE_NAME...;* [Command]

This command is deprecated. Use `estimation` option `diffuse_filter` instead for estimating a model with non-stationary observed variables or `steady` option `nocheck` to prevent `steady` to check the steady state returned by your steady state file.

Dynare also has the ability to estimate Bayesian VARs:

`bvar_density` *;* [Command]

Computes the marginal density of an estimated BVAR model, using Minnesota priors.

See `bvar-a-la-sims.pdf`, which comes with Dynare distribution, for more information on this command.

Dynare can also run the smoother on a calibrated model:

`calib_smoother` [*VARIABLE_NAME*]*...;* [Command]
`calib_smoother` (*OPTIONS...*) [*VARIABLE_NAME*]*...;* [Command]

Description

This command computes the smoothed variables (and possible the filtered variables) on a `calibrated` model.

A datafile must be provided, and the observable variables declared with `varobs`. The smoother is based on a first-order approximation of the model.

By default, the command computes the smoothed variables and shocks and stores the results in `oo_.SmoothedVariables` and `oo_.SmoothedShocks`. It also fills `oo_.UpdatedVariables`.

Options

`datafile = FILENAME`
: See [datafile], page 53.

`filtered_vars`
: Triggers the computation of filtered variables. See [filtered_vars], page 60, for more details.

`filter_step_ahead = [INTEGER1:INTEGER2]`
: See [filter_step_ahead], page 60.

4.15 Forecasting

On a calibrated model, forecasting is done using the `forecast` command. On an estimated model, use the `forecast` option of `estimation` command.

It is also possible to compute forecasts on a calibrated or estimated model for a given constrained path of the future endogenous variables. This is done, from the reduced form representation of the DSGE model, by finding the structural shocks that are needed to match the restricted paths. Use `conditional_forecast`, `conditional_forecast_paths` and `plot_conditional_forecast` for that purpose.

Finally, it is possible to do forecasting with a Bayesian VAR using the `bvar_forecast` command.

`forecast` [*VARIABLE_NAME*...]; [Command]
`forecast` (*OPTIONS*...) [*VARIABLE_NAME*...]; [Command]

Description

This command computes a simulation of a stochastic model from an arbitrary initial point.

When the model also contains deterministic exogenous shocks, the simulation is computed conditionally to the agents knowing the future values of the deterministic exogenous variables.

`forecast` must be called after `stoch_simul`.

`forecast` plots the trajectory of endogenous variables. When a list of variable names follows the command, only those variables are plotted. A 90% confidence interval is plotted around the mean trajectory. Use option `conf_sig` to change the level of the confidence interval.

Options

`periods` = *INTEGER*
Number of periods of the forecast. Default: `5`.

`conf_sig` = *DOUBLE*
Level of significance for confidence interval. Default: `0.90`

`nograph` See [nograph], page 41.

`nodisplay`
See [nodisplay], page 41.

`graph_format` = *FORMAT*
`graph_format` = (*FORMAT*, *FORMAT*...)
See [graph_format], page 41.

Initial Values

`forecast` computes the forecast taking as initial values the values specified in `histval` (see Section 4.7 [Initial and terminal conditions], page 22). When no `histval` block is present, the initial values are the one stated in `initval`. When `initval` is followed by command `steady`, the initial values are the steady state (see Section 4.10 [Steady state], page 30).

Output

The results are stored in `oo_.forecast`, which is described below.

Example

```
varexo_det tau;
varexo e;
```

```
...

shocks;
var e; stderr 0.01;
var tau;
periods 1:9;
values -0.15;
end;

stoch_simul(irf=0);

forecast;
```

`oo_.forecast` [MATLAB/Octave variable]

Variable set by the `forecast` command, or by the `estimation` command if used with the `forecast` option and if no Metropolis-Hastings has been computed (in that case, the forecast is computed for the posterior mode). Fields are of the form:

`oo_.forecast.`*`FORECAST_MOMENT`*`.`*`VARIABLE_NAME`*

where *FORECAST_MOMENT* is one of the following:

`HPDinf`	Lower bound of a 90% HPD interval[6] of forecast due to parameter uncertainty
`HPDsup`	Lower bound of a 90% HPD interval due to parameter uncertainty
`HPDTotalinf`	Lower bound of a 90% HPD interval of forecast due to parameter uncertainty and future shocks (only with the `estimation` command)
`HPDTotalsup`	Lower bound of a 90% HPD interval due to parameter uncertainty and future shocks (only with the `estimation` command)
`Mean`	Mean of the posterior distribution of forecasts
`Median`	Median of the posterior distribution of forecasts
`Std`	Standard deviation of the posterior distribution of forecasts

`oo_.PointForecast` [MATLAB/Octave variable]

Set by the `estimation` command, if it is used with the `forecast` option and if either `mh_replic > 0` or `load_mh_file` option is used.

Contains the distribution of forecasts taking into account the uncertainty about both parameters and shocks.

Fields are of the form:

`oo_.PointForecast.`*`MOMENT_NAME`*`.`*`VARIABLE_NAME`*

`oo_.MeanForecast` [MATLAB/Octave variable]

Set by the `estimation` command, if it is used with the `forecast` option and if either `mh_replic > 0` or `load_mh_file` option is used.

Contains the distribution of forecasts where the uncertainty about shocks is averaged out. The distribution of forecasts therefore only represents the uncertainty about parameters.

Fields are of the form:

`oo_.MeanForecast.`*`MOMENT_NAME`*`.`*`VARIABLE_NAME`*

[6] See option [conf_sig], page 69 to change the size of the HPD interval

`conditional_forecast` (*OPTIONS*...) [*VARIABLE_NAME*...]; [Command]

Description

This command computes forecasts on an estimated or calibrated model for a given constrained path of some future endogenous variables. This is done using the reduced form first order state-space representation of the DSGE model by finding the structural shocks that are needed to match the restricted paths. Consider the an augmented state space representation that stacks both predetermined and non-predetermined variables into a vector y_t:

$y_t = Ty_{t-1} + R\varepsilon_t$

Both y_t and ε_t are split up into controlled and uncontrolled ones to get:

$y_t(contr\_vars) = Ty_{t-1}(contr\_vars) + R(contr\_vars, uncontr\_shocks)\varepsilon_t(uncontr\_shocks) + R(contr\_vars, contr\_shocks)\varepsilon_t(contr\_shocks)$

which can be solved algebraically for $\varepsilon_t(contr\_shocks)$.

Using these controlled shocks, the state-space representation can be used for forecasting. A few things need to be noted. First, it is assumed that controlled exogenous variables are fully under control of the policy maker for all forecast periods and not just for the periods where the endogenous variables are controlled. For all uncontrolled periods, the controlled exogenous variables are assumed to be 0. This implies that there is no forecast uncertainty arising from these exogenous variables in uncontrolled periods. Second, by making use of the first order state space solution, even if a higher-order approximation was performed, the conditional forecasts will be based on a first order approximation. Third, although controlled exogenous variables are taken as instruments perfectly under the control of the policy-maker, they are nevertheless random and unforeseen shocks from the perspective of the households. That is, households are in each period surprised by the realization of a shock that keeps the controlled endogenous variables at their respective level. Fourth, keep in mind that if the structural innovations are correlated, because the calibrated or estimated covariance matrix has non zero off diagonal elements, the results of the conditional forecasts will depend on the ordering of the innovations (as declared after `varexo`). As in VAR models, a Cholesky decomposition is used to factorize the covariance matrix and identify orthogonal impulses. It is preferable to declare the correlations in the `model` block (explicitly imposing the identification restrictions), unless you are satisfied with the implicit identification restrictions implied by the Cholesky decomposition.

This command has to be called after `estimation` or `stoch_simul`.

Use `conditional_forecast_paths` block to give the list of constrained endogenous, and their constrained future path. Option `controlled_varexo` is used to specify the structural shocks which will be matched to generate the constrained path.

Use `plot_conditional_forecast` to graph the results.

Options

`parameter_set = calibration | prior_mode | prior_mean | posterior_mode | posterior_mean | posterior_median`

Specify the parameter set to use for the forecasting. No default value, mandatory option.

`controlled_varexo = (`*VARIABLE_NAME*`...)`

Specify the exogenous variables to use as control variables. No default value, mandatory option.

`periods = `*INTEGER*

Number of periods of the forecast. Default: `40`. `periods` cannot be less than the number of constrained periods.

`replic = INTEGER`
: Number of simulations. Default: `5000`.

`conf_sig = DOUBLE`
: Level of significance for confidence interval. Default: `0.80`

Output

The results are not stored in the `oo_` structure but in a separate structure `forecasts` saved to the harddisk into a file called `conditional_forecasts.mat`.

`forecasts.cond` [MATLAB/Octave variable]

Variable set by the `conditional_forecast` command. It stores the conditional forecasts. Fields are `periods+1` by 1 vectors storing the steady state (time 0) and the subsequent `periods` forecasts periods. Fields are of the form:

`forecasts.cond.`*`FORECAST_MOMENT`*`.`*`VARIABLE_NAME`*

where *FORECAST_MOMENT* is one of the following:

`Mean`	Mean of the conditional forecast distribution.
`ci`	Confidence interval of the conditional forecast distribution. The size corresponds to `conf_sig`.

`forecasts.uncond` [MATLAB/Octave variable]

Variable set by the `conditional_forecast` command. It stores the unconditional forecasts. Fields are of the form:

`forecasts.uncond.`*`FORECAST_MOMENT`*`.`*`VARIABLE_NAME`*

`forecasts.instruments` [MATLAB/Octave variable]

Variable set by the `conditional_forecast` command. Stores the names of the exogenous instruments.

`forecasts.controlled_variables` [MATLAB/Octave variable]

Variable set by the `conditional_forecast` command. Stores the position of the constrained endogenous variables in declaration order.

`forecasts.graphs` [MATLAB/Octave variable]

Variable set by the `conditional_forecast` command. Stores the information for generating the conditional forecast plots.

Example

```
var y a
varexo e u;

...

estimation(...);

conditional_forecast_paths;
var y;
periods 1:3, 4:5;
values 2, 5;
var a;
periods 1:5;
values 3;
```

```
    end;

    conditional_forecast(parameter_set = calibration, controlled_varexo = (e, u), replic =

    plot_conditional_forecast(periods = 10) a y;
```

`conditional_forecast_paths` *;* [Block]

Describes the path of constrained endogenous, before calling `conditional_forecast`. The syntax is similar to deterministic shocks in `shocks`, see `conditional_forecast` for an example.

The syntax of the block is the same than the deterministic shocks in the `shocks` blocks (see Section 4.8 [Shocks on exogenous variables], page 27).

`plot_conditional_forecast` [*VARIABLE_NAME*. . .]*;* [Command]
`plot_conditional_forecast` (*periods* = *INTEGER*) [*VARIABLE_NAME*. . .]*;* [Command]

Description

Plots the conditional (plain lines) and unconditional (dashed lines) forecasts.

To be used after `conditional_forecast`.

Options

`periods` = *INTEGER*
: Number of periods to be plotted. Default: equal to `periods` in `conditional_forecast`. The number of periods declared in `plot_conditional_forecast` cannot be greater than the one declared in `conditional_forecast`.

`bvar_forecast` *;* [Command]

This command computes (out-of-sample) forecasts for an estimated BVAR model, using Minnesota priors.

See `bvar-a-la-sims.pdf`, which comes with Dynare distribution, for more information on this command.

If the model contains strong non-linearities or if some perfectly expected shocks are considered, the forecasts and the conditional forecasts can be computed using an extended path method. The forecast scenario describing the shocks and/or the constrained paths on some endogenous variables should be build. The first step is the forecast scenario initialization using the function `init_plan`:

`HANDLE = init_plan` (*DATES*) *;* [MATLAB/Octave command]

Creates a new forecast scenario for a forecast period (indicated as a dates class, see [dates class members], page 111). This function return a handle on the new forecast scenario.

The forecast scenario can contain some simple shocks on the exogenous variables. This shocks are described using the function `basic_plan`:

`HANDLE = basic_plan` (*HANDLE, 'VARIABLE_NAME', 'SHOCK_TYPE', DATES, MATLAB VECTOR OF DOUBLE* | [*DOUBLE* | *EXPRESSION* [*DOUBLE* | | *EXPRESSION*]]) *;* [MATLAB/Octave command]

Adds to the forecast scenario a shock on the exogenous variable indicated between quotes in the second argument. The shock type has to be specified in the third argument between quotes: 'surprise' in case of an unexpected shock or 'perfect_foresight' for a perfectly anticipated shock. The fourth argument indicates the period of the shock using a dates class (see [dates class members], page 111). The last argument is the shock path indicated as a Matlab vector of double. This function return the handle of the updated forecast scenario.

The forecast scenario can also contain a constrained path on an endogenous variable. The values of the related exogenous variable compatible with the constrained path are in this case computed. In other words, a conditional forecast is performed. This kind of shock is described with the function `flip_plan`:

`HANDLE = flip_plan` (*HANDLE, 'VARIABLE_NAME, 'VARIABLE_NAME', 'SHOCK_TYPE', DATES, MATLAB VECTOR OF DOUBLE* | [*DOUBLE* | *EXPRESSION* [*DOUBLE* | | *EXPRESSION*]]) *;* [MATLAB/Octave command]

Adds to the forecast scenario a constrained path on the endogenous variable specified between quotes in the second argument. The associated exogenous variable provided in the third argument between quotes, is considered as an endogenous variable and its values compatible with the constrained path on the endogenous variable will be computed. The nature of the expectation on the constrained path has to be specified in the fourth argument between quotes: 'surprise' in case of an unexpected path or 'perfect_foresight' for a perfectly anticipated path. The fifth argument indicates the period where the path of the endogenous variable is constrained using a dates class (see [dates class members], page 111). The last argument contains the constrained path as a Matlab vector of double. This function return the handle of the updated forecast scenario.

Once the forecast scenario if fully described, the forecast is computed with the command `det_cond_forecast`:

`DSERIES = det_cond_forecast` (*HANDLE*[, *DSERIES* [, *DATES*]]) *;* [MATLAB/Octave command]

Computes the forecast or the conditional forecast using an extended path method for the given forecast scenario (first argument). The past values of the endogenous and exogenous variables provided with a dseries class (see [dseries class members], page 120) can be indicated in the second argument. By default, the past values of the variables are equal to their steady-state values. The initial date of the forecast can be provided in the third argument. By default, the forecast will start at the first date indicated in the `init_plan` command. This function returns a dset containing the historical and forecast values for the endogenous and exogenous variables.

Example

```
/* conditional forecast using extended path method
with perfect foresight on r path*/
var y r
varexo e u;

...

smoothed = dseries('smoothed_variables.csv');

fplan = init_plan(2013Q4:2029Q4);

fplan = flip_plan(fplan, 'y', 'u', 'surprise', 2013Q4:2014Q4,  [1 1.1 1.2 1.1 ]);

fplan = flip_plan(fplan, 'r', 'e', 'perfect_foresight', 2013Q4:2014Q4,  [2 1.9 1.9 1.9 ]

dset_forecast = det_cond_forecast(fplan, smoothed);

plot(dset_forecast.{'y','u'});
plot(dset_forecast.{'r','e'});
```

4.16 Optimal policy

Dynare has tools to compute optimal policies for various types of objectives. You can either solve for optimal policy under commitment with `ramsey_policy`, for optimal policy under discretion with `discretionary_policy` or for optimal simple rule with `osr`.

`osr` [*VARIABLE_NAME*. . .]; [Command]
`osr` (*OPTIONS*. . .) [*VARIABLE_NAME*. . .]; [Command]

Description

This command computes optimal simple policy rules for linear-quadratic problems of the form:

$\min_\gamma E(y_t'Wy_t)$

such that:

$A_1 E_t y_{t+1} + A_2 y_t + A_3 y_{t-1} + Ce_t = 0$

where:

- E denotes the unconditional expectations operator;
- γ are parameters to be optimized. They must be elements of the matrices A_1, A_2, A_3, i.e. be specified as parameters in the `params`-command and be entered in the `model`-block;
- y are the endogenous variables, specified in the `var`-command, whose (co)-variance enters the loss function;
- e are the exogenous stochastic shocks, specified in the `var_exo`-command;
- W is the weighting matrix;

The linear quadratic problem consists of choosing a subset of model parameters to minimize the weighted (co)-variance of a specified subset of endogenous variables, subject to a linear law of motion implied by the first order conditions of the model. A few things are worth mentioning. First, y denotes the selected endogenous variables' deviations from their steady state, i.e. in case they are not already mean 0 the variables entering the loss function are automatically demeaned so that the centered second moments are minimized. Second, `osr` only solves linear quadratic problems of the type resulting from combining the specified quadratic loss function with a first order approximation to the model's equilibrium conditions. The reason is that the first order state-space representation is used to compute the unconditional (co)-variances. Hence, `osr` will automatically select `order=1`. Third, because the objective involves minimizing a weighted sum of unconditional second moments, those second moments must be finite. In particular, unit roots in y are not allowed.

The subset of the model parameters over which the optimal simple rule is to be optimized, γ, must be listed with `osr_params`.

The weighting matrix W used for the quadratic objective function is specified in the `optim_weights`-block. By attaching weights to endogenous variables, the subset of endogenous variables entering the objective function, y, is implicitly specified.

The linear quadratic problem is solved using the numerical optimizer `csminwel` of Chris Sims.

Options

The `osr` command will subsequently run `stoch_simul` and accepts the same options, including restricting the endogenous variables by listing them after the command, as `stoch_simul` (see Section 4.13.1 [Computing the stochastic solution], page 40) plus

`maxit = INTEGER` Determines the maximum number of iterations
used in the non-linear solver. Default: `1000`

`tolf = DOUBLE` Convergence criterion for termination based on
the function value. Iteration will cease when it proves impossible to improve the function value by more than tolf. Default: `1e-7`

The value of the objective is stored in the variable `oo_.osr.objective_function`, which is described below.

After running `osr` the parameters entering the simple rule will be set to their optimal value so that subsequent runs of `stoch_simul` will be conducted at these values.

`osr_params` *PARAMETER_NAME. . . ;* [Command]

This command declares parameters to be optimized by `osr`.

`optim_weights` *;* [Block]

This block specifies quadratic objectives for optimal policy problems

More precisely, this block specifies the nonzero elements of the weight matrix W used in the quadratic form of the objective function in `osr`.

An element of the diagonal of the weight matrix is given by a line of the form:

VARIABLE_NAME EXPRESSION;

An off-the-diagonal element of the weight matrix is given by a line of the form:

VARIABLE_NAME, *VARIABLE_NAME EXPRESSION*;

Example

```
var y inflation r;
varexo y_ inf_;

parameters delta sigma alpha kappa gammarr gammax0 gammac0 gamma_y_ gamma_inf_;

delta =  0.44;
kappa =  0.18;
alpha =  0.48;
sigma = -0.06;

gammarr = 0;
gammax0 = 0.2;
gammac0 = 1.5;
gamma_y_ = 8;
gamma_inf_ = 3;

model(linear);
y  = delta * y(-1)  + (1-delta)*y(+1)+sigma *(r - inflation(+1)) + y_;
inflation  =   alpha * inflation(-1) + (1-alpha) * inflation(+1) + kappa*y + inf_;
r = gammax0*y(-1)+gammac0*inflation(-1)+gamma_y_*y_+gamma_inf_*inf_;
end;

shocks;
var y_; stderr 0.63;
var inf_; stderr 0.4;
end;

optim_weights;
inflation 1;
y 1;
y, inflation 0.5;
end;
```

```
osr_params gammax0 gammac0 gamma_y_ gamma_inf_;
osr y;
```

`oo_.osr.objective_function` [MATLAB/Octave variable]

After an execution of the `osr` command, this variable contains the value of the objective under optimal policy.

`ramsey_model` (*OPTIONS...*); [Command]

Description

This command computes the First Order Conditions for maximizing the policy maker objective function subject to the constraints provided by the equilibrium path of the economy.

The planner objective must be declared with the `planner_objective` command.

This command only creates the expanded model, it doesn't perform any computations. It needs to be followed by other instructions to actually perfrom desired computations. Note that it is the only way to perform perfect foresight simulation of the Ramsey policy problem.

See Section 4.6 [Auxiliary variables], page 21, for an explanation of how Lagrange multipliers are automatically created.

