

# Dynare

---

A program for solving rational expectation models  
Edition 2.5.1 for Dynare version 2.5.2  
January 2003

Michel Juillard, CEPREMAP and University Paris 8

---

Copyright © 1996, 2003 Michel Juillard.

This is the second edition of the Dynare documentation, and is consistent with version 2.5.2 of Dynare.

Permission is granted to make and distribute verbatim copies of this manual provided the copyright notice and this permission notice are preserved on all copies.

Permission is granted to copy and distribute modified versions of this manual under the conditions for verbatim copying, provided that the entire resulting derived work is distributed under the terms of a permission notice identical to this one.

Permission is granted to copy and distribute translations of this manual into another language, under the same conditions as for modified versions.

Portions of this document have been adapted from the **Octave** manual, published by the John W. Eaton.

# Table of Contents

<b>Preface</b> .....	<b>ii</b>
<b>1 Introduction</b> .....	<b>iii</b>
1.1 Software requirements .....	iii
1.2 Installation .....	iii
1.2.1 Installing the GAUSS version .....	iii
1.2.2 Installing the Matlab version .....	iii
1.2.3 Installing the Scilab version .....	iv
1.3 Executing Dynare .....	iv
<b>2 Model file commands</b> .....	<b>v</b>
2.1 General declarations .....	v
2.1.1 periods .....	v
2.1.2 var .....	v
2.1.3 varexo .....	v
2.1.4 parameters .....	v
2.2 Model declaration .....	vi
2.2.1 model .....	vi
2.3 Initial and terminal conditions .....	vi
2.3.1 initval .....	vii
2.3.2 endval .....	viii
2.4 Shocks on exogenous variables .....	ix
2.4.1 shocks .....	ix
2.4.2 Sigma_e .....	x
2.5 Computations and simulations .....	xi
2.5.1 steady .....	xi
2.5.2 check .....	xi
2.5.3 simul .....	xi
2.5.4 stoch_simul .....	xii
2.6 Displaying and saving results .....	xiii
2.6.1 rplot .....	xiii
2.6.2 dynatype .....	xiii
2.6.3 dynasave .....	xiii
<b>3 Examples</b> .....	<b>xv</b>
<b>4 Bibliography</b> .....	<b>xvi</b>

## Preface

Dynare is a pre-processor and a collection of GAUSS, MATLAB or SCILAB routines which solve non-linear models with forward looking variables. It is the result of research carried at CEPREMAP by several people (see Laffargue, 1990, Boucekkine, 1995, and Juillard, 1996, Collard and Juillard 2001a and 2001b). Although it can be put to other use, Dynare has been built in order to study the transitory dynamics of non-linear models with consistent expectations.

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, Dynare uses a Newton-type algorithm, first proposed by Laffargue (1990), instead of a first order technique like the one proposed by Fair and Taylor (1983), and used in earlier generation simulation programs. We believe this approach to be in general both faster and more robust. The details of the algorithm used in Dynare can be found in Juillard (1996).

In a stochastic context, Dynare computes one or several simulations corresponding to a random draw of the shocks. Starting with version 2.3 (not available for GAUSS), Dynare uses a second order Taylor approximation of the expectation functions (see Judd, 1996, Collard and Juillard, 2001a, 2001b, and Schmitt-Grohe and Uribe, 2002).

# 1 Introduction

In practice, the simulation process 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 GAUSS, MATLAB or SCILAB instructions are generated; in the second step, the program actually computes the simulation. Both steps are triggered by a single keyword: **dynare**.

## 1.1 Software requirements

This version of Dynare works only under Windows 95/98/NT/2000. For a Unix version, please, write me.

The Gauss version of Dynare has been written with Gauss version 3.2. It most likely doesn't work with previous versions.

The Matlab version has been written with Matlab 6.1.

The Scilab version has been tested with Scilab 2.6 and 2.7 (CVS 7/30/2002).

## 1.2 Installation

In case of update from a previous version, it is a good idea to copy the old version in a backup directory so as to be able to revert to it in case of problems. None of the previous files are usefull anymore, so you are strongly encouraged to remove them from directory 'c:\dynare'.

Unpack the zip file in the directory 'c:\' (If you want to use another directory, see below). The Gauss version is automatically installed in 'c:\dynare\gauss', the Matlab version in 'c:\dynare\matlab' and the Scilab version in 'c:\dynare\scilab'.

### 1.2.1 Installing the GAUSS version

If you had any previous version of Dynare, use the Gauss editor or any text editor to remove all references to it from the library file 'user.lcg'.

After unpacking the archive, start the Gauss program and type the following:

```
library pgraph
lib user c:\dynare\gauss\dynare.src
lib user c:\dynare\gauss\dynare1.src
lib user c:\dynare\gauss\dynare2.src
lib user c:\dynare\gauss\dynare3.src
```

If you installed Dynare for Gauss in a directory different from 'c:\dynare\gauss', change the above instructions accordingly and edit the following line in 'dynare.src'

```
declare string PARSER = "c:\\dynare\\gauss\dynare_g ";
```

### 1.2.2 Installing the Matlab version

After unpacking the archive, start the Matlab program and use the menu File/Set path to add 'c:\dynare\matlab' to the list of your paths.