Options

This command accepts the following options:

`planner_discount` = *EXPRESSION*
: Declares the discount factor of the central planner. Default: `1.0`

`instruments` = (*VARIABLE_NAME*,...)
: Declares instrument variables for the computation of the steady state under optimal policy. Requires a `steady_state_model` block or a `..._steadystate.m` file. See below.

Steady state

Dynare takes advantage of the fact that the Lagrange multipliers appear linearly in the equations of the steady state of the model under optimal policy. Nevertheless, it is in general very difficult to compute the steady state with simply a numerical guess in `initval` for the endogenous variables.

It greatly facilitates the computation, if the user provides an analytical solution for the steady state (in `steady_state_model` block or in a `..._steadystate.m` file). In this case, it is necessary to provide a steady state solution CONDITIONAL on the value of the instruments in the optimal policy problem and declared with option `instruments`. Note that choosing the instruments is partly a matter of interpretation and you can choose instruments that are handy from a mathematical point of view but different from the instruments you would refer to in the analysis of the paper. A typical example is choosing inflation or nominal interest rate as an instrument.

`ramsey_policy` [*VARIABLE_NAME*...]; [Command]
`ramsey_policy` (*OPTIONS*...) [*VARIABLE_NAME*...]; [Command]

Description

This command computes the first order approximation of the policy that maximizes the policy maker objective function submitted to the constraints provided by the equilibrium path of the economy.

The planner objective must be declared with the `planner_objective` command.

See Section 4.6 [Auxiliary variables], page 21, for an explanation of how this operator is handled internally and how this affects the output.

Options

This command accepts all options of `stoch_simul`, plus:

`planner_discount` = *EXPRESSION*
: Declares the discount factor of the central planner. Default: `1.0`

`instruments` = (*VARIABLE_NAME*,...)
: Declares instrument variables for the computation of the steady state under optimal policy. Requires a `steady_state_model` block or a `..._steadystate.m` file. See below.

Note that only first order approximation is available (*i.e.* `order=1` must be specified).

Output

This command generates all the output variables of `stoch_simul`.

In addition, it stores the value of planner objective function under Ramsey policy in `oo_.planner_objective_value`.

Steady state

Dynare takes advantage of the fact that the Lagrange multipliers appear linearly in the equations of the steady state of the model under optimal policy. Nevertheless, it is in general very difficult to compute the steady state with simply a numerical guess in `initval` for the endogenous variables.

It greatly facilitates the computation, if the user provides an analytical solution for the steady state (in `steady_state_model` block or in a `..._steadystate.m` file). In this case, it is necessary to provide a steady state solution CONDITIONAL on the value of the instruments in the optimal policy problem and declared with option `instruments`. Note that choosing the instruments is partly a matter of interpretation and you can choose instruments that are handy from a mathematical point of view but different from the instruments you would refer to in the analysis of the paper. A typical example is choosing inflation or nominal interest rate as an instrument.

`discretionary_policy` [*VARIABLE_NAME*...]; [Command]
`discretionary_policy` (*OPTIONS*...) [*VARIABLE_NAME*...]; [Command]

Description

This command computes an approximation of the optimal policy under discretion. The algorithm implemented is essentially an LQ solver, and is described by *Dennis (2007)*.

You should ensure that your model is linear and your objective is quadratic. Also, you should set the `linear` option of the `model` block.

Options

This command accepts the same options than `ramsey_policy`, plus:

`discretionary_tol` = *NON-NEGATIVE DOUBLE*
: Sets the tolerance level used to assess convergence of the solution algorithm. Default: `1e-7`.

`maxit` = *INTEGER*
: Maximum number of iterations. Default: `3000`.

`planner_objective` *MODEL_EXPRESSION;* [Command]

This command declares the policy maker objective, for use with `ramsey_policy` or `discretionary_policy`.

You need to give the one-period objective, not the discounted lifetime objective. The discount factor is given by the `planner_discount` option of `ramsey_policy` and `discretionary_policy`. The objective function can only contain current endogenous variables and no exogenous ones. This limitation is easily circumvented by defining an appropriate auxiliary variable in the model.

With `ramsey_policy`, you are not limited to quadratic objectives: you can give any arbitrary nonlinear expression.

With `discretionary_policy`, the objective function must be quadratic.

4.17 Sensitivity and identification analysis

Dynare provides an interface to the global sensitivity analysis (GSA) toolbox (developed by the Joint Research Center (JRC) of the European Commission), which is now part of the official Dynare distribution. The GSA toolbox can be used to answer the following questions:

1. What is the domain of structural coefficients assuring the stability and determinacy of a DSGE model?
2. Which parameters mostly drive the fit of, *e.g.*, GDP and which the fit of inflation? Is there any conflict between the optimal fit of one observed series versus another?
3. How to represent in a direct, albeit approximated, form the relationship between structural parameters and the reduced form of a rational expectations model?

The discussion of the methodologies and their application is described in *Ratto (2008)*.

With respect to the previous version of the toolbox, in order to work properly, the GSA toolbox no longer requires that the Dynare estimation environment is set up.

Sensitivity analysis results are saved locally in `<mod_file>/GSA`, where `<mod_file>.mod` is the name of the DYNARE model file.

4.17.1 Sampling

The following binary files are produced:

- `<mod_file>_prior.mat`: this file stores information about the analyses performed sampling from the prior ranges, *i.e.* `pprior=1` and `ppost=0`;
- `<mod_file>_mc.mat`: this file stores information about the analyses performed sampling from multivariate normal, *i.e.* `pprior=0` and `ppost=0`;
- `<mod_file>_post.mat`: this file stores information about analyses performed using the Metropolis posterior sample, *i.e.* `ppost=1`.

4.17.2 Stability Mapping

Figure files produced are of the form `<mod_file>_prior_*.fig` and store results for stability mapping from prior Monte-Carlo samples:

- `<mod_file>_prior_stab_SA_*.fig`: plots of the Smirnov test analyses confronting the cdf of the sample fulfilling Blanchard-Kahn conditions with the cdf of the rest of the sample;
- `<mod_file>_prior_stab_indet_SA_*.fig`: plots of the Smirnov test analyses confronting the cdf of the sample producing indeterminacy with the cdf of the original prior sample;
- `<mod_file>_prior_stab_unst_SA_*.fig`: plots of the Smirnov test analyses confronting the cdf of the sample producing unstable (explosive roots) behavior with the cdf of the original prior sample;
- `<mod_file>_prior_stable_corr_*.fig`: plots of bivariate projections of the sample fulfilling Blanchard-Kahn conditions;

- `<mod_file>_prior_indeterm_corr_*.fig`: plots of bivariate projections of the sample producing indeterminacy;
- `<mod_file>_prior_unstable_corr_*.fig`: plots of bivariate projections of the sample producing instability;
- `<mod_file>_prior_unacceptable_corr_*.fig`: plots of bivariate projections of the sample producing unacceptable solutions, *i.e.* either instability or indeterminacy or the solution could not be found (*e.g.* the steady state solution could not be found by the solver).

Similar conventions apply for `<mod_file>_mc_*.fig` files, obtained when samples from multivariate normal are used.

4.17.3 Reduced Form Mapping

The mapping of the reduced form solution forces the use of samples from prior ranges or prior distributions, *i.e.*: `pprior=1` and `ppost=0`. It uses 250 samples to optimize smoothing parameters and 1000 samples to compute the fit. The rest of the sample is used for out-of-sample validation. One can also load a previously estimated mapping with a new Monte-Carlo sample, to look at the forecast for the new Monte-Carlo sample.

The following synthetic figures are produced:

- `<mod_file>_redform_<endo name>_vs_lags_*.fig`: shows bar charts of the sensitivity indices for the ten most important parameters driving the reduced form coefficients of the selected endogenous variables (`namendo`) versus lagged endogenous variables (`namlagendo`); suffix `log` indicates the results for log-transformed entries;
- `<mod_file>_redform_<endo name>_vs_shocks_*.fig`: shows bar charts of the sensitivity indices for the ten most important parameters driving the reduced form coefficients of the selected endogenous variables (`namendo`) versus exogenous variables (`namexo`); suffix `log` indicates the results for log-transformed entries;
- `<mod_file>_redform_GSA(_log).fig`: shows bar chart of all sensitivity indices for each parameter: this allows one to notice parameters that have a minor effect for any of the reduced form coefficients.

Detailed results of the analyses are shown in the subfolder `<mod_file>/GSA/redform_stab`, where the detailed results of the estimation of the single functional relationships between parameters θ and reduced form coefficient are stored in separate directories named as:

- `<namendo>_vs_<namlagendo>`: for the entries of the transition matrix;
- `<namendo>_vs_<namexo>`: for entries of the matrix of the shocks.

Moreover, analyses for log-transformed entries are denoted with the following suffixes (y denotes the generic reduced form coefficient):

- `log`: $y^* = \log(y)$;
- `minuslog`: $y^* = \log(-y)$;
- `logsquared`: $y^* = \log(y^2)$ for symmetric fat tails;
- `logskew`: $y^* = \log(|y + \lambda|)$ for asymmetric fat tails.

The optimal type of transformation is automatically selected without the need of user intervention.

4.17.4 RMSE

The RMSE analysis can be performed with different types of sampling options:

1. When `pprior=1` and `ppost=0`, the toolbox analyzes the RMSEs for the Monte-Carlo sample obtained by sampling parameters from their prior distributions (or prior ranges): this analysis provides some hints about what parameter drives the fit of which observed series, prior to the full estimation;

2. When `pprior=0` and `ppost=0`, the toolbox analyzes the RMSEs for a multivariate normal Monte-Carlo sample, with covariance matrix based on the inverse Hessian at the optimum: this analysis is useful when maximum likelihood estimation is done (*i.e.* no Bayesian estimation);
3. When `ppost=1` the toolbox analyzes the RMSEs for the posterior sample obtained by Dynare's Metropolis procedure.

The use of cases 2 and 3 requires an estimation step beforehand. To facilitate the sensitivity analysis after estimation, the `dynare_sensitivity` command also allows you to indicate some options of the `estimation` command. These are:

- `datafile`
- `nobs`
- `first_obs`
- `prefilter`
- `presample`
- `nograph`
- `nodisplay`
- `graph_format`
- `conf_sig`
- `loglinear`
- `mode_file`

Binary files produced my RMSE analysis are:

- `<mod_file>_prior_*.mat`: these files store the filtered and smoothed variables for the prior Monte-Carlo sample, generated when doing RMSE analysis (`pprior=1` and `ppost=0`);
- `<mode_file>_mc_*.mat`: these files store the filtered and smoothed variables for the multivariate normal Monte-Carlo sample, generated when doing RMSE analysis (`pprior=0` and `ppost=0`).

Figure files `<mod_file>_rmse_*.fig` store results for the RMSE analysis.

- `<mod_file>_rmse_prior*.fig`: save results for the analysis using prior Monte-Carlo samples;
- `<mod_file>_rmse_mc*.fig`: save results for the analysis using multivariate normal Monte-Carlo samples;
- `<mod_file>_rmse_post*.fig`: save results for the analysis using Metropolis posterior samples.

The following types of figures are saved (we show prior sample to fix ideas, but the same conventions are used for multivariate normal and posterior):

- `<mod_file>_rmse_prior_*.fig`: for each parameter, plots the cdfs corresponding to the best 10% RMSEs of each observed series;
- `<mod_file>_rmse_prior_dens_*.fig`: for each parameter, plots the pdfs corresponding to the best 10% RMESs of each observed series;
- `<mod_file>_rmse_prior_<name of observedseries>_corr_*.fig`: for each observed series plots the bi-dimensional projections of samples with the best 10% RMSEs, when the correlation is significant;
- `<mod_file>_rmse_prior_lnlik*.fig`: for each observed series, plots in red the cdf of the log-likelihood corresponding to the best 10% RMSEs, in green the cdf of the rest of the sample and in blue the cdf of the full sample; this allows one to see the presence of some idiosyncratic behavior;
- `<mod_file>_rmse_prior_lnpost*.fig`: for each observed series, plots in red the cdf of the log-posterior corresponding to the best 10% RMSEs, in green the cdf of the rest of the sample and in blue the cdf of the full sample; this allows one to see idiosyncratic behavior;

- `<mod_file>_rmse_prior_lnprior*.fig`: for each observed series, plots in red the cdf of the log-prior corresponding to the best 10% RMSEs, in green the cdf of the rest of the sample and in blue the cdf of the full sample; this allows one to see idiosyncratic behavior;
- `<mod_file>_rmse_prior_lik_SA_*.fig`: when `lik_only=1`, this shows the Smirnov tests for the filtering of the best 10% log-likelihood values;
- `<mod_file>_rmse_prior_post_SA_*.fig`: when `lik_only=1`, this shows the Smirnov test for the filtering of the best 10% log-posterior values.

4.17.5 Screening Analysis

Screening analysis does not require any additional options with respect to those listed in [Sampling Options], page 83. The toolbox performs all the analyses required and displays results.

The results of the screening analysis with Morris sampling design are stored in the subfolder `<mod_file>/GSA/SCREEN`. The data file `<mod_file>_prior` stores all the information of the analysis (Morris sample, reduced form coefficients, etc.).

Screening analysis merely concerns reduced form coefficients. Similar synthetic bar charts as for the reduced form analysis with Monte-Carlo samples are saved:

- `<mod_file>_redform_<endo name>_vs_lags_*.fig`: shows bar charts of the elementary effect tests for the ten most important parameters driving the reduced form coefficients of the selected endogenous variables (`namendo`) versus lagged endogenous variables (`namlagendo`);
- `<mod_file>_redform_<endo name>_vs_shocks_*.fig`: shows bar charts of the elementary effect tests for the ten most important parameters driving the reduced form coefficients of the selected endogenous variables (`namendo`) versus exogenous variables (`namexo`);
- `<mod_file>_redform_screen.fig`: shows bar chart of all elementary effect tests for each parameter: this allows one to identify parameters that have a minor effect for any of the reduced form coefficients.

4.17.6 Identification Analysis

Setting the option `identification=1`, an identification analysis based on theoretical moments is performed. Sensitivity plots are provided that allow to infer which parameters are most likely to be less identifiable.

Prerequisite for properly running all the identification routines, is the keyword `identification;` in the Dynare model file. This keyword triggers the computation of analytic derivatives of the model with respect to estimated parameters and shocks. This is required for option `morris=2`, which implements *Iskrev (2010)* identification analysis.

For example, the placing `identification; dynare_sensitivity(identification=1, morris=2);` in the Dynare model file trigger identification analysis using analytic derivatives *Iskrev (2010)*, jointly with the mapping of the acceptable region.

The identification analysis with derivatives can also be triggered by the commands `identification;` This does not do the mapping of acceptable regions for the model and uses the standard random sampler of Dynare. It completely offsets any use of the sensitivity analysis toolbox.

4.17.7 Performing Sensitivity and Identification Analysis

`dynare_sensitivity` *;* [Command]
`dynare_sensitivity (`*OPTIONS...*`);` [Command]

Description

This command triggers sensitivity analysis on a DSGE model.

Options

Sampling Options

`nsam` = *INTEGER*
: Size of the Monte-Carlo sample. Default: `2048`

`ilptau` = *INTEGER*
: If equal to `1`, use LP_τ quasi-Monte-Carlo. If equal to `0`, use LHS Monte-Carlo. Default: `1`

`pprior` = *INTEGER*
: If equal to `1`, sample from the prior distributions. If equal to `0`, sample from the multivariate normal $N(\bar{\theta}, \Sigma)$, where $\bar{\theta}$ is the posterior mode and $\Sigma = H^{-1}$, H is the Hessian at the mode. Default: `1`

`prior_range` = *INTEGER*
: If equal to `1`, sample uniformly from prior ranges. If equal to `0`, sample from prior distributions. Default: `1`

`morris` = *INTEGER*
: If equal to `0`, ANOVA mapping (Type I error) If equal to `1`, Screening analysis (Type II error) If equal to `2`, Analytic derivatives (similar to Type II error, only valid when `identification=1`).Default: `1` when `identification=1`, `0` otherwise

`morris_nliv` = *INTEGER*
: Number of levels in Morris design. Default: `6`

`morris_ntra` = *INTEGER*
: Number trajectories in Morris design. Default: `20`

`ppost` = *INTEGER*
: If equal to `1`, use Metropolis posterior sample. If equal to `0`, do not use Metropolis posterior sample. NB: This overrides any other sampling option. Default: `0`

`neighborhood_width` = *DOUBLE*
: When `pprior=0` and `ppost=0`, allows for the sampling of parameters around the value specified in the `mode_file`, in the range `xparam1`$\pm$ |`xparam1` $\times$ `neighborhood_width`|. Default: `0`

Stability Mapping Options

`stab` = *INTEGER*
: If equal to `1`, perform stability mapping. If equal to `0`, do not perform stability mapping. Default: `1`

`load_stab` = *INTEGER*
: If equal to `1`, load a previously created sample. If equal to `0`, generate a new sample. Default: `0`

`alpha2_stab` = *DOUBLE*
: Critical value for correlations ρ in filtered samples: plot couples of parmaters with $|\rho| >$ `alpha2_stab`. Default: `0.3`

`ksstat` = *DOUBLE*
: Critical value for Smirnov statistics d: plot parameters with $d >$ `ksstat`. Default: `0.1`

`pvalue_ks` = *DOUBLE*
: The threshold *pvalue* for significant Kolmogorov-Smirnov test (*i.e.* plot parameters with *pvalue* $<$ `pvalue_ks`). Default: `0.001`

`pvalue_corr` = *DOUBLE*
: The threshold *pvalue* for significant correlation in filtered samples (*i.e.* plot bivariate samples when *pvalue* $<$ `pvalue_corr`). Default: `0.001`

Reduced Form Mapping Options

`redform` = *INTEGER*
: If equal to `1`, prepare Monte-Carlo sample of reduced form matrices. If equal to `0`, do not prepare Monte-Carlo sample of reduced form matrices. Default: `0`

`load_redform` = *INTEGER*
: If equal to `1`, load previously estimated mapping. If equal to `0`, estimate the mapping of the reduced form model. Default: `0`

`logtrans_redform` = *INTEGER*
: If equal to `1`, use log-transformed entries. If equal to `0`, use raw entries. Default: `0`

`threshold_redform` = [*DOUBLE DOUBLE*]
: The range over which the filtered Monte-Carlo entries of the reduced form coefficients should be analyzed. The first number is the lower bound and the second is the upper bound. An empty vector indicates that these entries will not be filtered. Default: `empty`

`ksstat_redform` = *DOUBLE*
: Critical value for Smirnov statistics d when reduced form entries are filtered. Default: `0.1`

`alpha2_redform` = *DOUBLE*
: Critical value for correlations ρ when reduced form entries are filtered. Default: `0.3`

`namendo` = (*VARIABLE_NAME*...)
: List of endogenous variables. '`:`' indicates all endogenous variables. Default: `empty`

`namlagendo` = (*VARIABLE_NAME*...)
: List of lagged endogenous variables. '`:`' indicates all lagged endogenous variables. Analyze entries `[namendo`×`namlagendo]` Default: `empty`

`namexo` = (*VARIABLE_NAME*...)
: List of exogenous variables. '`:`' indicates all exogenous variables. Analyze entries `[namendo`×`namexo]`. Default: `empty`

RMSE Options

`rmse` = *INTEGER*
: If equal to `1`, perform RMSE analysis. If equal to `0`, do not perform RMSE analysis. Default: `0`

`load_rmse` = *INTEGER*
: If equal to `1`, load previous RMSE analysis. If equal to `0`, make a new RMSE analysis. Default: `0`

`lik_only` = *INTEGER*
: If equal to `1`, compute only likelihood and posterior. If equal to `0`, compute RMSE's for all observed series. Default: `0`

`var_rmse` = (*VARIABLE_NAME*...)
: List of observed series to be considered. '`:`' indicates all observed variables. Default: `varobs`

`pfilt_rmse` = *DOUBLE*
: Filtering threshold for RMSE's. Default: `0.1`

`istart_rmse` = *INTEGER*
: Value at which to start computing RMSE's (use `2` to avoid big intitial error). Default: `presample+1`

`alpha_rmse` = *DOUBLE*
: Critical value for Smirnov statistics d: plot parameters with $d >$ `alpha_rmse`. Default: `0.002`

`alpha2_rmse` = *DOUBLE*
: Critical value for correlation ρ: plot couples of parmaters with $|\rho| =$ `alpha2_rmse`. Default: `1.0`

`datafile` = *FILENAME*
: See [datafile], page 53.

`nobs` = *INTEGER*
`nobs` = [*INTEGER1*:*INTEGER2*]
: See [nobs], page 53.

`first_obs` = *INTEGER*
: See [first_obs], page 53.

`prefilter` = *INTEGER*
: See [prefilter], page 53.

`presample` = *INTEGER*
: See [presample], page 53.

`nograph`
: See [nograph], page 41.

`nodisplay`
: See [nodisplay], page 41.

`graph_format` = *FORMAT*
`graph_format` = (*FORMAT*, *FORMAT*...)
: See [graph_format], page 41.

`conf_sig` = *DOUBLE*
: See [conf_sig], page 69.

`loglinear`
: See [loglinear], page 53.

`mode_file` = *FILENAME*
: See [mode_file], page 55.

`kalman_algo` = *INTEGER*
: See [kalman_algo], page 60.

Identification Analysis Options

`identification` = *INTEGER*
: If equal to `1`, performs identification anlysis (forcing `redform=0` and `morris=1`) If equal to `0`, no identification analysis. Default: `0`

`morris` = *INTEGER*
: See [morris], page 83.

`morris_nliv` = *INTEGER*
: See [morris_nliv], page 83.

`morris_ntra = INTEGER`
: See [morris_ntra], page 83.

`load_ident_files = INTEGER`
: Loads previously performed identification analysis. Default: `0`

`useautocorr = INTEGER`
: Use autocorrelation matrices in place of autocovariance matrices in moments for identification analysis. Default: `0`

`ar = INTEGER`
: Maximum number of lags for moments in identification analysis. Default: `1`

`lik_init = INTEGER`
: See [lik_init], page 54.

`identification ;` [Command]
`identification (OPTIONS...);` [Command]

Description

This command triggers identification analysis.

Options

`ar = INTEGER`
: Number of lags of computed autocorrelations (theoretical moments). Default: `1`

`useautocorr = INTEGER`
: If equal to `1`, compute derivatives of autocorrelation. If equal to `0`, compute derivatives of autocovariances. Default: `0`

`load_ident_files = INTEGER`
: If equal to `1`, allow Dynare to load previously computed analyzes. Default: `0`

`prior_mc = INTEGER`
: Size of Monte-Carlo sample. Default: `1`

`prior_range = INTEGER`
: Triggers uniform sample within the range implied by the prior specifications (when `prior_mc>1`). Default: `0`

`advanced = INTEGER`
: Shows a more detailed analysis, comprised of an analysis for the linearized rational expectation model as well as the associated reduced form solution. Further performs a brute force search of the groups of parameters best reproducing the behavior of each single parameter. The maximum dimension of the group searched is triggered by `max_dim_cova_group`. Default: `0`

`max_dim_cova_group = INTEGER`
: In the brute force search (performed when `advanced=1`) this option sets the maximum dimension of groups of parameters that best reproduce the behavior of each single model parameter. Default: `2`

`periods = INTEGER`
: When the analytic Hessian is not available (*i.e.* with missing values or diffuse Kalman filter or univariate Kalman filter), this triggers the length of stochastic simulation to compute Simulated Moments Uncertainty. Default: `300`

`replic = INTEGER`
: When the analytic Hessian is not available, this triggers the number of replicas to compute Simulated Moments Uncertainty. Default: `100`

`gsa_sample_file = INTEGER`
: If equal to `0`, do not use sample file. If equal to `1`, triggers gsa prior sample. If equal to `2`, triggers gsa Monte-Carlo sample (*i.e.* loads a sample corresponding to `pprior=0` and `ppost=0` in the `dynare_sensitivity` options). Default: `0`

`gsa_sample_file = FILENAME`
: Uses the provided path to a specific user defined sample file. Default: `0`

`parameter_set = calibration | prior_mode | prior_mean | posterior_mode | posterior_mean | posterior_median`
: Specify the parameter set to use. Default: `prior_mean`

`lik_init = INTEGER`
: See [lik_init], page 54.

`kalman_algo = INTEGER`
: See [kalman_algo], page 60.

`nograph`
: See [nograph], page 41.

`nodisplay`
: See [nodisplay], page 41.

`graph_format = FORMAT`
`graph_format = ( FORMAT, FORMAT... )`
: See [graph_format], page 41.

4.18 Markov-switching SBVAR

Given a list of variables, observed variables and a data file, Dynare can be used to solve a Markov-switching SBVAR model according to *Sims, Waggoner and Zha (2008)*. Having done this, you can create forecasts and compute the marginal data density, regime probabilities, IRFs, and variance decomposition of the model.

The commands have been modularized, allowing for multiple calls to the same command within a `<mod_file>.mod` file. The default is to use `<mod_file>` to tag the input (output) files used (produced) by the program. Thus, to call any command more than once within a `<mod_file>.mod` file, you must use the `*_tag` options described below.

`markov_switching (OPTIONS...);` [Command]

Description

Declares the Markov state variable information of a Markov-switching SBVAR model.

Options

`chain = INTEGER`
: The Markov chain. Default: `none`

`state = INTEGER`
: This state has duration equal to `duration`. Exactly one of `state` and `number_of_states` must be passed. Default: `none`

`number_of_states = INTEGER`
: Total number of states. Implies that all states have the same duration. Exactly one of `state` and `number_of_states` must be passed. Default: `none`

`duration = DOUBLE | inf`
: The duration of the state or states. Default: `none`

`svar (OPTIONS...);` [Command]

Description

Each Makov chain can control the switching of a set of parameters. We allow the parameters to be divided equation by equation and by variance or slope and intercept.

Options

`coefficients`
: Specifies that only the slope and intercept in the given equations are controlled by the given chain. One, but not both, of `coefficients` or `variances` must appear. Default: `none`

`variances`
: Specifies that only variances in the given equations are controlled by the given chain. One, but not both, of `coefficients` or `variances` must appear. Default: `none`

`equations`
: Defines the equation controlled by the given chain. If not specified, then all equations are controlled by `chain`. Default: `none`

`chain = INTEGER`
: Specifies a Markov chain defined by [markov_switching], page 87. Default: `none`

`sbvar (OPTIONS...);` [Command]

Description

To be documented. For now, see the wiki: `http://www.dynare.org/DynareWiki/SbvarOptions`

Options

`datafile`

`freq`

`initial_year`
`initial_subperiod`
`final_year`
`final_subperiod`
`data`

`vlist`

`vlistlog`

`vlistper`

`restriction_fname`
`nlags`

`cross_restrictions`
`contemp_reduced_form`
`real_pseudo_forecast`
`no_bayesian_prior`
`dummy_obs`
`nstates`

`indxscalesstates`
`alpha`

`beta`

`gsig2_lmdm`
`q_diag`

`flat_prior`
`ncsk`

`nstd`

`ninv`

`indxparr`

`indxovr`

`aband`

`indxap`

`apband`

`indximf`

`indxfore`

`foreband`

`indxgforhat`
`indxgimfhat`
`indxestima`
`indxgdls`

`eq_ms`

`cms`

`ncms`

`eq_cms`

`tlindx`

`tlnumber`

`cnum`

`forecast`

`coefficients_prior_hyperparameters`

svar_identification *;* [Block]

Description

This block is terminated by `end;`, and contains lines of the form:

```
UPPER_CHOLESKY;
LOWER_CHOLESKY;
EXCLUSION CONSTANTS;
EXCLUSION LAG INTEGER; VARIABLE_NAME [,VARIABLE_NAME...]
EXCLUSION LAG INTEGER; EQUATION INTEGER, VARIABLE_NAME [,VARIABLE_NAME...]
RESTRICTION EQUATION INTEGER, EXPRESSION = EXPRESSION;
```

To be documented. For now, see the wiki: http://www.dynare.org/DynareWiki/MarkovSwitchingInterface `ms_estimation` (*OPTIONS...*); [Command]

Description

Triggers the creation of an initialization file for, and the estimation of, a Markov-switching SBVAR model. At the end of the run, the A^0, A^+, Q and ζ matrices are contained in the `oo_.ms` structure.

Options

General Options

`file_tag` = *FILENAME*
: The portion of the filename associated with this run. This will create the model initialization file, `init_<file_tag>.dat`. Default: `<mod_file>`

`output_file_tag` = *FILENAME*
: The portion of the output filename that will be assigned to this run. This will create, among other files, `est_final_<output_file_tag>.out`, `est_intermediate_<output_file_tag>.out`. Default: `<file_tag>`

`no_create_init`
: Do not create an initialization file for the model. Passing this option will cause the *Initialization Options* to be ignored. Further, the model will be generated from the output files associated with the previous estimation run (*i.e.* `est_final_<file_tag>.out`, `est_intermediate_<file_tag>.out` or `init_<file_tag>.dat`, searched for in sequential order). This functionality can be useful for continuing a previous estimation run to ensure convergence was reached or for reusing an initialization file. NB: If this option is not passed, the files from the previous estimation run will be overwritten. Default: `off` (*i.e.* create initialization file)

Initialization Options

`coefficients_prior_hyperparameters` = [*DOUBLE1 DOUBLE2 DOUBLE3 DOUBLE4 DOUBLE5 DOUBLE6*]
: Sets the hyper parameters for the model. The six elements of the argument vector have the following interpretations:

`Position`	`Interpretation`
`1`	Overall tightness for A^0 and A^+
`2`	Relative tightness for A^+
`3`	Relative tightness for the constant term
`4`	Tightness on lag decay (range: 1.2 - 1.5); a faster decay produces better inflation process
`5`	Weight on nvar sums of coeffs dummy observations (unit roots)
`6`	Weight on single dummy initial observation including constant

Default: `[1.0 1.0 0.1 1.2 1.0 1.0]`

`freq` = *INTEGER* | `monthly` | `quarterly` | `yearly`
: Frequency of the data (*e.g.* `monthly`, `12`). Default: `4`

`initial_year` = *INTEGER*
: The first year of data. Default: `none`

`initial_subperiod` = *INTEGER*
: The first period of data (*i.e.* for quarterly data, an integer in [`1,4`]). Default: `1`

`final_year` = *INTEGER*
: The last year of data. Default: Set to encompass entire dataset.

`final_subperiod` = *INTEGER*
: The final period of data (*i.e.* for monthly data, an integer in [`1,12`]. Default: When final_year is also missing, set to encompass entire dataset; when final_year is indicated, set to the maximum number of subperiods given the frequency (*i.e.* 4 for quarterly data, 12 for monthly,...).

`datafile` = *FILENAME*
: See [datafile], page 53.

`xls_sheet` = *NAME*
: See [xls_sheet], page 53.

`xls_range` = *RANGE*
: See [xls_range], page 53.

`nlags` = *INTEGER*
: The number of lags in the model. Default: `1`

`cross_restrictions`
: Use cross A^0 and A^+ restrictions. Default: `off`

`contemp_reduced_form`
: Use contemporaneous recursive reduced form. Default: `off`

`no_bayesian_prior`
: Do not use Bayesian prior. Default: `off` (*i.e.* use Bayesian prior)

`alpha` = *INTEGER*
: Alpha value for squared time-varying structural shock lambda. Default: `1`

`beta` = *INTEGER*
: Beta value for squared time-varying structural shock lambda. Default: `1`

`gsig2_lmdm` = *INTEGER*
: The variance for each independent λ parameter under `SimsZha` restrictions. Default: `50^2`

`specification` = `sims_zha` | `none`
: This controls how restrictions are imposed to reduce the number of parameters. Default: `Random Walk`

Estimation Options

`convergence_starting_value` = *DOUBLE*
: This is the tolerance criterion for convergence and refers to changes in the objective function value. It should be rather loose since it will gradually be tightened during estimation. Default: `1e-3`

`convergence_ending_value` = *DOUBLE*
: The convergence criterion ending value. Values much smaller than square root machine epsilon are probably overkill. Default: `1e-6`

`convergence_increment_value` = *DOUBLE*
: Determines how quickly the convergence criterion moves from the starting value to the ending value. Default: `0.1`

`max_iterations_starting_value = INTEGER`
: This is the maximum number of iterations allowed in the hill-climbing optimization routine and should be rather small since it will gradually be increased during estimation. Default: `50`

`max_iterations_increment_value = DOUBLE`
: Determines how quickly the maximum number of iterations is increased. Default: `2`

`max_block_iterations = INTEGER`
: The parameters are divided into blocks and optimization proceeds over each block. After a set of blockwise optimizations are performed, the convergence criterion is checked and the blockwise optimizations are repeated if the criterion is violated. This controls the maximum number of times the blockwise optimization can be performed. Note that after the blockwise optimizations have converged, a single optimization over all the parameters is performed before updating the convergence value and maximum number of iterations. Default: `100`

`max_repeated_optimization_runs = INTEGER`
: The entire process described by [max_block_iterations], page 92 is repeated until improvement has stopped. This is the maximum number of times the process is allowed to repeat. Set this to `0` to not allow repetitions. Default: `10`

`function_convergence_criterion = DOUBLE`
: The convergence criterion for the objective function when `max_repeated_optimizations_runs` is positive. Default: `0.1`

`parameter_convergence_criterion = DOUBLE`
: The convergence criterion for parameter values when `max_repeated_optimizations_runs` is positive. Default: `0.1`

`number_of_large_perturbations = INTEGER`
: The entire process described by [max_block_iterations], page 92 is repeated with random starting values drawn from the posterior. This specifies the number of random starting values used. Set this to `0` to not use random starting values. A larger number should be specified to ensure that the entire parameter space has been covered. Default: `5`

`number_of_small_perturbations = INTEGER`
: The number of small perturbations to make after the large perturbations have stopped improving. Setting this number much above `10` is probably overkill. Default: `5`

`number_of_posterior_draws_after_perturbation = INTEGER`
: The number of consecutive posterior draws to make when producing a small perturbation. Because the posterior draws are serially correlated, a small number will result in a small perturbation. Default: `1`

`max_number_of_stages = INTEGER`
: The small and large perturbation are repeated until improvement has stopped. This specifics the maximum number of stages allowed. Default: `20`

`random_function_convergence_criterion = DOUBLE`
: The convergence criterion for the objective function when `number_of_large_perturbations` is positive. Default: `0.1`

`random_parameter_convergence_criterion = DOUBLE`
: The convergence criterion for parameter values when `number_of_large_perturbations` is positive. Default: `0.1`

Example

```
ms_estimation(datafile=data, initial_year=1959, final_year=2005,
nlags=4, max_repeated_optimization_runs=1, max_number_of_stages=0);

ms_estimation(file_tag=second_run, datafile=data, initial_year=1959,
final_year=2005, nlags=4, max_repeated_optimization_runs=1,
max_number_of_stages=0);

ms_estimation(file_tag=second_run, output_file_tag=third_run,
no_create_init, max_repeated_optimization_runs=5,
number_of_large_perturbations=10);
```

`ms_simulation` *;* [Command]
`ms_simulation` (*OPTIONS...*)*;* [Command]

Description

Simulates a Markov-switching SBVAR model.

Options

`file_tag` = *FILENAME*
: The portion of the filename associated with the `ms_estimation` run. Default: `<mod_file>`

`output_file_tag` = *FILENAME*
: The portion of the output filename that will be assigned to this run. Default: `<file_tag>`

`mh_replic` = *INTEGER*
: The number of draws to save. Default: `10,000`

`drop` = *INTEGER*
: The number of burn-in draws. Default: `0.1*mh_replic*thinning_factor`

`thinning_factor` = *INTEGER*
: The total number of draws is equal to `thinning_factor*mh_replic+drop`. Default: `1`

`adaptive_mh_draws` = *INTEGER*
: Tuning period for Metropolis-Hastings draws. Default: `30,000`

`save_draws`
: Save all elements of A^0, A^+, Q, and ζ, to a file named `draws_<<file_tag>>.out` with each draw on a separate line. A file that describes how these matrices are laid out is contained in `draws_header_<<file_tag>>.out`. A file called `load_flat_file.m` is provided to simplify loading the saved files into the corresponding variables `A0`, `Aplus`, `Q`, and `Zeta` in your MATLAB/Octave workspace. Default: `off`

Example

```
ms_simulation(file_tag=second_run);

ms_simulation(file_tag=third_run, mh_replic=5000, thinning_factor=3);
```

`ms_compute_mdd ;` [Command]
`ms_compute_mdd (OPTIONS...);` [Command]

Description

Computes the marginal data density of a Markov-switching SBVAR model from the posterior draws. At the end of the run, the Muller and Bridged log marginal densities are contained in the `oo_.ms` structure.

Options

`file_tag = FILENAME`
: See [file_tag], page 93.

`output_file_tag = FILENAME`
: See [output_file_tag], page 93.

`simulation_file_tag = FILENAME`
: The portion of the filename associated with the simulation run. Default: `<file_tag>`

`proposal_type = INTEGER`
: The proposal type:

`1`	Gaussian
`2`	Power
`3`	Truncated Power
`4`	Step
`5`	Truncated Gaussian

Default: `3`

`proposal_lower_bound = DOUBLE`
: The lower cutoff in terms of probability. Not used for `proposal_type` in `[1,2]`. Required for all other proposal types. Default: `0.1`

`proposal_upper_bound = DOUBLE`
: The upper cutoff in terms of probability. Not used for `proposal_type` equal to `1`. Required for all other proposal types. Default: `0.9`

`mdd_proposal_draws = INTEGER`
: The number of proposal draws. Default: `100,000`

`mdd_use_mean_center`
: Use the posterior mean as center. Default: `off`

`ms_compute_probabilities ;` [Command]
`ms_compute_probabilities (OPTIONS...);` [Command]

Description

Computes smoothed regime probabilities of a Markov-switching SBVAR model. Output `.eps` files are contained in `<output_file_tag/Output/Probabilities>`.

Options

`file_tag = FILENAME`
: See [file_tag], page 93.

`output_file_tag = FILENAME`
: See [output_file_tag], page 93.

`filtered_probabilities`
: Filtered probabilities are computed instead of smoothed. Default: `off`

`real_time_smoothed`
: Smoothed probabilities are computed based on time `t` information for $0 \leq t \leq nobs$. Default: `off`

`ms_irf ;` [Command]
`ms_irf (OPTIONS...);` [Command]

Description

Computes impulse response functions for a Markov-switching SBVAR model. Output `.eps` files are contained in `<output_file_tag/Output/IRF>`, while data files are contained in `<output_file_tag/IRF>`.

Options

`file_tag = FILENAME`
: See [file_tag], page 93.

`output_file_tag = FILENAME`
: See [output_file_tag], page 93.

`simulation_file_tag = FILENAME`
: See [simulation_file_tag], page 94.

`horizon = INTEGER`
: The forecast horizon. Default: `12`

`filtered_probabilities`
: Uses filtered probabilities at the end of the sample as initial conditions for regime probabilities. Only one of `filtered_probabilities`, `regime` and `regimes` may be passed. Default: `off`

`error_band_percentiles = [DOUBLE1 ...]`
: The percentiles to compute. Default: `[0.16 0.50 0.84]`. If `median` is passed, the default is `[0.5]`

`shock_draws = INTEGER`
: The number of regime paths to draw. Default: `10,000`

`shocks_per_parameter = INTEGER`
: The number of regime paths to draw under parameter uncertainty. Default: `10`

`thinning_factor = INTEGER`
: Only 1/`thinning_factor` of the draws in posterior draws file are used. Default: `1`

`free_parameters = NUMERICAL_VECTOR`
: A vector of free parameters to initialize theta of the model. Default: use estimated parameters

`parameter_uncertainty`
: Calculate IRFs under parameter uncertainty. Requires that `ms_simulation` has been run. Default: `off`

`regime = INTEGER`
: Given the data and model parameters, what is the ergodic probability of being in the specified regime. Only one of `filtered_probabilities`, `regime` and `regimes` may be passed. Default: `off`

`regimes` Describes the evolution of regimes. Only one of `filtered_probabilities`, `regime` and `regimes` may be passed. Default: `off`

`median` A shortcut to setting `error_band_percentiles=[0.5]`. Default: `off`

`ms_forecast` *;* [Command]
`ms_forecast` (*OPTIONS...*); [Command]

Description

Generates forecasts for a Markov-switching SBVAR model. Output `.eps` files are contained in `<output_file_tag/Output/Forecast>`, while data files are contained in `<output_file_tag/Forecast>`.

Options

`file_tag` = *FILENAME*
See [file_tag], page 93.

`output_file_tag` = *FILENAME*
See [output_file_tag], page 93.

`simulation_file_tag` = *FILENAME*
See [simulation_file_tag], page 94.

`data_obs_nbr` = *INTEGER*
The number of data points included in the output. Default: `0`

`error_band_percentiles` = [*DOUBLE1* ...]
See [error_band_percentiles], page 95.

`shock_draws` = *INTEGER*
See [shock_draws], page 95.

`shocks_per_parameter` = *INTEGER*
See [shocks_per_parameter], page 95.

`thinning_factor` = *INTEGER*
See [thinning_factor], page 95.

`free_parameters` = *NUMERICAL_VECTOR*
See [free_parameters], page 95.

`parameter_uncertainty`
See [parameter_uncertainty], page 95.

`regime` = *INTEGER*
See [regime], page 95.

`regimes`
See [regimes], page 96.

`median`
See [median], page 96.

`ms_variance_decomposition` *;* [Command]
`ms_variance_decomposition` (*OPTIONS...*); [Command]

Description

Computes the variance decomposition for a Markov-switching SBVAR model. Output `.eps` files are contained in `<output_file_tag/Output/Variance_Decomposition>`, while data files are contained in `<output_file_tag/Variance_Decomposition>`.

Options

`file_tag = FILENAME`
: See [file_tag], page 93.

`output_file_tag = FILENAME`
: See [output_file_tag], page 93.

`simulation_file_tag = FILENAME`
: See [simulation_file_tag], page 94.

`horizon = INTEGER`
: See [horizon], page 95.

`filtered_probabilities`
: See [filtered_probabilities], page 95.

`no_error_bands`
: Do not output percentile error bands (*i.e.* compute mean). Default: `off` (*i.e.* output error bands)

`error_band_percentiles = [DOUBLE1 ...]`
: See [error_band_percentiles], page 95.

`shock_draws = INTEGER`
: See [shock_draws], page 95.

`shocks_per_parameter = INTEGER`
: See [shocks_per_parameter], page 95.

`thinning_factor = INTEGER`
: See [thinning_factor], page 95.

`free_parameters = NUMERICAL_VECTOR`
: See [free_parameters], page 95.

`parameter_uncertainty`
: See [parameter_uncertainty], page 95.

`regime = INTEGER`
: See [regime], page 95.

`regimes`
: See [regimes], page 96.

4.19 Displaying and saving results

Dynare has comments to plot the results of a simulation and to save the results.

`rplot` *VARIABLE_NAME...;* [Command]

Plots the simulated path of one or several variables, as stored in *oo_.endo_simul* by either *simul* (see Section 4.12 [Deterministic simulation], page 37) or *stoch_simul* with option *periods* (see Section 4.13.1 [Computing the stochastic solution], page 40). The variables are plotted in levels.

`dynatype` (*FILENAME*) [*VARIABLE_NAME...*]; [Command]

This command prints the listed variables in a text file named *FILENAME*. If no *VARIABLE_NAME* is listed, all endogenous variables are printed.

`dynasave` (*FILENAME*) [*VARIABLE_NAME...*]; [Command]

This command saves the listed variables in a binary file named *FILENAME*. If no *VARIABLE_NAME* are listed, all endogenous variables are saved.

In MATLAB or Octave, variables saved with the `dynasave` command can be retrieved by the command:

```
load -mat FILENAME
```

4.20 Macro-processing language

It is possible to use "macro" commands in the `.mod` file for doing the following tasks: including modular source files, replicating blocks of equations through loops, conditionally executing some code, writing indexed sums or products inside equations...

The Dynare macro-language provides a new set of *macro-commands* which can be inserted inside `.mod` files. It features:

- file inclusion
- loops (`for` structure)
- conditional inclusion (`if/then/else` structures)
- expression substitution

Technically, this macro language is totally independent of the basic Dynare language, and is processed by a separate component of the Dynare pre-processor. The macro processor transforms a `.mod` file with macros into a `.mod` file without macros (doing expansions/inclusions), and then feeds it to the Dynare parser. The key point to understand is that the macro-processor only does *text substitution* (like the C preprocessor or the PHP language). Note that it is possible to see the output of the macro-processor by using the `savemacro` option of the `dynare` command (see Section 3.1 [Dynare invocation], page 6).

The macro-processor is invoked by placing *macro directives* in the `.mod` file. Directives begin with an at-sign followed by a pound sign (`@#`). They produce no output, but give instructions to the macro-processor. In most cases, directives occupy exactly one line of text. In case of need, two anti-slashes (`\\`) at the end of the line indicates that the directive is continued on the next line. The main directives are:

- `@#include`, for file inclusion,
- `@#define`, for defining a macro-processor variable,
- `@#if`, `@#ifdef`, `@#ifndef`, `@#else`, `@#endif` for conditional statements,
- `@#for`, `@#endfor` for constructing loops.

The macro-processor maintains its own list of variables (distinct of model variables and of MATLAB/Octave variables). These macro-variables are assigned using the `@#define` directive, and can be of four types: integer, character string, array of integers, array of strings.

4.20.1 Macro expressions

It is possible to construct macro-expressions which can be assigned to macro-variables or used within a macro-directive. The expressions are constructed using literals of the four basic types (integers, strings, arrays of strings, arrays of integers), macro-variables names and standard operators.

String literals have to be enclosed between **double** quotes (like `"name"`). Arrays are enclosed within brackets, and their elements are separated by commas (like `[1,2,3]` or `["US", "EA"]`).

Note that there is no boolean type: *false* is represented by integer zero and *true* is any non-null integer.

The following operators can be used on integers:

- arithmetic operators: `+`, `-`, `*`, `/`
- comparison operators: `<`, `>`, `<=`, `>=`, `==`, `!=`
- logical operators: `&&`, `||`, `!`
- integer ranges, using the following syntax: `INTEGER1:INTEGER2` (for example, `1:4` is equivalent to integer array `[1,2,3,4]`)

The following operators can be used on strings:

- comparison operators: `==`, `!=`
- concatenation of two strings: `+`

- extraction of substrings: if `s` is a string, then `s[3]` is a string containing only the third character of `s`, and `s[4:6]` contains the characters from 4th to 6th

The following operators can be used on arrays:

- dereferencing: if `v` is an array, then `v[2]` is its 2nd element
- concatenation of two arrays: `+`
- difference `-`: returns the first operand from which the elements of the second operand have been removed
- extraction of sub-arrays: *e.g.* `v[4:6]`
- testing membership of an array: `in` operator (for example: `"b" in ["a", "b", "c"]` returns `1`)
- getting the length of an array: `length` operator (for example: `length(["a", "b", "c"])` returns `3` and, hence, `1:length(["a", "b", "c"])` is equivalent to integer array `[1,2,3]`)

Macro-expressions can be used at two places:

- inside macro directives, directly;
- in the body of the `.mod` file, between an at-sign and curly braces (like `@{expr}`): the macro processor will substitute the expression with its value.

In the following, *MACRO_EXPRESSION* designates an expression constructed as explained above.

4.20.2 Macro directives

`@#include "FILENAME"` [Macro directive]

This directive simply includes the content of another file at the place where it is inserted. It is exactly equivalent to a copy/paste of the content of the included file. Note that it is possible to nest includes (*i.e.* to include a file from an included file).

Example

```
@#include "modelcomponent.mod"
```

`@#define MACRO_VARIABLE = MACRO_EXPRESSION` [Macro directive]

Defines a macro-variable.

Example 1

```
@#define x = 5              // Integer
@#define y = "US"           // String
@#define v = [ 1, 2, 4 ]    // Integer array
@#define w = [ "US", "EA" ] // String array
@#define z = 3 + v[2]       // Equals 5
@#define t = ("US" in w)    // Equals 1 (true)
```

Example 2

```
@#define x = [ "B", "C" ]
@#define i = 2

model;
  A = @{x[i]};
end;
```

is strictly equivalent to:

```
model;
  A = C;
end;
```

`@#if` *MACRO_EXPRESSION* [Macro directive]
`@#ifdef` *MACRO_VARIABLE* [Macro directive]
`@#ifndef` *MACRO_VARIABLE* [Macro directive]
`@#else` [Macro directive]
`@#endif` [Macro directive]

Conditional inclusion of some part of the `.mod` file. The lines between `@#if`, `@#ifdef` or `@#ifndef` and the next `@#else` or `@#endif` is executed only if the condition evaluates to a non-null integer. The `@#else` branch is optional and, if present, is only evaluated if the condition evaluates to `0`.

Example

Choose between two alternative monetary policy rules using a macro-variable:

```
@#define linear_mon_pol = 0 // or 1
...
model;
@#if linear_mon_pol
  i = w*i(-1) + (1-w)*i_ss + w2*(pie-piestar);
@#else
  i = i(-1)^w * i_ss^(1-w) * (pie/piestar)^w2;
@#endif
...
end;
```

Example

Choose between two alternative monetary policy rules using a macro-variable. As `linear_mon_pol` was not previously defined in this example, the second equation will be chosen:

```
model;
@#ifdef linear_mon_pol
  i = w*i(-1) + (1-w)*i_ss + w2*(pie-piestar);
@#else
  i = i(-1)^w * i_ss^(1-w) * (pie/piestar)^w2;
@#endif
...
end;
```

Choose between two alternative monetary policy rules using a macro-variable. As `linear_mon_pol` was not previously defined in this example, the first equation will be chosen:

```
model;
@#ifndef linear_mon_pol
  i = w*i(-1) + (1-w)*i_ss + w2*(pie-piestar);
@#else
  i = i(-1)^w * i_ss^(1-w) * (pie/piestar)^w2;
@#endif
...
end;
```

`@#for` *MACRO_VARIABLE in MACRO_EXPRESSION* [Macro directive]
`@#endfor` [Macro directive]

Loop construction for replicating portions of the `.mod` file. Note that this construct can enclose variable/parameters declaration, computational tasks, but not a model declaration.

Example

```
model;
@#for country in [ "home", "foreign" ]
  GDP_@{country} = A * K_@{country}^a * L_@{country}^(1-a);
@#endfor
end;
```

is equivalent to:

```
model;
  GDP_home = A * K_home^a * L_home^(1-a);
  GDP_foreign = A * K_foreign^a * L_foreign^(1-a);
end;
```

`@#echo` *`MACRO_EXPRESSION`* [Macro directive]

Asks the preprocessor to display some message on standard output. The argument must evaluate to a string.

`@#error` *`MACRO_EXPRESSION`* [Macro directive]

Asks the preprocessor to display some error message on standard output and to abort. The argument must evaluate to a string.

4.20.3 Typical usages

4.20.3.1 Modularization

The `@#include` directive can be used to split `.mod` files into several modular components.

Example setup:

`modeldesc.mod`
: Contains variable declarations, model equations and shocks declarations

`simul.mod`
: Includes `modeldesc.mod`, calibrates parameters and runs stochastic simulations

`estim.mod`
: Includes `modeldesc.mod`, declares priors on parameters and runs Bayesian estimation

Dynare can be called on `simul.mod` and `estim.mod`, but it makes no sense to run it on `modeldesc.mod`.

The main advantage is that it is no longer needed to manually copy/paste the whole model (at the beginning) or changes to the model (during development).

4.20.3.2 Indexed sums or products

The following example shows how to construct a moving average:

```
@#define window = 2

var x MA_x;
...
model;
...
MA_x = 1/@{2*window+1}*(
@#for i in -window:window
        +x(@{i})
@#endfor
       );
...
```

```
end;
```

After macro-processing, this is equivalent to:

```
var x MA_x;
...
model;
...
MA_x = 1/5*(
        +x(-2)
        +x(-1)
        +x(0)
        +x(1)
        +x(2)
       );
...
end;
```

4.20.3.3 Multi-country models

Here is a skeleton example for a multi-country model:

```
@#define countries = [ "US", "EA", "AS", "JP", "RC" ]
@#define nth_co = "US"

@#for co in countries
var Y_@{co} K_@{co} L_@{co} i_@{co} E_@{co} ...;
parameters a_@{co} ...;
varexo ...;
@#endfor

model;
@#for co in countries
 Y_@{co} = K_@{co}^a_@{co} * L_@{co}^(1-a_@{co});
...
@# if co != nth_co
 (1+i_@{co}) = (1+i_@{nth_co}) * E_@{co}(+1) / E_@{co}; // UIP relation
@# else
 E_@{co} = 1;
@# endif
@#endfor
end;
```

4.20.3.4 Endogeneizing parameters

When doing the steady state calibration of the model, it may be useful to consider a parameter as an endogenous (and vice-versa).

For example, suppose production is defined by a CES function:

$y = \left(\alpha^{1/\xi}\ell^{1-1/\xi} + (1-\alpha)^{1/\xi}k^{1-1/\xi}\right)^{\xi/(\xi-1)}$

The labor share in GDP is defined as:

`lab_rat` $= (w\ell)/(py)$

In the model, α is a (share) parameter, and `lab_rat` is an endogenous variable.

It is clear that calibrating α is not straightforward; but on the contrary, we have real world data for `lab_rat`, and it is clear that these two variables are economically linked.

The solution is to use a method called *variable flipping*, which consist in changing the way of computing the steady state. During this computation, α will be made an endogenous variable and `lab_rat` will be made a parameter. An economically relevant value will be calibrated for `lab_rat`, and the solution algorithm will deduce the implied value for α.

An implementation could consist of the following files:

`modeqs.mod`

This file contains variable declarations and model equations. The code for the declaration of α and `lab_rat` would look like:

```
@#if steady
 var alpha;
 parameter lab_rat;
@#else
 parameter alpha;
 var lab_rat;
@#endif
```

`steady.mod`

This file computes the steady state. It begins with:

```
@#define steady = 1
@#include "modeqs.mod"
```

Then it initializes parameters (including `lab_rat`, excluding α, computes the steady state (using guess values for endogenous, including α, then saves values of parameters and endogenous at steady state in a file, using the `save_params_and_steady_state` command.

`simul.mod`

This file computes the simulation. It begins with:

```
@#define steady = 0
@#include "modeqs.mod"
```

Then it loads values of parameters and endogenous at steady state from file, using the `load_params_and_steady_state` command, and computes the simulations.

4.20.4 MATLAB/Octave loops versus macro-processor loops

Suppose you have a model with a parameter ρ, and you want to make simulations for three values: $\rho = 0.8, 0.9, 1$. There are several ways of doing this:

With a MATLAB/Octave loop

```
rhos = [ 0.8, 0.9, 1];
for i = 1:length(rhos)
  rho = rhos(i);
  stoch_simul(order=1);
end
```

Here the loop is not unrolled, MATLAB/Octave manages the iterations. This is interesting when there are a lot of iterations.

With a macro-processor loop (case 1)

```
rhos = [ 0.8, 0.9, 1];
@#for i in 1:3
  rho = rhos(@{i});
  stoch_simul(order=1);
@#endfor
```

This is very similar to previous example, except that the loop is unrolled. The macro-processor manages the loop index but not the data array (`rhos`).

With a macro-processor loop (case 2)

```
@#for rho_val in [ "0.8", "0.9", "1"]
```

```
      rho = @{rho_val};
      stoch_simul(order=1);
    @#endfor
```

The advantage of this method is that it uses a shorter syntax, since list of values directly given in the loop construct. Note that values are given as character strings (the macro-processor does not know floating point values. The inconvenient is that you can not reuse an array stored in a MATLAB/Octave variable.

4.21 Verbatim inclusion

Pass everything contained within the `verbatim` block to the `<mod_file>.m` file.

`verbatim` *;* [Block]

Description

By default, whenever Dynare encounters code that is not understood by the parser, it is directly passed to the preprocessor output.

In order to force this behavior you can use the `verbatim` block. This is useful when the code you want passed to the `<mod_file>.m` file contains tokens recognized by the Dynare preprocessor.

Example

```
verbatim;
% Anything contained in this block will be passed
% directly to the <modfile>.m file, including comments
var = 1;
end;
```

4.22 Misc commands

`set_dynare_seed` (*INTEGER*) [Command]
`set_dynare_seed` (*'default'*) [Command]
`set_dynare_seed` (*'clock'*) [Command]
`set_dynare_seed` (*'reset'*) [Command]
`set_dynare_seed` (*'ALGORITHM', INTEGER*) [Command]

Sets the seed used for random number generation. It is possible to set a given integer value, to use a default value, or to use the clock (by using the latter, one will therefore get different results across different Dynare runs). The `reset` option serves to reset the seed to the value set by the last `set_dynare_seed` command. On MATLAB 7.8 or above, it is also possible to choose a specific algorithm for random number generation; accepted values are `mcg16807`, `mlfg6331_64`, `mrg32k3a`, `mt19937ar` (the default), `shr3cong` and `swb2712`.

`save_params_and_steady_state` (*FILENAME*)*;* [Command]

For all parameters, endogenous and exogenous variables, stores their value in a text file, using a simple name/value associative table.

- for parameters, the value is taken from the last parameter initialization
- for exogenous, the value is taken from the last initval block
- for endogenous, the value is taken from the last steady state computation (or, if no steady state has been computed, from the last initval block)

Note that no variable type is stored in the file, so that the values can be reloaded with `load_params_and_steady_state` in a setup where the variable types are different.

The typical usage of this function is to compute the steady-state of a model by calibrating the steady-state value of some endogenous variables (which implies that some parameters must be endogeneized during the steady-state computation).

You would then write a first `.mod` file which computes the steady state and saves the result of the computation at the end of the file, using `save_params_and_steady_state`.

In a second file designed to perform the actual simulations, you would use `load_params_and_steady_state` just after your variable declarations, in order to load the steady state previously computed (including the parameters which had been endogeneized during the steady state computation).

The need for two separate `.mod` files arises from the fact that the variable declarations differ between the files for steady state calibration and for simulation (the set of endogenous and parameters differ between the two); this leads to different `var` and `parameters` statements.

Also note that you can take advantage of the `@#include` directive to share the model equations between the two files (see Section 4.20 [Macro-processing language], page 98).

`load_params_and_steady_state` (*FILENAME*); [Command]

For all parameters, endogenous and exogenous variables, loads their value from a file created with `save_params_and_steady_state`.

- for parameters, their value will be initialized as if they had been calibrated in the `.mod` file
- for endogenous and exogenous, their value will be initialized as they would have been from an initval block

This function is used in conjunction with `save_params_and_steady_state`; see the documentation of that function for more information.

`dynare_version` ; [MATLAB/Octave command]

Output the version of Dynare that is currently being used (*i.e.* the one that is highest on the MATLAB/Octave path).

`write_latex_definitions` ; [MATLAB/Octave command]

Writes the names, LaTeX names and long names of model variables to tables in a file named `<<M_.fname>>_latex_definitions.tex`.

5 The Configuration File

The configuration file is used to provide Dynare with information not related to the model (and hence not placed in the model file). At the moment, it is only used when using Dynare to run parallel computations.

On Linux and Mac OS X, the default location of the configuration file is `$HOME/.dynare`, while on Windows it is `%APPDATA%\dynare.ini` (typically `C:\Documents and Settings\`*`USERNAME`*`\Application Data\dynare.ini` under Windows XP, or `C:\Users\`*`USERNAME`*`\AppData\dynare.ini` under Windows Vista/7/8). You can specify a non standard location using the `conffile` option of the `dynare` command (see Section 3.1 [Dynare invocation], page 6).

The parsing of the configuration file is case-sensitive and it should take the following form, with each option/choice pair placed on a newline:

```
[command0]
option0 = choice0
option1 = choice1

[command1]
option0 = choice0
option1 = choice1
```

The configuration file follows a few conventions (self-explanatory conventions such as *USER_NAME* have been excluded for concision):

COMPUTER_NAME
: Indicates the valid name of a server (*e.g.* `localhost`, `server.cepremap.org`) or an IP address.

DRIVE_NAME
: Indicates a valid drive name in Windows, without the trailing colon (*e.g.* `C`).

PATH
: Indicates a valid path in the underlying operating system (*e.g.* `/home/user/dynare/matlab/`).

PATH_AND_FILE
: Indicates a valid path to a file in the underlying operating system (*e.g.* `/usr/local/MATLAB/R2010b/bin/matlab`).

BOOLEAN
: Is `true` or `false`.

5.1 Dynare Configuration

This section explains how to configure Dynare for general processing. Currently, there is only one option available.

`[hooks]` [Configuration block]

Description

The `[hooks]` block can be used to specify configuration options that will be used when running Dynare.

Options

`GlobalInitFile = `*`PATH_AND_FILE`*
: The location of the global initialization file to be run at the end of `global_initialization.m`

Example

```
[hooks]
GlobalInitFile = /home/usern/dynare/myInitFile.m
```

5.2 Parallel Configuration

This section explains how to configure Dynare for parallelizing some tasks which require very little inter-process communication.

The parallelization is done by running several MATLAB or Octave processes, either on local or on remote machines. Communication between master and slave processes are done through SMB on Windows and SSH on UNIX. Input and output data, and also some short status messages, are exchanged through network filesystems. Currently the system works only with homogenous grids: only Windows or only Unix machines.

The following routines are currently parallelized:

- the Metropolis-Hastings algorithm;
- the Metropolis-Hastings diagnostics;
- the posterior IRFs;
- the prior and posterior statistics;
- some plotting routines.

Note that creating the configuration file is not enough in order to trigger parallelization of the computations: you also need to specify the `parallel` option to the `dynare` command. For more details, and for other options related to the parallelization engine, see see Section 3.1 [Dynare invocation], page 6.

You also need to verify that the following requirements are met by your cluster (which is composed of a master and of one or more slaves):

For a Windows grid
- a standard Windows network (SMB) must be in place;
- PsTools must be installed in the path of the master Windows machine;
- the Windows user on the master machine has to be user of any other slave machine in the cluster, and that user will be used for the remote computations.

For a UNIX grid
- SSH must be installed on the master and on the slave machines;
- SSH keys must be installed so that the SSH connection from the master to the slaves can be done without passwords, or using an SSH agent

We now turn to the description of the configuration directives:

`[cluster]` [Configuration block]

Description

When working in parallel, `[cluster]` is required to specify the group of computers that will be used. It is required even if you are only invoking multiple processes on one computer.

Options

`Name = `*`CLUSTER_NAME`*
The reference name of this cluster.

`Members = NODE_NAME[(WEIGHT)] NODE_NAME[(WEIGHT)] ...`

A list of nodes that comprise the cluster with an optional computing weight specified for that node. The computing weight indicates how much more powerful one node is with respect to the others (*e.g.* `n1(2) n2(1) n3(3)`, means that `n1` is two times more powerful than `n2` whereas `n3` is three times more powerful than `n2`). Each node is separated by at least one space and the weights are in parenthesis with no spaces separating them from their node.

Example

```
[cluster]
Name = c1
Members = n1 n2 n3

[cluster]
Name = c2
Members = n1(4) n2 n3
```

`[node]` [Configuration block]

Description

When working in parallel, `[node]` is required for every computer that will be used. The options that are required differ, depending on the underlying operating system and whether you are working locally or remotely.

Options

`Name = NODE_NAME`

The reference name of this node.

`CPUnbr = INTEGER | [INTEGER:INTEGER]`

If just one integer is passed, the number of processors to use. If a range of integers is passed, the specific processors to use (processor counting is defined to begin at one as opposed to zero). Note that using specific processors is only possible under Windows; under Linux and Mac OS X, if a range is passed the same number of processors will be used but the range will be adjusted to begin at one.

`ComputerName = COMPUTER_NAME`

The name or IP address of the node. If you want to run locally, use `localhost` (case-sensitive).

`Port = INTEGER`

The port number to connect to on the node. The default is empty, meaning that the connection will be made to the default SSH port (22).

`UserName = USER_NAME`

The username used to log into a remote system. Required for remote runs on all platforms.

`Password = PASSWORD`

The password used to log into the remote system. Required for remote runs originating from Windows.

`RemoteDrive = DRIVE_NAME`

The drive to be used for remote computation. Required for remote runs originating from Windows.

`RemoteDirectory` = *PATH*
: The directory to be used for remote computation. Required for remote runs on all platforms.

`DynarePath` = *PATH*
: The path to the `matlab` subdirectory within the Dynare installation directory. The default is the empty string.

`MatlabOctavePath` = *PATH_AND_FILE*
: The path to the MATLAB or Octave executable. The default value is `matlab`.

`SingleCompThread` = *BOOLEAN*
: Whether or not to disable MATLAB's native multithreading. The default value is `true`. Option meaningless under Octave.

`OperatingSystem` = *OPERATING_SYSTEM*
: The operating system associated with a node. Only necessary when creating a cluster with nodes from different operating systems. Possible values are `unix` or `windows`. There is no default value.

Example

```
[node]
Name = n1
ComputerName = localhost
CPUnbr = 1

[node]
Name = n2
ComputerName = dynserv.cepremap.org
CPUnbr = 5
UserName = usern
RemoteDirectory = /home/usern/Remote
DynarePath = /home/usern/dynare/matlab
MatlabOctavePath = matlab

[node]
Name = n3
ComputerName = dynserv.dynare.org
Port = 3333
CPUnbr = [2:4]
UserName = usern
RemoteDirectory = /home/usern/Remote
DynarePath = /home/usern/dynare/matlab
MatlabOctavePath = matlab
```

6 Time Series

Dynare provides a Matlab/Octave class for handling time series data, which is based on a class for handling dates. Dynare also provides a new type for dates, so that the basic user do not have to worry about class and methods for dates. Below, you will first find the class and methods used for creating and dealing with dates and then the class used for using time series.

6.1 Dates

6.1.1 dates in a mod file

Dynare understands dates in a mod file. Users can declare annual, quarterly, monthly or weekly dates using the following syntax:

```
1990Y
1990Q3
1990M11
1990W49
```

Behind the scene, Dynare's preprocessor translates these expressions into instantiations of the Matlab/Octave's class `dates` described below. Basic operations can be performed on dates:

plus binary operator (+)
: An integer scalar, interpreted as a number of periods, can be added to a date. For instance, if `a = 1950Q1` then `b = 1951Q2` and `b = a + 5` are identical.

plus unary operator (+)
: Increments a date by one period. `+1950Q1` is identical to `1950Q2`, `++++1950Q1` is identical to `1951Q1`.

minus binary operator (-)
: Has two functions: difference and subtraction. If the second argument is a date, calculates the difference between the first date and the second date (*e.g.* `1951Q2-1950Q1` is equal to `5`). If the second argument is an integer `X`, subtracts `X` periods from the date (*e.g.* `1951Q2-2` is equal to `1950Q4`).

minus unary operator (-)
: Subtracts one period to a date. `-1950Q1` is identical to `1949Q4`. The unary minus operator is the reciprocal of the unary plus operator, `+-1950Q1` is identical to `1950Q1`.

colon operator (:)
: Can be used to create a range of dates. For instance, `r = 1950Q1:1951Q1` creates a `dates` object with five elements: `1950Q1`, `1950Q2`, `1950Q3`, `1950Q4` and `1951Q1`. By default the increment between each element is one period. This default can be changed using, for instance, the following instruction: `1950Q1:2:1951Q1` which will instantiate a `dates` object with three elements: `1950Q1`, `1950Q3` and `1951Q1`.

horzcat operator ([,])
: Concatenates `dates` objects without removing repetitions. For instance `[1950Q1, 1950Q2]` is a a `dates` object with two elements (`1950Q1` and `1950Q2`).

vertcat operator ([;])
: Same as `horzcat` operator.

eq operator (equal, ==)
: Tests if two `dates` objects are equal. `+1950Q1==1950Q2` returns `1`, `1950Q1==1950Q2` returns `0`. If the compared objects have both `n>1` elements, the `eq` operator returns a column vector, `n` by `1`, of zeros and ones.

ne operator (not equal, ~=)
: Tests if two `dates` objects are not equal. `+1950Q1~=1950Q2` returns `0` while `1950Q1~=1950Q2` returns `1`. If the compared objects both have `n>1` elements, the `ne` operator returns an `n` by `1` column vector of zeros and ones.

lt operator (less than, <)
: Tests if a `dates` object preceeds another `dates` object. For instance, `1950Q1<1950Q3` returns `1`. If the compared objects have both `n>1` elements, the `lt` operator returns a column vector, `n` by `1`, of zeros and ones.

gt operator (greater than, >)
: Tests if a `dates` object follows another `dates` object. For instance, `1950Q1>1950Q3` returns `0`. If the compared objects have both `n>1` elements, the `gt` operator returns a column vector, `n` by `1`, of zeros and ones.

le operator (less or equal, <=)
: Tests if a `dates` object preceeds another `dates` object or is equal to this object. For instance, `1950Q1<=1950Q3` returns `1`. If the compared objects have both `n>1` elements, the `le` operator returns a column vector, `n` by `1`, of zeros and ones.

ge operator (greater or equal, >=)
: Tests if a `dates` object follows another `dates` object or is equal to this object. For instance, `1950Q1>=1950Q3` returns `0`. If the compared objects have both `n>1` elements, the `ge` operator returns a column vector, `n` by `1`, of zeros and ones.

One can select an element, or some elements, in a `dates` object as he would extract some elements from a vector in Matlab/Octave. Let `a = 1950Q1:1951Q1` be a `dates` object, then `a(1)==1950Q1` returns `1`, `a(end)==1951Q1` returns `1` and `a(end-1:end)` selects the two last elements of `a` (by instantiating the `dates` object `[1950Q4, 1951Q1]`).

*Remark*Dynare substitutes any occurrence of dates in the mod file into an instantiation of the `dates` class regardless of the context. For instance, `d = 1950Q1;` will be translated as `d = dates('1950Q1');`. This automatic substitution can lead to a crash if a date is defined in a string. Typically, if the user wants to display a date:

```
disp('Initial period is 1950Q1');
```

Dynare will translate this as:

```
disp('Initial period is dates('1950Q1')');
```

which will lead to a crash because this expression is illegal in Matlab. For this situation, Dynare provides the `$` escape parameter. The following expression:

```
disp('Initial period is $1950Q1');
```

will be translated as:

```
disp('Initial period is 1950Q1');
```

in the generated MATLAB script.

6.1.2 dates class

The `dates` class has three members:

`freq`
: an integer equal to 1, 4, 12 or 52 (resp. for annual, quarterly, monthly or weekly dates).

`ndat`
: an integer scalar, the number of declared dates in the object.

`time`
: a `ndat`*2 array of integers, the years are stored in the first column, the subperiods (1 for annual dates, 1-4 for quarterly dates, 1-12 for monthly dates and 1-52 for weekly dates) are stored in the second column.

Each member is private, one can display the content of a member but cannot change its value:

```
>> d = dates('2009Q2');
>> d.time

ans =

        2009           2

>>
```

Note that it is not possible to mix frequencies in a `dates` object: all the elements must have common frequency. The `dates` class has five constructors:

`dates ()` [dates]
`dates (FREQ)` [dates]

Returns an empty `dates` object with a given frequency (if the constructor is called with one input argument). `FREQ` is a character equal to 'Y' or 'A' for annual dates, 'Q' for quarterly dates, 'M' for monthly dates or 'W' for weekly dates. Note that `FREQ` is not case sensitive, so that, for instance, 'q' is also allowed for quarterly dates. The frequency can also be set with an integer scalar equal to 1 (annual), 4 (quarterly), 12 (monthly) or 52 (weekly). The instantiation of empty objects can be used to rename the `dates` class. For instance, if one only works with quarterly dates, he can create `qq` as:

```
qq = dates('Q')
```

and a `dates` object holding the date `2009Q2`:

```
d0 = qq(2009,2);
```

which is much simpler if `dates` objects have to be defined programmatically.

`dates (STRING)` [dates]
`dates (STRING, STRING, ...)` [dates]

Returns a `dates` object that represents a date as given by the string `STRING`. This string has to be interpretable as a date (only strings of the following forms are admitted: `'1990Y'`, `'1990A'`, `'1990Q1'`, `'1990M2'`, `'1990W5'`), the routine `isdate` can be used to test if a string is interpretable as a date. If more than one argument is provided, they should all be dates represented as strings, the resulting `dates` object contains as many elements as arguments to the constructor.

`dates (DATES)` [dates]
`dates (DATES, DATES, ...)` [dates]

Returns a copy of the `dates` object `DATES` passed as input arguments. If more than one argument is provided, they should all be `dates` objects. The number of elements in the instantiated `dates` object is equal to the sum of the elements in the `dates` passed as arguments to the constructor.

`dates (FREQ, YEAR, SUBPERIOD)` [dates]

where `FREQ` is a single character ('Y', 'A', 'Q', 'M', 'W') or integer (1, 4, 12 or 52) specifying the frequency, `YEAR` and `SUBPERIOD` are `n*1` vectors of integers. Returns a `dates` object with `n` elements. If `FREQ` is equal to `'Y', 'A'` or `1`, the third argument is not needed (because `SUBPERIOD` is necessarily a vector of ones in this case).

Examples

```
do1 = dates('1950Q1');
do2 = dates('1950Q2','1950Q3');
do3 = dates(do1,do2);
do4 = dates('Q',1950, 1);
```

A list of the available methods, by alphabetical order, is given below. Note that the Matlab/Octave classes do not allow in place modifications: when a method is applied to an object a new object is instantiated. For instance, to apply the method `multiplybytwo` to an object `X` we write:

```
Y = X.multiplybytwo()
```

or equivalently:

```
Y = multiplybytwo(X)
```

the object `X` is left unchanged, and the object `Y` is a modified copy of `X`.

`C =` `append` (*A*, *B*) [dates]

Appends `dates` object *B*, or a string that can be interpreted as a date, to the `dates` object *A*. If *B* is a `dates` object it is assumed that it has no more than one element.

Example

```
>> D = dates('1950Q1','1950Q2');
>> d = dates('1950Q3');
>> E = D.append(d);
>> F = D.append('1950Q3')
>> isequal(E,F)

ans =

     1
>> F
F = <dates: 1950Q1, 1950Q2, 1950Q3>
```

`C =` `colon` (*A*, *B*) [dates]

`C =` `colon` (*A*, `i`, *B*) [dates]

Overloads the Matlab/Octave colon (:) operator. *A* and *B* are `dates` objects. The optional increment *i* is a scalar integer (default value is `i=1`). This method returns a `dates` object and can be used to create ranges of dates.

Example

```
>> A = dates('1950Q1');
>> B = dates('1951Q2');
>> C = A:B
C = <dates: 1950Q1, 1950Q2, 1950Q3, 1950Q4, 1951Q1>
>> D = A:2:B
D = <dates: 1950Q1, 1950Q3, 1951Q1>
```

`B =` `double` (*A*) [dates]

Overloads the Matlab/Octave `double` function. *A* is a `dates` object. The method returns a floating point representation of a `dates` object, the integer and fractional parts respectively corresponding to the year and the subperiod. The fractional part is the subperiod number minus one divided by the frequency (`1`, `4`, `12` or `52`).

Example

```
>> a = dates('1950Q1'):dates('1950Q4');
>> a.double()

ans =

   1950.00
   1950.25
   1950.50
   1950.75
```

`C = eq (A, B)` [dates]

Overloads the Matlab/Octave `eq` (equal, `==`) operator. `dates` objects *A* and *B* must have the same number of elements (say, `n`). The returned argument is a `n` by `1` vector of zeros and ones. The i-th element of *C* is equal to `1` if and only if the dates `A(i)` and `B(i)` are the same.

Example

```
>> A = dates('1950Q1','1951Q2');
>> B = dates('1950Q1','1950Q2');
>> A==B

ans =

     1
     0
```

`C = ge (A, B)` [dates]

Overloads the Matlab/Octave `ge` (greater or equal, `>=`) operator. `dates` objects *A* and *B* must have the same number of elements (say, `n`). The returned argument is a `n` by `1` vector of zeros and ones. The i-th element of *C* is equal to `1` if and only if the date `A(i)` is posterior or equal to the date `B(i)`.

Example

```
>> A = dates('1950Q1','1951Q2');
>> B = dates('1950Q1','1950Q2');
>> A>=B

ans =

     1
     1
```

`C = gt (A, B)` [dates]

Overloads the Matlab/Octave `gt` (greater than, `>=`) operator. `dates` objects *A* and *B* must have the same number of elements (say, `n`). The returned argument is a `n` by `1` vector of zeros and ones. The i-th element of *C* is equal to `1` if and only if the date `A(i)` is posterior to the date `B(i)`.

Example

```
>> A = dates('1950Q1','1951Q2');
>> B = dates('1950Q1','1950Q2');
>> A>B

ans =

     0
     1
```

`D = horzcat (A, B, C, ...)` [dates]

Overloads the Matlab/Octave `horzcat` operator. All the input arguments must be `dates` objects. The returned argument is a `dates` object gathering all the dates given in the input arguments (repetitions are not removed).

Example

```
>> A = dates('1950Q1');
>> B = dates('1950Q2');
>> C = [A, B];
>> C
C = <dates: 1950Q1, 1950Q2>
```

`C = intersect (A, B)` [dates]

Overloads the Matlab/Octave `intersect` function. All the input arguments must be `dates` objects. The returned argument is a `dates` object gathering all the common dates given in the input arguments. If A and B are disjoint `dates` objects, the function returns an empty `dates` object. Returned dates in `dates` object C are sorted by increasing order.

Example

```
>> A = dates('1950Q1'):dates('1951Q4');
>> B = dates('1951Q1'):dates('1951Q4');
>> C = intersect(A, B);
>> C
C = <dates: 1951Q1, 1951Q2, 1951Q3, 1951Q4>
```

`C = setdiff (A, B)` [dates]

Overloads the Matlab/Octave `setdiff` function. All the input arguments must be `dates` objects. The returned argument is a `dates` object all dates present in A but not in B. If A and B are disjoint `dates` objects, the function returns A. Returned dates in `dates` object C are sorted by increasing order.

Example

```
>> A = dates('1950Q1'):dates('1969Q4') ;
>> B = dates('1960Q1'):dates('1969Q4') ;
>> C = dates('1970Q1'):dates('1979Q4') ;
>> d1 = setdiff(d1,d2);
>> d2 = setdiff(d1,d3);
d1 = <dates: 1950Q1, 1950Q2,  ..., 1959Q3, 1959Q4>
d2 = <dates: 1950Q1, 1950Q2,  ..., 1969Q3, 1969Q4>
```

B = **isempty** (*A*) [dates]

Overloads the Matlab/Octave isempty function for `dates` object.

Example

```
>> A = dates('1950Q1'):dates('1951Q4');
>> A.isempty()

ans =

     0
```

C = **isequal** (*A*, *B*) [dates]

Overloads the Matlab/Octave `isequal` function for `dates` objects.

Example

```
>> A = dates('1950Q1'):dates('1951Q4');
>> isequal(A,A)

ans =

     1
```

C = **le** (*A*, *B*) [dates]

Overloads the Matlab/Octave `le` (less or equal, `<=`) operator. `dates` objects *A* and *B* must have the same number of elements (say, `n`). The returned argument is a `n` by `1` vector of zeros and ones. The i-th element of *C* is equal to `1` if and only if the date `A(i)` is not posterior to the date `B(i)`.

Example

```
>> A = dates('1950Q1','1951Q2');
>> B = dates('1950Q1','1950Q2');
>> A<=B

ans =

     1
     0
```

B = **length** (*A*) [dates]

Overloads the Matlab/Octave `length` function. Returns the number of dates in `dates` object *A* (*B* is a scalar integer).

Example

```
>> A = dates('1950Q1','1951Q2');
>> A.length()

ans =

     2
```

`C = lt (A, B)` [dates]

Overloads the Matlab/Octave `lt` (less than, `<=`) operator. `dates` objects *A* and *B* must have the same number of elements (say, `n`). The returned argument is a `n` by `1` vector of zeros and ones. The i-th element of *C* is equal to `1` if and only if the date `A(i)` preceeds the date `B(i)`.

Example

```
>> A = dates('1950Q1','1951Q2');
>> B = dates('1950Q1','1950Q2');
>> A<B

ans =

     0
     0
```

`D = max (A, B, C, ...)` [dates]

Overloads the Matlab/Octave `max` function. All input arguments must be `dates` objects. The function returns a single element `dates` object containing the greatest date.

Example

```
>> A = {dates('1950Q2'), dates('1953Q4','1876Q2'), dates('1794Q3')};
>> max(A{:})
ans = <dates: 1953Q4>
```

`D = min (A, B, C, ...)` [dates]

Overloads the Matlab/Octave `min` function. All input arguments must be `dates` objects. The function returns a single element `dates` object containing the smallest date.

Example

```
>> A = {dates('1950Q2'), dates('1953Q4','1876Q2'), dates('1794Q3')};
>> min(A{:})
ans = <dates: 1794Q3>
```

`C = minus (A, B)` [dates]

Overloads the Matlab/Octave `minus` operator (`-`). If both input arguments are `dates` objects, then number of periods between *A* and *B* is returned (so that `A+C=B`). If *B* is a vector of integers, the `minus` operator shifts the `dates` object by *B* periods backward.

Example

```
>> d1 = dates('1950Q1','1950Q2','1960Q1');
>> d2 = dates('1950Q3','1950Q4','1960Q1');
>> ee = d2-d1

ee =

     2
     2
     0
```

```
>> d1-(-ee)
ans = <dates: 1950Q3, 1950Q4, 1960Q1>
```

`C = ne (A, B)` [dates]

Overloads the Matlab/Octave `ne` (not equal, `~=`) operator. `dates` objects *A* and *B* must have the same number of elements (say, `n`) or one of the inputs must be a single element `dates` object. The returned argument is a `n` by `1` vector of zeros and ones. The i-th element of *C* is equal to `1` if and only if the dates `A(i)` and `B(i)` are different.

Example

```
>> A = dates('1950Q1','1951Q2');
>> B = dates('1950Q1','1950Q2');
>> A~=B

ans =

     0
     1
```

`C = plus (A, B)` [dates]

Overloads the Matlab/Octave `plus` operator (`+`). If both input arguments are `dates` objects, then the method combines A and B without removing repetitions. If *B* is a vector of integers, the `plus` operator shifts the `dates` object by *B* periods forward.

Example

```
>> d1 = dates('1950Q1','1950Q2')+dates('1960Q1');
>> d2 = (dates('1950Q1','1950Q2')+2)+dates('1960Q1');
>> ee = d2-d1;

ee =

     2
     2
     0

>> d1+ee
ans = <dates: 1950Q3, 1950Q4, 1960Q1>
```

`C = pop (A)` [dates]
`C = pop (A,B)` [dates]

Pop method for `dates` class. If only one input is provided, the method removes the last element of a `dates` object. If a second input argument is provided, a scalar integer between `1` and `A.length()`, the method removes element number *B* from `dates` object *A*.

Example

```
>> d1 = dates('1950Q1','1950Q2');
>> d1.pop()
ans = <dates: 1950Q1>
```

```
>> d1.pop(1)
ans = <dates: 1950Q2>
```

B = sort (*A*) [dates]

Sort method for dates objects. Returns a dates object with elements sorted by increasing order.

Example

```
>> dd = dates('1945Q3','1938Q4','1789Q3');
>> dd.sort()
ans = <dates: 1789Q3, 1938Q4, 1945Q3>
```

B = uminus (*A*) [dates]

Overloads the Matlab/Octave unary minus operator. Returns a dates object with elements shifted one period backward.

Example

```
>> dd = dates('1945Q3','1938Q4','1973Q1');
>> -dd
ans = <dates: 1945Q2, 1938Q3, 1972Q4>
```

D = union (*A*, *B*, *C*, ...) [dates]

Overloads the Matlab/Octave union function. Returns a dates object with elements sorted by increasing order (repetitions are removed, to keep the repetitions use the horzcat or plus operators).

Example

```
>> d1 = dates('1945Q3','1973Q1','1938Q4');
>> d2 = dates('1973Q1','1976Q1');
>> union(d1,d2)
ans = <dates: 1938Q4, 1945Q3, 1973Q1, 1976Q1>
```

B = unique (*A*) [dates]

Overloads the Matlab/Octave unique function. Returns a dates object with repetitions removed (only the last occurence of a date is kept).

Example

```
>> d1 = dates('1945Q3','1973Q1','1945Q3');
>> d1.unique()
ans = <dates: 1973Q1, 1945Q3>
```

B = uplus (*A*) [dates]

Overloads the Matlab/Octave unary plus operator. Returns a dates object with elements shifted one period ahead.

Example

```
>> dd = dates('1945Q3','1938Q4','1973Q1');
>> +dd
ans = <dates: 1945Q4, 1939Q1, 1973Q2>
```

6.2 dseries class

The Matlab/Octave `dseries` class handles time series data. As any Matlab/Octave statements, this class can be used in a Dynare's mod file. A `dseries` object has eight members:

`nobs`	A scalar integer, the number of observations.
`vobs`	A scalar integer, the number of variables.
`name`	A cell of strings, the names of the variables.
`tex`	A cell of strings, the tex names of the variables.
`freq`	A scalar integer equal to 1, 4, 12 or 52, the frequency of the dataset.
`init`	A single element `dates` object, the initial date of the sample.
`dates`	A `dates` object with `nobs` element, the dates of the sample.
`data`	A `nobs` by `vobs` array of doubles, the data.

`freq`, `nobs`, `vobs`, `data`, `name`, `tex` are private members. The following constructors are available:

`dseries ()` [dseries]
`dseries (`*`INITIAL_DATE`*`)` [dseries]

Instantiates an empty `dseries` object, with, if defined, an initial date given by the single element `dates` object *INITIAL_DATE* (the frequency is then set accordingly).

`dseries (`*`FILENAME`*`)` [dseries]

Instantiates and populates a `dseries` object with a data file specified by *FILENAME*, a string passed as input. Valid file types are `.m` file, `.mat` file, `.csv` file, and `.xls` file. A typical `.m` file will have the following form:

```
INIT__ = '1994Q3';
NAMES__ = {'azert';'yuiop'};
TEX__ = {'azert';'yuiop'};

azert = randn(100,1);
yuiop = randn(100,1);
```

If a `.mat` file is used instead, it should provide the same informations. Note that the `INIT__` variable can be either a `dates` object or a string which could be used to instantiate the same `dates` object.

`dseries (`*`DATA_MATRIX`*`[, `*`INITIAL_DATE`*`[, `*`LIST_OF_NAMES`*`[, `*`LIST_OF_TEX_NAMES`*`]]])` [dseries]

If the data is not read from a file, it can be provided via a TxN matrix as the first argument to `dseries`' constructor, with T representing the number of observations on N variables. The optional second argument, *INITIAL_DATE*, can be either a `dates` object representing the period of the first observation or a string which would be used to instantiate a `dates` object. Its default value is `dates('1Y')`. The optional third argument, *LIST_OF_NAMES*, is a N by 1 cell of strings with one entry for each variable name. The default name associated with column `i` of *DATA_MATRIX* is `Variable_i`. The final argument, *LIST_OF_TEX_NAMES*, is a N by 1 cell of strings composed of the LaTeX names associated with the variables. The default LaTeX name associated with column `i` of *DATA_MATRIX* is `Variable\_i`.

Examples

Various ways to create a `dseries` object:

```
In a mod file:
do1 = dseries(1999Q3);
do2 = dseries('filename.csv');
do3 = dseries([1; 2; 3], 1999Q3, {'var123'}, {'var_{123}'});

In a Matlab/Octave script:
>> do1 = dseries(dates('1999Q3'));
>> do2 = dseries('filename.csv');
>> do3 = dseries([1; 2; 3], dates('1999Q3'), {'var123'}, {'var_{123}'});
```

One can easily create subsamples from a `dseries` object using the overloaded parenthesis operator. If *ds* is a `dseries` object with T observations and d is a `dates` object with $S < T$ elements, such that $min(d)$ is not smaller than the date associated to the first observation in *ds* and $max(d)$ is not greater than the date associated to the last observation, then `ds(d)` instantiates a new `dseries` object containing the subsample defined by d.

A list of the available methods, by alphabetical order, is given below.

`[A, B] = align (A, B)` [dseries]

If `dseries` objects A and B are defined on different time ranges, this function extends A and/or B with NaNs so that they are defined on the same time range. Note that both `dseries` objects must have the same frequency.

Example

```
>> ts0 = dseries(rand(5,1),dates('2000Q1')); % 2000Q1 -> 2001Q1
>> ts1 = dseries(rand(3,1),dates('2000Q4')); % 2000Q4 -> 2001Q2
>> [ts0, ts1] = align(ts0, ts1);             % 2000Q1 -> 2001Q2
>> ts0

ts0 is a dseries object:

       | Variable_1
2000Q1 | 0.81472
2000Q2 | 0.90579
2000Q3 | 0.12699
2000Q4 | 0.91338
2001Q1 | 0.63236
2001Q2 | NaN

>> ts1

ts1 is a dseries object:

       | Variable_1
2000Q1 | NaN
2000Q2 | NaN
2000Q3 | NaN
2000Q4 | 0.66653
2001Q1 | 0.17813
2001Q2 | 0.12801
```

B = `baxter_king_filter` (*A*, *hf*, *lf*, *K*) [dseries]

Implementation of the Baxter and King (1999) band pass filter for `dseries` objects. This filter isolates business cycle fluctuations with a period of length ranging between *hf* (high frequency) to *lf* (low frequency) using a symmetric moving average smoother with $2K + 1$ points, so that K observations at the beginning and at the end of the sample are lost in the computation of the filter. The default value for *hf* is 6, for *lf* is 32, and for K is 12.

Example

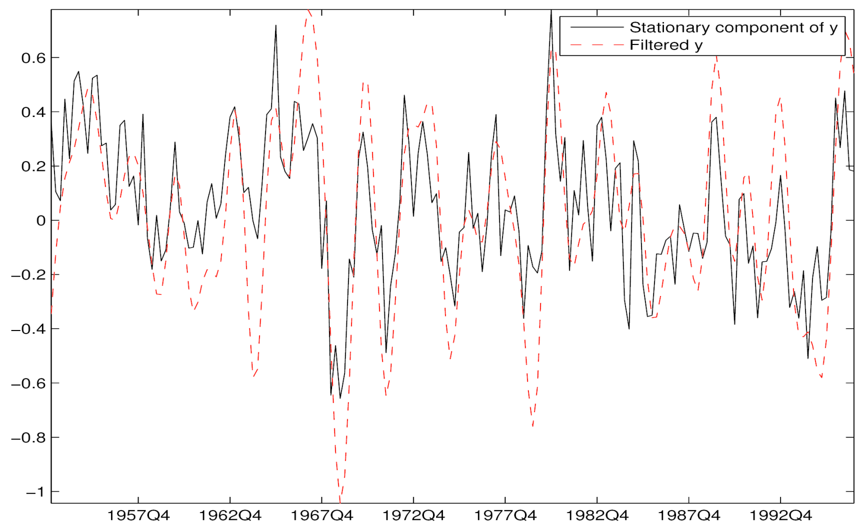
```
% Simulate a component model (stochastic trend, deterministic trend, and a
% stationary autoregressive process).
e = .2*randn(200,1);
u = randn(200,1);
stochastic_trend = cumsum(e);
deterministic_trend = .1*transpose(1:200);
x = zeros(200,1);
for i=2:200
    x(i) = .75*x(i-1) + e(i);
end
y = x + stochastic_trend + deterministic_trend;

% Instantiates time series objects.
ts0 = dseries(y,'1950Q1');
ts1 = dseries(x,'1950Q1'); % stationary component.

% Apply the Baxter-King filter.
ts2 = ts0.baxter_king_filter();

% Plot the filtered time series.
plot(ts1(ts2.dates).data,'-k'); % Plot of the stationary component.
hold on
plot(ts2.data,'--r');           % Plot of the filtered y.
hold off
axis tight
id = get(gca,'XTick');
set(gca,'XTickLabel',strings(ts.dates(id)));
```

The previous code should produce something like:



[*error_flag*, *message*] = check (*A*) [dseries]

Sanity check of `dseries` object *A*. Returns 1 if there is an error, 0 otherwise. The second output argument is a string giving brief informations about the error.

B = cumsum (*A*[, *d*[, *v*]]) [dseries]

Overloads the Matlab/Octave `cumsum` function for `dseries` objects. The cumulated sum cannot be computed if the variables in `dseries` object *A* has `NaN`s. If a `dates` object *d* is provided as a second argument, then the method computes the cumulated sum with the additional constraint that the variables in the `dseries` object *B* are zero in period *d*. If a single observation `dseries` object *v* is provided as a third argument, the cumulated sum in *B* is such that `B(d)` matches *v* (`dseries` objects *A* and *v* must have the same number of variables).

Example

```
>> ts1 = dseries(ones(10,1));
>> ts2 = ts1.cumsum();
>> ts2

ts2 is a dseries object:

    | cumsum(Variable_1)
1Y  | 1
2Y  | 2
3Y  | 3
4Y  | 4
5Y  | 5
6Y  | 6
7Y  | 7
8Y  | 8
9Y  | 9
10Y | 10

>> ts3 = cumsum(dates('3Y'));
>> ts3
```

```
ts3 is a dseries object:

    | cumsum(Variable_1)
1Y  | -2
2Y  | -1
3Y  | 0
4Y  | 1
5Y  | 2
6Y  | 3
7Y  | 4
8Y  | 5
9Y  | 6
10Y | 7

>> ts4 = ts1.cumsum(dates('3Y'),dseries(pi));
>> ts4

ts4 is a dseries object:

    | cumsum(Variable_1)
1Y  | 1.1416
2Y  | 2.1416
3Y  | 3.1416
4Y  | 4.1416
5Y  | 5.1416
6Y  | 6.1416
7Y  | 7.1416
8Y  | 8.1416
9Y  | 9.1416
10Y | 10.1416
```

`C = eq (A, B)` [dseries]

Overloads the Matlab/Octave `eq` (equal, `==`) operator. `dseries` objects A and B must have the same number of observations (say, T) and variables (N). The returned argument is a T by N matrix of zeros and ones. Element (i, j) of C is equal to `1` if and only if observation i for variable j in A and B are the same.

Example

```
>> ts0 = dseries(2*ones(3,1));
>> ts1 = dseries([2; 0; 2]);
>> ts0==ts1

ans =

     1
     0
     1
```

`B = exp (A)` [dseries]

Overloads the Matlab/Octave `exp` function for `dseries` objects.

Example

```
>> ts0 = dseries(rand(10,1));
>> ts1 = ts0.exp();
```

C = `extract` (*A*, *B*[, ...]) [dseries]

Extracts some variables from a `dseries` object *A* and returns a `dseries` object *C*. The input arguments following *A* are strings representing the variables to be selected in the new `dseries` object *C*. To simplify the creation of sub-objects, the `dseries` class overloads the curly braces (`D = extract (A, B, C)` is equivalent to `D = A{B,C}`) and allows implicit loops (defined between a pair of @ symbol, see examples below) or Matlab/Octave's regular expressions (introduced by square brackets).

Examples

The following selections are equivalent:

```
>> ts0 = dseries(ones(100,10));
>> ts1 = ts0{'Variable_1','Variable_2','Variable_3'};
>> ts2 = ts0{'Variable_@1,2,3@'}
>> ts3 = ts0{'Variable_[1-3]$'}
>> isequal(ts1,ts2) && isequal(ts1,ts3)

ans =

      1
```

It is possible to use up to two implicit loops to select variables:

```
names = {'GDP_1';'GDP_2';'GDP_3'; 'GDP_4'; 'GDP_5'; 'GDP_6'; 'GDP_7'; 'GDP_8'; ...
      'GDP_9'; 'GDP_10'; 'GDP_11'; 'GDP_12'; ...
      'HICP_1';'HICP_2';'HICP_3'; 'HICP_4'; 'HICP_5'; 'HICP_6'; 'HICP_7'; 'HICP_8'; .
      'HICP_9'; 'HICP_10'; 'HICP_11'; 'HICP_12'};

ts0 = dseries(randn(4,24),dates('1973Q1'),names);
ts0{'@GDP,HICP@_@1,3,5@'}

ans is a dseries object:

       | GDP_1    | GDP_3    | GDP_5    | HICP_1   | HICP_3   | HICP_5
1973Q1 | 1.7906   | -1.6606  | -0.57716 | 0.60963  | -0.52335 | 0.26172
1973Q2 | 2.1624   | 3.0125   | 0.52563  | 0.70912  | -1.7158  | 1.7792
1973Q3 | -0.81928 | 1.5008   | 1.152    | 0.2798   | 0.88568  | 1.8927
1973Q4 | -0.03705 | -0.35899 | 0.85838  | -1.4675  | -2.1666  | -0.62032
```

D = `horzcat` (*A*, *B*[, ...]) [dseries]

Overloads the `horzcat` Matlab/Octave's method for `dseries` objects. Returns a `dseries` object *D* containing the variables in `dseries` objects passed as inputs: *A*, *B*, ... If the inputs are not defined on the same time ranges, the method adds `NaN`s to the variables so that the variables are redefined on the smallest common time range. Note that the names in the `dseries` objects passed as inputs must be different and these objects must have common frequency.

Example

```
>> ts0 = dseries(rand(5,2),'1950Q1',{'nifnif';'noufnouf'});
>> ts1 = dseries(rand(7,1),'1950Q3',{'nafnaf'});
>> ts2 = [ts0, ts1];
>> ts2

ts2 is a dseries object:

       | nifnif  | noufnouf | nafnaf
1950Q1 | 0.17404 | 0.71431  | NaN
1950Q2 | 0.62741 | 0.90704  | NaN
1950Q3 | 0.84189 | 0.21854  | 0.83666
1950Q4 | 0.51008 | 0.87096  | 0.8593
1951Q1 | 0.16576 | 0.21184  | 0.52338
1951Q2 | NaN     | NaN      | 0.47736
1951Q3 | NaN     | NaN      | 0.88988
1951Q4 | NaN     | NaN      | 0.065076
1952Q1 | NaN     | NaN      | 0.50946
```

B = `hpcycle` (*A*[, *lambda*]) [dseries]

Extracts the cycle component from a `dseries` *A* object using Hodrick Prescott (1997) filter and returns a `dseries` object, *B*. The default value for *lambda*, the smoothing parameter, is 1600.

Example

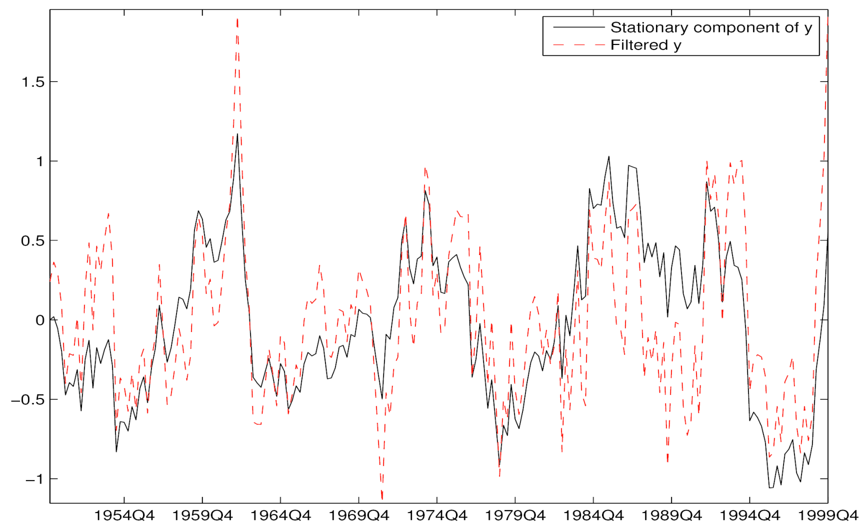
```
% Simulate a component model (stochastic trend, deterministic trend, and a
% stationary autoregressive process).
e = .2*randn(200,1);
u = randn(200,1);
stochastic_trend = cumsum(e);
deterministic_trend = .1*transpose(1:200);
x = zeros(200,1);
for i=2:200
    x(i) = .75*x(i-1) + e(i);
end
y = x + stochastic_trend + deterministic_trend;

% Instantiates time series objects.
ts0 = dseries(y,'1950Q1');
ts1 = dseries(x,'1950Q1'); % stationary component.

% Apply the HP filter.
ts2 = ts0.hpcycle();

% Plot the filtered time series.
plot(ts1(ts2.dates).data,'-k'); % Plot of the stationary component.
hold on
plot(ts2.data,'--r');           % Plot of the filtered y.
hold off
axis tight
id = get(gca,'XTick');
set(gca,'XTickLabel',strings(ts.dates(id)));
```

The previous code should produce something like:



B = `hptrend` (*A*[, *lambda*]) [dseries]

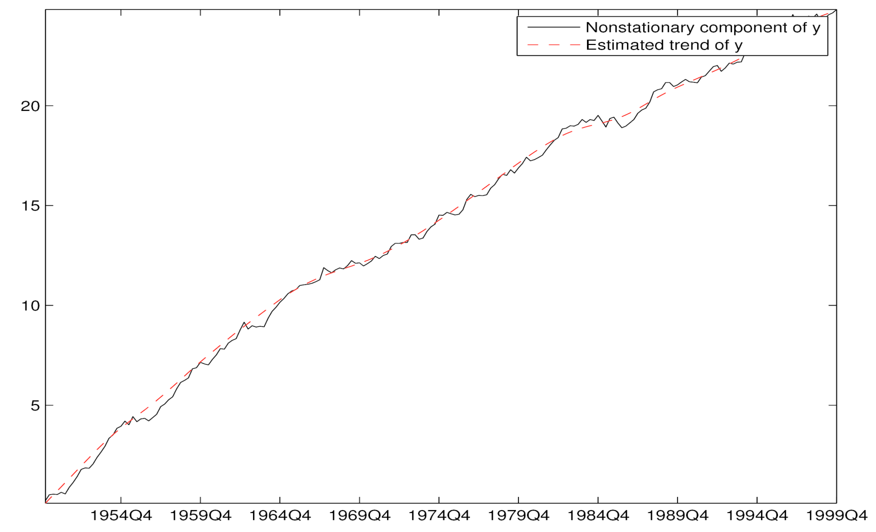
Extracts the trend component from a `dseries` *A* object using Hodrick Prescott (1997) filter and returns a `dseries` object, *B*. Default value for *lambda*, the smoothing parameter, is 1600.

*Example*Using the same generating data process as in the previous example:

```
ts1 = dseries(stochastic_trend + deterministic_trend,'1950Q1');
% Apply the HP filter.
ts2 = ts0.hptrend();

% Plot the filtered time series.
plot(ts1.data,'-k'); % Plot of the nonstationary components.
hold on
plot(ts2.data,'--r');            % Plot of the estimated trend.
hold off
axis tight
id = get(gca,'XTick');
set(gca,'XTickLabel',strings(ts0.dates(id)));
```

The previous code should produce something like:



`C = insert (A, B, I)` [dseries]

Inserts variables contained in `dseries` object *B* in `dseries` object *A* at positions specified by integer scalars in vector *I*, returns augmented `dseries` object *C*. The integer scalars in *I* must take values between `1` and `A.length()+1` and refers to *A*'s column numbers. The `dseries` objects *A* and *B* need not to be defined over the same time ranges, but it is assumed that they have common frequency.

Example

```
>> ts0 = dseries(ones(2,4),'1950Q1',{'Sly'; 'Gobbo'; 'Sneaky'; 'Stealthy'});
>> ts1 = dseries(pi*ones(2,1),'1950Q1',{'Noddy'});
>> ts2 = ts0.insert(ts1,3)

ts2 is a dseries object:

       | Sly | Gobbo | Noddy  | Sneaky | Stealthy
1950Q1 | 1   | 1     | 3.1416 | 1      | 1
1950Q2 | 1   | 1     | 3.1416 | 1      | 1

>> ts3 = dseries([pi*ones(2,1) sqrt(pi)*ones(2,1)],'1950Q1',{'Noddy';'Tessie Bear'});
>> ts4 = ts0.insert(ts1,[3, 4])

ts4 is a dseries object:

       | Sly | Gobbo | Noddy  | Sneaky | Tessie Bear | Stealthy
1950Q1 | 1   | 1     | 3.1416 | 1      | 1.7725      | 1
1950Q2 | 1   | 1     | 3.1416 | 1      | 1.7725      | 1
```

`B = isempty (A)` [dseries]

Overloads the Matlab/octave's `isempty` function. Returns `1` if `dseries` object *A* is empty, `0` otherwise.

`C = isequal (A,B)` [dseries]

Overloads the Matlab/octave's `isequal` function. Returns `1` if `dseries` objects *A* and `B` are identical, `0` otherwise.

`B = lag (A[, p])` [dseries]

Returns lagged time series. Default value of *p*, the number of lags, is `1`.

Examples

```
>> ts0 = dseries(transpose(1:4),'1950Q1')

ts0 is a dseries object:

       | Variable_1
1950Q1 | 1
1950Q2 | 2
1950Q3 | 3
1950Q4 | 4

>> ts1 = ts0.lag()

ts1 is a dseries object:

       | lag(Variable_1,1)
1950Q1 | NaN
1950Q2 | 1
1950Q3 | 2
1950Q4 | 3

>> ts2 = ts0.lag(2)

ts2 is a dseries object:

       | lag(Variable_1,2)
1950Q1 | NaN
1950Q2 | NaN
1950Q3 | 1
1950Q4 | 2
```

`dseries` class overloads the parenthesis so that `ts.lag(p)` can be written more compactly as `ts(-p)`. For instance:

```
>> ts0.lag(1)

ans is a dseries object:

       | lag(Variable_1,1)
1950Q1 | NaN
1950Q2 | 1
1950Q3 | 2
1950Q4 | 3
```

or alternatively:

```
>> ts0(-1)
```

```
ans is a dseries object:

       | lag(Variable_1,1)
1950Q1 | NaN
1950Q2 | 1
1950Q3 | 2
1950Q4 | 3
```

B = `lead` (*A*[, *p*]) [dseries]

Returns leaded time series. Default value of *p*, the number of leads, is `1`. As for the `lag` method, the `dseries` class overloads the parenthesis so that `ts.lead(p)` is equivalent to `ts(p)`.

Example

```
>> ts0 = dseries(transpose(1:4),'1950Q1');
>> ts1 = ts0.lead()

ts1 is a dseries object:

       | lead(Variable_1,1)
1950Q1 | 2
1950Q2 | 3
1950Q3 | 4
1950Q4 | NaN

>> ts2 = ts0(2)

ts2 is a dseries object:

       | lead(Variable_1,2)
1950Q1 | 3
1950Q2 | 4
1950Q3 | NaN
1950Q4 | NaN
```

Remark

The overloading of the parenthesis for `dseries` objects, allows to easily create new `dseries` objects by copying/pasting equations declared in the `model` block. For instance, if an Euler equation is defined in the `model` block:

```
model;
    ...
    1/C - beta/C(1)*(exp(A(1))*K^(alpha-1)+1-delta) ;
    ...
end;
```

and if variables *C*, *A* and *K* are defined as `dseries` objects, then by writting:

```
Residuals = 1/C - beta/C(1)*(exp(A(1))*K^(alpha-1)+1-delta) ;
```

outside of the `model` block, we create a new `dseries` object, called `Residuals`, for the residuals of the Euler equation (the conditional expectation of the equation defined in the `model` block is zero, but the residuals are non zero).

B = log (*A*) [dseries]

Overloads the Matlab/Octave `log` function for `dseries` objects.

Example

```
>> ts0 = dseries(rand(10,1));
>> ts1 = ts0.log();
```

C = merge (*A*, *B*) [dseries]

Merges two `dseries` objects *A* and *B* in `dseries` object *C*. Objects *A* and *B* need to have common frequency but can be defined on different time ranges. If a variable, say `x`, is defined both in `dseries` objects *A* and *B*, then the merge will select the variable `x` as defined in the second input argument, *B*.

Example

```
>> ts0 = dseries(rand(3,2),'1950Q1',{'A1';'A2'})

ts0 is a dseries object:

       | A1       | A2
1950Q1 | 0.42448  | 0.92477
1950Q2 | 0.60726  | 0.64208
1950Q3 | 0.070764 | 0.1045

>> ts1 = dseries(rand(3,1),'1950Q2',{'A1'})

ts1 is a dseries object:

       | A1
1950Q2 | 0.70023
1950Q3 | 0.3958
1950Q4 | 0.084905

>> merge(ts0,ts1)

ans is a dseries object:

       | A1       | A2
1950Q1 | NaN      | 0.92477
1950Q2 | 0.70023  | 0.64208
1950Q3 | 0.3958   | 0.1045
1950Q4 | 0.084905 | NaN

>> merge(ts1,ts0)

ans is a dseries object:

       | A1       | A2
1950Q1 | 0.42448  | 0.92477
1950Q2 | 0.60726  | 0.64208
1950Q3 | 0.070764 | 0.1045
1950Q4 | NaN      | NaN
```

`C = minus (A, B)` [dseries]

Overloads the `minus` (`-`) operator for `dseries` objects, element by element subtraction. If both A and B are `dseries` objects, they do not need to be defined over the same time ranges. If A and B are `dseries` objects with T_A and T_B observations and N_A and N_B variables, then N_A must be equal to N_B or 1 and N_B must be equal to N_A or 1. If $T_A = T_B$, `isequal(A.init,B.init)` returns 1 and $N_A = N_B$, then the `minus` operator will compute for each couple (t, n), with $1 \leq t \leq T_A$ and $1 \leq n \leq N_A$, `C.data(t,n)=A.data(t,n)-B.data(t,n)`. If N_B is equal to 1 and $N_A > 1$, the smaller `dseries` object (B) is "broadcast" across the larger `dseries` (A) so that they have compatible shapes, the `minus` operator will subtract the variable defined in B from each variable in A. If B is a double scalar, then the method `minus` will subtract B from all the observations/variables in A. If B is a row vector of length N_A, then the `minus` method will subtract `B(i)` from all the observations of variable `i`, for $i = 1, ..., N_A$. If B is a column vector of length T_A, then the `minus` method will subtract `B` from all the variables.

Example

```
>> ts0 = dseries(rand(3,2));
>> ts1 = ts0{'Variable_2'};
>> ts0-ts1

ans is a dseries object:

   | minus(Variable_1,Variable_2) | minus(Variable_2,Variable_2)
1Y | -0.48853                     | 0
2Y | -0.50535                     | 0
3Y | -0.32063                     | 0

>> ts1

ts1 is a dseries object:

   | Variable_2
1Y | 0.703
2Y | 0.75415
3Y | 0.54729

>> ts1-ts1.data(1)

ans is a dseries object:

   | minus(Variable_2,0.703)
1Y | 0
2Y | 0.051148
3Y | -0.15572

>> ts1.data(1)-ts1

ans is a dseries object:

   | minus(0.703,Variable_2)
1Y | 0
2Y | -0.051148
3Y | 0.15572
```

`C = mpower (A, B)` [dseries]

Overloads the `mpower` (`^`) operator for `dseries` objects and computes element-by-element power. A is a `dseries` object with `N` variables and `T` observations. If B is a real scalar, then `mpower(A,B)` returns a `dseries` object C with `C.data(t,n)=A.data(t,n)^C`. If B is a `dseries` object with `N` variables and `T` observations then `mpower(A,B)` returns a `dseries` object C with `C.data(t,n)=A.data(t,n)^C.data(t,n)`.

Example

```
>> ts0 = dseries(transpose(1:3));
>> ts1 = ts0^2

ts1 is a dseries object:

   | power(Variable_1,2)
1Y | 1
2Y | 4
3Y | 9

>> ts2 = ts0^ts0

ts2 is a dseries object:

   | power(Variable_1,Variable_1)
1Y | 1
2Y | 4
3Y | 27
```

`C = mrdivide (A, B)` [dseries]

Overloads the `mrdivide` (`/`) operator for `dseries` objects, element by element division (like the `./` Matlab/Octave operator). If both A and B are `dseries` objects, they do not need to be defined over the same time ranges. If A and B are `dseries` objects with T_A and T_B observations and N_A and N_B variables, then N_A must be equal to N_B or 1 and N_B must be equal to N_A or 1. If $T_A = T_B$, `isequal(A.init,B.init)` returns 1 and $N_A = N_B$, then the `mrdivide` operator will compute for each couple (t, n), with $1 \leq t \leq T_A$ and $1 \leq n \leq N_A$, `C.data(t,n)=A.data(t,n)/B.data(t,n)`. If N_B is equal to 1 and $N_A > 1$, the smaller `dseries` object (B) is "broadcast" across the larger `dseries` (A) so that they have compatible shapes. In this case the `mrdivides` operator will divide each variable defined in A by the variable in B, observation per observation. If B is a double scalar, then `mrdivide` will divide all the observations/variables in A by B. If B is a row vector of length N_A, then `mrdivide` will divide all the observations of variable `i` by `B(i)`, for $i = 1, ..., N_A$. If B is a column vector of length T_A, then `mrdivide` will perform a division of all the variables by `B`, element by element.

Example

```
>> ts0 = dseries(rand(3,2))

ts0 is a dseries object:

   | Variable_1 | Variable_2
1Y | 0.72918    | 0.90307
2Y | 0.93756    | 0.21819
3Y | 0.51725    | 0.87322
```

```
>> ts1 = ts0{'Variable_2'};
>> ts0/ts1

ans is a dseries object:

   | divide(Variable_1,Variable_2) | divide(Variable_2,Variable_2)
1Y | 0.80745                       | 1
2Y | 4.2969                        | 1
3Y | 0.59235                       | 1
```

C = `mtimes` (*A*, *B*) [dseries]

Overloads the `mtimes` (`*`) operator for `dseries` objects and the Hadammard product (the `.*` Matlab/Octave operator). If both A and B are `dseries` objects, they do not need to be defined over the same time ranges. If A and B are `dseries` objects with T_A and T_B observations and N_A and N_B variables, then N_A must be equal to N_B or 1 and N_B must be equal to N_A or 1. If $T_A = T_B$, `isequal(A.init,B.init)` returns 1 and $N_A = N_B$, then the `mtimes` operator will compute for each couple (t, n), with $1 \leq t \leq T_A$ and $1 \leq n \leq N_A$, `C.data(t,n)=A.data(t,n)*B.data(t,n)`. If N_B is equal to 1 and $N_A > 1$, the smaller `dseries` object (B) is "broadcast" across the larger `dseries` (A) so that they have compatible shapes, `mtimes` operator will multiply each variable defined in A by the variable in B, observation per observation. If B is a double scalar, then the method `mtimes` will multiply all the observations/variables in A by B. If B is a row vector of length N_A, then the `mtimes` method will multiply all the observations of variable `i` by `B(i)`, for $i = 1, ..., N_A$. If B is a column vector of length T_A, then the `mtimes` method will perform a multiplication of all the variables by `B`, element by element.

C = `ne` (*A*, *B*) [dseries]

Overloads the Matlab/Octave `ne` (equal, `~=`) operator. `dseries` objects A and B must have the same number of observations (say, T) and variables (N). The returned argument is a T by N matrix of zeros and ones. Element (i, j) of C is equal to `1` if and only if observation i for variable j in A and B are not equal.

Example

```
>> ts0 = dseries(2*ones(3,1));
>> ts1 = dseries([2; 0; 2]);
>> ts0~=ts1

ans =

   0
   1
   0
```

h = `plot` (*A*) [dseries]
h = `plot` (*A*, *B*) [dseries]
h = `plot` (*A*[, ...]) [dseries]
h = `plot` (*A*, *B*[, ...]) [dseries]

Overloads Matlab/Octave's `plot` function for `dseries` objects. Returns a Matlab/Octave plot handle, that can be used to modify the properties of the plotted time series. If only one `dseries` object, A, is passed as argument, then the `plot` function will put the associated dates on the x-abscissa. If this `dseries` object contains only one variable, additional arguments can be passed to modify the properties of the plot (as one would do with the Matlab/Octave's version of the `plot` function). If `dseries` object A contains more than one variable, it is not possible to pass these additional arguments and the properties of the plotted time series must be modify using the returned plot handle and the Matlab/Octave `set` function (see example below). If two `dseries` objects, A and B, are passed as input arguments, the `plot` function will plot the variables in A against the variables in B (the number of variables in each object must be the same otherwise an error is issued). Again, if each object contains only one variable additional arguments can be passed to modify the properties of the plotted time series, otherwise the Matlab/Octave `set` command has to be used.

Examples

Define a `dseries` object with two variables (named by default `Variable_1` and `Variable_2`):

```
>> ts = dseries(randn(100,2),'1950Q1');
```

The following command will plot the first variable in `ts`

```
>> plot(ts{'Variable_1'},'-k','linewidth',2);
```

The next command will draw all the variables in `ts` on the same figure:

```
>> h = plot(ts);
```

If one wants to modify the properties of the plotted time series (line style, colours, ...), the `set` function can be used (see Matlab's documentation):

```
>> set(h(1),'-k','linewidth',2);
>> set(h(2),'--r');
```

The follwing command will plot `Variable_1` against `exp(Variable_1)`:

```
>> plot(ts{'Variable_1'},ts{'Variable_1'}.exp(),'ok');
```

Again, the properties can also be modified using the returned plot handle and the `set` function:

```
>> h = plot(ts, ts.exp());
>> set(h(1),'ok');
>> set(h(2),'+r');
```

C = `plus` (*A*, *B*) [dseries]

Overloads the `plus` (`+`) operator for `dseries` objects, element by element addition. If both A and B are `dseries` objects, they do not need to be defined over the same time ranges. If A and B are `dseries` objects with T_A and T_B observations and N_A and N_B variables, then N_A must be equal to N_B or 1 and N_B must be equal to N_A or 1. If $T_A = T_B$, `isequal(A.init,B.init)` returns 1 and $N_A = N_B$, then the `plus` operator will compute for each couple (t, n), with $1 \leq t \leq T_A$ and $1 \leq n \leq N_A$, `C.data(t,n)=A.data(t,n)+B.data(t,n)`. If N_B is equal to 1 and $N_A > 1$, the smaller `dseries` object (B) is "broadcast" across the larger `dseries` (A) so that they have compatible shapes, the `plus` operator will add the variable defined in B to each variable in A. If B is a double scalar, then the method `plus` will add B to all the observations/variables in A. If B is a row vector of length N_A, then the `plus` method will add `B(i)` to all the observations of variable `i`, for $i = 1, ..., N_A$. If B is a column vector of length T_A, then the `plus` method will add `B` to all the variables.

C = `pop` (*A*[, *B*]) [dseries]

Removes variable B from `dseries` object A. By default, if the second argument is not provided, the last variable is removed.

Example

```
>> ts0 = dseries(ones(3,3));
>> ts1 = ts0.pop('Variable_2');

ts1 is a dseries object:

   | Variable_1 | Variable_3
1Y | 1          | 1
2Y | 1          | 1
3Y | 1          | 1
```

B = `qdiff` (*A*) [dseries]
B = `qgrowth` (*A*) [dseries]

Computes quarterly differences or growth rates.

Example

```
>> ts0 = dseries(transpose(1:4),'1950Q1');
>> ts1 = ts0.qdiff()

ts1 is a dseries object:

       | qdiff(Variable_1)
1950Q1 | NaN
1950Q2 | 1
1950Q3 | 1
1950Q4 | 1

>> ts0 = dseries(transpose(1:6),'1950M1');
>> ts1 = ts0.qdiff()

ts1 is a dseries object:

        | qdiff(Variable_1)
1950M1  | NaN
1950M2  | NaN
1950M3  | NaN
1950M4  | 3
1950M5  | 3
1950M6  | 3
```

B = `rename` (*A*,*oldname*,*newname*) [dseries]

Rename variable *oldname* to *newname* in `dseries` object *A*. Returns a `dseries` object.

Example

```
>> ts0 = dseries(ones(2,2));
>> ts1 = ts0.rename('Variable_1','Stinkly')

ts1 is a dseries object:

   | Stinkly | Variable_2
1Y | 1       | 1
2Y | 1       | 1
```

`save (A, basename[, format])` [dseries]

Overloads the Matlab/Octave `save` function and saves `dseries` object *A* to disk. Possible formats are `csv` (this is the default), `m` (Matlab/Octave script), and `mat` (Matlab binary data file). The name of the file without extension is specified by *basename*.

Example

```
>> ts0 = dseries(ones(2,2));
>> ts0.save('ts0');
```

The last command will create a file `ts0.csv` with the following content:

```
,Variable_1,Variable_2
1Y,            1,             1
2Y,            1,             1
```

To create a Matlab/octave script, the following command:

```
>> ts0.save('ts0','m');
```

will produce a file `ts0.m` with the following content:

```
% File created on 14-Nov-2013 12:08:52.

FREQ__ = 1;
INIT__ = ' 1Y';

NAMES__ = {'Variable_1'; 'Variable_2'};
TEX__ = {'Variable_{1}'; 'Variable_{2}'};

Variable_1 = [
              1
              1];

Variable_2 = [
              1
              1];
```

The generated (`csv`, `m`, or `mat`) files can be loaded when instantiating a `dseries` object as explained above.

`B = set_names (A, s1, s2, ...)` [dseries]

Renames variables in `dseries` object *A* and returns a `dseries` object *B* with new names *s1*, *s2*, *s3*, ... The number of input arguments after the first one (`dseries` object *A*) must be equal to `A.vobs` (the number of variables in *A*). *s1* will be the name of the first variable in *B*, *s2* the name of the second variable in *B*, and so on.

Example

```
>> ts0 = dseries(ones(1,3));
>> ts1 = ts0.set_names('Barbibul',[],'Barbouille')

ts1 is a dseries object:

   | Barbibul | Variable_2 | Barbouille
1Y | 1        | 1          | 1
```

`[T, N ] = size (A[, dim])` [dseries]

Overloads the Matlab/Octave's `size` function. Returns the number of observations in `dseries` object *A* (*ie* `A.nobs`) and the number of variables (*ie* `A.vobs`). If a second input argument is passed, the `size` function returns the number of observations if `dim=1` or the number of variables if `dim=2` (for all other values of *dim* an error is issued).

Example

```
>> ts0 = dseries(ones(1,3));
>> ts0.size()

ans =

     1     3
```

`B = tex_rename (A, name, newtexname)` [dseries]

Redefines the tex name of variable *name* to *newtexname* in `dseries` object *A*. Returns a `dseries` object.

`B = uminus (A)` [dseries]

Overloads `uminus` (`-`, unary minus) for `dseries` object.

Example

```
>> ts0 = dseries(1)

ts0 is a dseries object:

   | Variable_1
1Y | 1

>> ts1 = -ts0

ts1 is a dseries object:

   | -Variable_1
1Y | -1
```

`D = vertcat (A, B[, ...])` [dseries]

Overloads the `vertcat` Matlab/Octave method for `dseries` objects. This method is used to append more observations to a `dseries` object. Returns a `dseries` object *D* containing the variables in `dseries` objects passed as inputs. All the input arguments must be `dseries` objects with the same variables defined on *different time ranges.*

Example

```
>> ts0 = dseries(rand(2,2),'1950Q1',{'nifnif';'noufnouf'});
>> ts1 = dseries(rand(2,2),'1950Q3',{'nifnif';'noufnouf'});
>> ts2 = [ts0; ts1]

ts2 is a dseries object:
```

```
               | nifnif   | noufnouf
        1950Q1 | 0.82558  | 0.31852
        1950Q2 | 0.78996  | 0.53406
        1950Q3 | 0.089951 | 0.13629
        1950Q4 | 0.11171  | 0.67865
```

B = `ydiff` (*A*) [dseries]
B = `ygrowth` (*A*) [dseries]

Computes yearly differences or growth rates.

7 Reporting

Dynare provides a simple interface for creating LaTeX reports, comprised of LaTeX tables and TikZ graphs. You can use the report as created through Dynare or pick out the pieces you want for inclusion in your own paper.

Reports are created and modified by calling methods on class objects. The objects are hierarchical, with the following order (from highest to lowest): `Report, Page, Section, Graph/Table/Vspace, Series`. For simplicity of syntax, we abstract away from these classes, allowing you to operate directly on a `Report` object, while maintaining the names of these classes in the `Report` Class methods you will use.

The report is created sequentially, command by command, hence the order of the commands matters. When an object of a certain hierarchy is inserted, all methods will function on that object until an object of equal or greater hierarchy is added. Hence, once you add a `Page` to the report, every time you add a `Section` object, it will be added to this `Page` until another `Page` is added to the report (via [addPage], page 141). This will become more clear with the example at the end of the section.

Options to the methods are passed differently than those to Dynare commands. They take the form of named options to Matlab functions where the arguments come in pairs (*e.g.* `function_name('option_1_name', 'option_1_value', 'option_2_name', 'option_2_value', ...)`, where `option_X_name` is the name of the option while `option_X_value` is the value assigned to that option). The ordering of the option pairs matters only in the unusual case when an option is provided twice (probably erroneously). In this case, the last value passed is the one that is used.

Below, you will see a list of methods available for the Report class and a clarifying example.

`report` *compiler, showDate, filename, margin, marginUnit, orientation, paper, title* [Method on `Report`]

Instantiates a `Report` object.

Options

`compiler, FILENAME`
: The full path to the LaTeX compiler on your system. If this option is not provided, Dynare will try to find the appropriate program to compile LaTeX on your system. Default is system dependent: Windows: the result of `findtexmf --file-type=exe pdflatex`, Mac OS X and Linux: the result of `which pdflatex`

`showDate, BOOLEAN`
: Display the date and time when the report was compiled. Default: `true`

`filename, FILENAME`
: The filename to use when saving this report. Default: `report.tex`

`margin, DOUBLE`
: The margin size. Default: `2.5`

`marginUnit, ‘cm’ | ‘in’`
: Units associated with the margin. Default: `‘cm’`

`orientation, ‘landscape’ | ‘portrait’`
: Paper orientation: Default: `‘portrait’`

`paper, ‘a4’ | ‘letter’`
: Paper size. Default: `‘a4’`

`title, STRING`
: Report Title. Default: `none`

`addPage` *footnote, orientation, paper, title, titleFormat* [Method on `Report`]

Adds a `Page` to the `Report`.

Options

`footnote, STRING`
: A footnote to be included at the bottom of this page. Default: `none`

`orientation, 'landscape' | 'portrait'`
: See [orientation], page 140.

`paper, 'a4' | 'letter'`
: See [paper], page 140.

`title, STRING | CELL_ARRAY_STRINGS`
: With one entry (a `STRING`), the title of the page. With more than one entry (a `CELL_ARRAY_STRINGS`), the title and subtitle(s) of the page. Default: `none`

`titleFormat, STRING | CELL_ARRAY_STRINGS`
: A string representing the LaTeX markup to use on the [title], page 141. The number of cell array entries must be equal to that of the [title], page 141 option. Default: `none`

`addSection` *cols, height* [Method on `Report`]

Adds a `Section` to a `Page`.

Options

`cols, INTEGER`
: The number of columns in the section. Default: `1`

`height, STRING`
: A string to be used with the `\sectionheight` LaTeX command. Default: `'!'`

`addGraph` *data, figname, figDirName, graphSize, showGrid, showLegend, showLegendBox, legendLocation, legendOrientation, legendFontSize, seriesToUse, shade, shadeColor, shadeOpacity, title, xlabel, ylabel, xrange, xTicks, xTickLabels, yrange, showZeroline* [Method on `Report`]

Adds a `Graph` to a `Section`.

Options

`data, dseries`
: The `dseries` that provides the data for the graph. Default: `none`

`figname, STRING`
: The name to use when saving this figure. Default: `[tempname '.tex']`

`figDirName, STRING`
: The name of the folder in which to store this figure. Default: `tmpFigDir`

`graphSize, NUMERICAL_VECTOR`
: The width and height to be passed to the third and fourth elements of the array passed to the `'Position'` option of Matlab's `figure` command, passed as a vector of size 2. Default: Matlab sets width and height

`showGrid, BOOLEAN`
: Whether or not to display the minor grid on the graph. Default: `true`

`showLegend, BOOLEAN`
: Whether or not to display the legend. Default: `false`

`showLegendBox, BOOLEAN`
: Whether or not to display a box around the legend. Default: `false`

`legendLocation, 'North' | 'South' | 'East' | 'West' | 'NorthEast' | 'SouthEast' | 'NorthWest' | 'SouthWest' | 'NorthOutside' | 'SouthOutside' | 'EastOutside' | 'WestOutside' | 'NorthEastOutside' | 'SouthEastOutside' | 'NorthWestOutside' | 'SouthWestOutside' | 'Best' | 'BestOutside'`
: Where to place the legend in the graph. NB: some of these are not available under Octave. Default: `'SouthEast'`

`legendOrientation, 'vertical' | 'horizontal'`
: Orientation of the legend. Default: `'horizontal'`

`legendFontSize, DOUBLE`
: The font size for legend entries. Default: `8`

`seriesToUse, CELL_ARRAY_STRINGS`
: The names of the series contained in the `dseries` provided to the [data], page 141 option. If empty, use all series provided to [data], page 141 option. Default: `empty`

`shade, dates`
: The date range showing the portion of the graph that should be shaded. Default: `none`

`shadeColor, MATLAB_COLOR_NAME`
: The color to use in the shaded portion of the graph. Default: `'green'`

`shadeOpacity, DOUBLE`
: The opacity of the shaded area, must be in $[0, 1]$. Default: `.2`

`title, STRING`
: Title for the graph. Default: `none`

`xlabel, STRING`
: The x-axis label. Default: `none`

`ylabel, STRING`
: The y-axis label. Default: `none`

`xrange, dates`
: The boundary on the x-axis to display in the graph. Default: all

`xTicks, NUMERICAL_VECTOR`
: Used only in conjunction with [xTickLabels], page 142, this option denotes the numerical position of the label along the x-axis. The positions begin at 1. Default: set by Matlab/Octave.

`xTickLabels, CELL_ARRAY_STRINGS`
: The labels to be mapped to the ticks provided by [xTicks], page 142. Default: the dates of the `dseries`

`yrange, NUMERICAL_VECTOR`
: The boundary on the y-axis to display in the graph, represented as a `NUMERICAL_VECTOR` of size 2, with the first entry less than the second entry. Default: all

`showZeroline, BOOLEAN`
: Display a solid black line at $y = 0$. Default: `false`

`addTable` *data, showHlines, precision, range, seriesToUse, title, titleSize, vlineAfter, vlineAfterEndOfPeriod, showVlines* [Method on `Report`]

Adds a `Table` to a `Section`.

Options

`data, dseries`
: See [data], page 141.

`showHlines, BOOLEAN`
: Whether or not to show horizontal lines separating the rows. Default: `false`

`precision, INTEGER`
: The number of decimal places to report in the table data. Default: `1`

`range, dates`
: The date range of the data to be displayed. Default: `all`

`seriesToUse, CELL_ARRAY_STRINGS`
: See [seriesToUse], page 142.

`title, STRING`
: Title for the table. Default: `none`

`titleSize, STRING`
: LaTeX string representing the size of the table title. Default: `large`

`vlineAfter, dates | CELL_ARRAY_DATES`
: Show a vertical line after the specified date (or dates if a cell array of dates is passed). Default: `empty`

`vlineAfterEndOfPeriod, BOOLEAN`
: Show a vertical line after the end of every period (*i.e.* after every year, after the fourth quarter, etc.). Default: `false`

`showVlines, BOOLEAN`
: Whether or not to show vertical lines separating the columns. Default: `false`

`addSeries` *data, graphLineColor, graphLineStyle, graphLineWidth, graphMarker, graphMarkerEdgeColor, graphMarkerFaceColor, graphMarkerSize, tableDataRhs, tableRowColor, tableShowMarkers, tableAlignRight, tableNegColor, tablePosColor, tableSubSectionHeader, zerotol* [Method on `Report`]

Adds a `Series` to a `Graph` or a `Table`.

Options

`data, dseries`
: See [data], page 141.

`graphLineColor, MATLAB_COLOR`
: Color to use for the series in a graph. Default: `‘k’`

`graphLineStyle, ‘none’ | ‘-’ | ‘--’ | ‘:’ | ‘-.’`
: Line style for this series in a graph. Default: `’-’`

`graphLineWidth DOUBLE`
: Line width for this series in a graph. Default: `0.5`

`graphMarker, ‘+’ | ‘o’ | ‘*’ | ‘.’ | ‘x’ | ‘s’ | ‘square’ | ‘d’ | ‘diamond’ | ‘^’ | ‘v’ | ‘>’ | ‘<’ | ‘p’ | ‘pentagram’ | ‘h’ | ‘hexagram’ | ‘none’`
: The Marker to use on this series in a graph. Default: `none`

`graphMarkerEdgeColor, MATLAB_COLOR`
: The edge color of the graph marker. Default: `‘auto’`

`graphMarkerFaceColor, MATLAB_COLOR`
: The face color of the graph marker. Default: `‘auto’`

`graphMarkerSize, DOUBLE`
: The size of the graph marker. Default: `6`

`tableDataRhs, dseries`
: A series to be added to the right of the current series. Usefull for displaying aggregate data for a series. *e.g* if the series is quarterly `tableDataRhs` could point to the yearly averages of the quarterly series. This would cause quarterly data to be displayed followed by annual data. Default: `empty`

`tableRowColor, STRING`
: The color that you want the row to be. Predefined values include `LightCyan` and `Gray`. Default: `white`.

`tableShowMarkers, BOOLEAN`
: In a Table, if `true`, surround each cell with brackets and color it according to [tableNegColor], page 144 and [tablePosColor], page 144. No effect for graphs. Default: `false`

`tableAlignRight, BOOLEAN`
: Whether or not to align the series name to the right of the cell. Default: `false`

`tableMarkerLimit, DOUBLE`
: For values less than $-1 *$ `tableMarkerLimit`, mark the cell with the color denoted by [tableNegColor], page 144. For those greater than `tableMarkerLimit`, mark the cell with the color denoted by [tablePosColor], page 144. Default: `1e-4`

`tableNegColor, LATEX_COLOR`
: The color to use when marking Table data that is less than zero. Default: `'red'`

`tablePosColor, LATEX_COLOR`
: The color to use when marking Table data that is greater than zero. Default: `'blue'`

`tableSubSectionHeader, STRING`
: A header for a subsection of the table. No data will be associated with it. It is equivalent to adding an empty series with a name. Default: `''`

`zerotol, DOUBLE`
: The zero tolerance. Anything smaller than `zerotol` and larger than `-zerotol` will be set to zero before being graphed. Default: $1e-6$

`addVspace` *hline, number* [Method on `Report`]

Adds a `Vspace` (vertical space) to a `Section`.

Options

`hline, INTEGER`
: The number of horizontal lines to be inserted. Default: `0`

`number, INTEGER`
: The number of new lines to be inserted. Default: `1`

`write` [Method on `Report`]

Writes the LaTeX representation of this `Report`, saving it to the file specified by [filename], page 140.

`compile` *compiler* [Method on `Report`]

Compiles the report written by [write], page 144 into a `pdf` file. If the report has not already been written (determined by the existence of the file specified by [filename], page 140, [write], page 144 is called. optionshead

`compiler, FILENAME`
: Like [compiler], page 140, except will not overwrite the value of `compiler` contained in the report object. Hence, passing the value here is useful for using different LaTeX compilers or just for passing the value at the last minute.

Example

The following code creates a one page report. The first part of the page contains two graphs displayed across two columns and one row. The bottom of the page displays a centered table.

```
%% Create dseries
dsq = dseries('quarterly.csv');
dsa = dseries('annual.csv');
dsca = dseries('annual_control.csv');

%% Report
rep = report();

%% Page 1
rep = rep.addPage('title', 'My Page Title', 'titleFormat', '\large\bfseries');

% Section 1
rep = rep.addSection('cols', 2);
rep = rep.addGraph('title', 'Graph (1,1)', 'showLegend', true, ...
                   'xrange', dates('2007q1'):dates('2013q4'), ...
                   'shade', dates('2012q2'):dates('2013q4'));
rep = rep.addSeries('data', dsq{'SERIES1'}, 'color', 'b', ...
                    'graphLineWidth', 1);
rep = rep.addSeries('data', dsq{'SERIES2'}, 'color', 'g', ...
                    'graphLineStyle', '--', 'graphLineWidth', 1.5);
rep = rep.addGraph('title', 'Graph (1,2)', 'showLegend', true, ...
                   'xrange', dates('2007q1'):dates('2013q4'), ...
                   'shade', dates('2012q2'):dates('2013q4'));
rep = rep.addSeries('data', dsq{'SERIES3'}, 'color', 'b', ...
                    'graphLineWidth', 1);
rep = rep.addSeries('data', dsq{'SERIES4'}, 'color', 'g', ...
                    'graphLineStyle', '--', 'graphLineWidth', 1.5);

% Section 2
rep = rep.addSection();
rep = rep.addTable('title', 'Table 1', ...
                   'range', dates('2012Y'):dates('2014Y'));
shortNames = {'US', 'EU'};
longNames  = {'United States', 'Euro Area'};
for i=1:length(shortNames)
    rep = rep.addSeries('data', dsa{['GDP_' shortNames{i}]});
    delta = dsa{['GDP_' shortNames{i}]}-dsca{['GDP_' shortNames{i}]};
    delta = delta.tex_rename('$\Delta$');
    rep = rep.addSeries('data', delta, ...
                        'tableShowMarkers', true, ...
                        'tableAlignRight', true);
end

%% Write & Compile Report
```

```
    rep.write();
    rep.compile();
```

8 Examples

Dynare comes with a database of example `.mod` files, which are designed to show a broad range of Dynare features, and are taken from academic papers for most of them. You should have these files in the `examples` subdirectory of your distribution.

Here is a short list of the examples included. For a more complete description, please refer to the comments inside the files themselves.

`ramst.mod`
: An elementary real business cycle (RBC) model, simulated in a deterministic setup.

`example1.mod`
`example2.mod`
: Two examples of a small RBC model in a stochastic setup, presented in *Collard (2001)* (see the file `guide.pdf` which comes with Dynare).

`example3.mod`
: A small RBC model in a stochastic setup, presented in *Collard (2001)*. The steady state is solved analytically using the `steady_state_model` block (see [steady_state_model], page 34).

`fs2000.mod`
: A cash in advance model, estimated by *Schorfheide (2000)*. The file shows how to use Dynare for estimation.

`fs2000_nonstationary.mod`
: The same model than `fs2000.mod`, but written in non-stationary form. Detrending of the equations is done by Dynare.

`bkk.mod`
: Multi-country RBC model with time to build, presented in *Backus, Kehoe and Kydland (1992)*. The file shows how to use Dynare's macro-processor.

`agtrend.mod`
: Small open economy RBC model with shocks to the growth trend, presented in *Aguiar and Gopinath (2004)*.

`NK_baseline.mod`
: Baseline New Keynesian Model estimated in *Fernández-Villaverde (2010)*. It demonstrates how to use an explicit steady state file to update parameters and call a numerical solver.

9 Dynare misc commands

`internals` *FLAG ROUTINENAME*[*.m*]|*MODFILENAME* [MATLAB/Octave command]

Depending on the value of *FLAG*, the `internals` command can be used to run unitary tests specific to a Matlab/Octave routine (if available), to display documentation about a Matlab/Octave routine, or to extract some informations about the state of Dynare.

Flags

`--test` Performs the unitary test associated to *ROUTINENAME* (if this routine exists and if the matalab/octave `m` file has unitary test sections).

Example

```
>> internals --test ROUTINENAME
```

if `routine.m` is not in the current directory, the full path has to be given:

```
>> internals --test ../matlab/fr/ROUTINENAME
```

`--info` Prints on screen the internal documentation of *ROUTINENAME* (if this routine exists and if this routine has a texinfo internal documentation header). The path to *ROUTINENAME* has to be provided, if the routine is not in the current directory.

Example

```
>> internals --doc ../matlab/fr/ROUTINENAME
```

At this time, will work properly for only a small number of routines. At the top of the (available) Matlab/Octave routines a commented block for the internal documentation is written in the GNU texinfo documentation format. This block is processed by calling texinfo from MATLAB. Consequently, texinfo has to be installed on your machine.

`--display-mh-history`

Displays information about the previously saved MCMC draws generated by a mod file named *MODFILENAME*. This file must be in the current directory.

Example

```
>> internals --display-mh-history MODFILENAME
```

`--load-mh-history`

Loads into the Matlab/Octave's workspace informations about the previously saved MCMC draws generated by a mod file named *MODFILENAME*.

Example

```
>> internals --load-mh-history MODFILENAME
```

This will create a structure called `mcmc_informations` (in the workspace) with the following fields:

`Nblck` The number of MCMC chains.

`InitialParameters`

A `Nblck*n`, where `n` is the number of estimated parameters, array of doubles. Initial state of the MCMC.

`LastParameters`

A `Nblck*n`, where `n` is the number of estimated parameters, array of doubles. Current state of the MCMC.

`InitialLogPost`
: A `Nblck*1` array of doubles. Initial value of the posterior kernel.

`LastLogPost`
: A `Nblck*1` array of doubles. Current value of the posterior kernel.

`InitialSeeds`
: A `1*Nblck` structure array. Initial state of the random number generator.

`LastSeeds`
: A `1*Nblck` structure array. Current state of the random number generator.

`AcceptanceRatio`
: A `1*Nblck` array of doubles. Current acceptance ratios.

10 Bibliography

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Command and Function Index

Variable Index