If you installed Dynare for Matlab in a directory different from 'c:\dynare\matlab', change the above instructions accordingly and edit the following line in 'dynare.m'

```
command = ['c:\dynare\matlab\dynare_m ' x];
```

### 1.2.3 Installing the Scilab version

In the top directory of your Scilab distribution (identified by the presence of the 'scilab.star' file), create a file 'scilab.ini' containing

```
load('c:/dynare/scilab/lib');
```

or add this lines to your 'scilab.ini' file if it already exists. Alternatively, the line can be added to the file 'scilab.star', after similar statements. This second solution has the advantage of keeping access to Dynare even after the command `clear`.

If you installed Dynare for Scilab in a directory different from 'c:\dynare\scilab', change the above instructions accordingly and edit the following line in 'dynare.sci'

```
command = 'c:\dynare\scilab\dynare_s '+fname;
```

Then, restart Scilab and run the command `uplib()`.

## 1.3 Executing Dynare

**dynare** 'filename'['.mod'] [Command]

**dynare** executes instruction included in 'filename.mod'. 'filename.mod' is the name of the model file containing the model and the processing instructions.

In Gauss, **dynare** creates an intermediary file <filename>.gau with the instructions for the simulations. The Gauss version still accepts the former '.mdl' extension, but it is now deprecated.

In Matlab, **dynare** creates three intermediary files:

- <filename>.m with the instructions for the simulations
- <filename>\_ff.m with the dynamic model equations
- <filename>\_fff.m with the long run static model equations

In Scilab, **dynare** creates three intermediary files:

- <filename>.sci with the instructions for the simulations
- <filename>\_ff.sci with the dynamic model equations
- <filename>\_fff.sci with the long run static model equations

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

#### Examples

```
dynare ramst
```

or

```
dynare ramst.mod
```

## 2 Model file commands

### 2.1 General declarations

#### 2.1.1 periods

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

Set 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;
```

#### 2.1.2 var

**var** *VARIABLE\_LIST*; [Command]  
*VARIABLE\_LIST* : *VARIABLE\_NAME* [,] *VARIABLE\_NAME* [,] ...

This required command declares the endogenous variables in the model. The variable names must start with a letter and can't contain the following characters : ()+/\*/^=!:;@#. or accentuated characters.

In GAUSS, setting *\_longname* = 1 allows the use of more than 8 characters in the variable names and makes a distinction between lower and upper case letters.

**Example**

```
var c gnp q1 q2;
```

#### 2.1.3 varexo

**varexo** *VARIABLE\_LIST*; [Commands]  
*VARIABLE\_LIST* : *VARIABLE\_NAME* [,] *VARIABLE\_NAME* [,] ...

This optional command declares the exogenous variables in the model. See command **var** for the syntax of variable names.

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

**Example**

```
varexo m gov;
```

## 2.1.4 parameters

**parameters** *PARAMETER\_LIST*; [Commands]  
*PARAMETER\_LIST* : *PARAMETER\_NAME* [,] *PARAMETER\_NAME* [,] ...

This optional command declares parameters used in the model, in variable initialization or in shock declarations. The parameters must then be assigned values using standard syntax of underlying matrix programming language. Be careful not to use names reserved by DYNARE or the package.

### Example

```
parameters alpha, bet;

alpha = 0.3;
bet = sqrt(2);
```

## 2.2 Model declaration

### 2.2.1 model

**model;** *EQUATION\_LIST* **end;** [Commands]

The equations of the model are written in a block delimited by **model;** and **end;**.

There must be as many equations as there are endogenous variables in the model. The lead and lag of the variables are written in parenthesis immediately after the variable name. Leads or lags of more than one period are allowed. All the functions available in GAUSS, MATLAB or SCILAB, respectively, are recognized. Each equation must be terminated by a semicolon (;).

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.

### Example 1

```
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

```
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;
```



## 2.3 Initial and terminal conditions

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 `shock`(see next section).

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

### 2.3.1 `initval`

**`initval`;**

[Command]

```
INITIALIZATION_STATEMENT;
[INITIALIZATION_STATEMENT]
...
end;
```

INITIALIZATION\_STATEMENT : VARIABLE\_NAME = EXPRESSION;

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

The required `initval`; ... `end`; block serves two purposes. It set the initial and, possibly, terminal conditions for the simulation and provides numerical initialization for various computation tasks (`steady`, `simul`, `stoch_simul`).

Theoretically, initial conditions are only necessary for lagged variables. However, as `initval` provides also numerical initialization, it is necessary to provide values for all variables in the model.

When the `initval` block is followed by the command `steady`, it is not necessary to provide exact initialization values for the endogenous variables. `steady` will use the values provided in the `initval` block as initial guess in the non-linear equation solver and computes exact values for the endogenous variables at the steady state. The steady state is defined by keeping constant the value of the exogenous variables.

#### Example

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

steady;
```

### 2.3.2 endval

**endval;** [Command]

```
INITIALIZATION_STATEMENT;
[INITIALIZATION_STATEMENT]
```

```
...
```

```
end;
```

```
INITIALIZATION_STATEMENT : VARIABLE_NAME = EXPRESSION;
```

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

The optional **endval; ... end;** block serves two purposes. It set the terminal conditions for the simulation with the LBJ algorithm, when those differ from the initial conditions. When it is the case, the **endval** block also provides the numerical initialization for various computation tasks (**steady**, **simul**), starting in period 1.

Theoretically, terminal conditions are required in the LBJ algorithm only for forward variables. However, as **endval** provides also numerical initialization, it is necessary to provide values for all variables in the model.

When the **endval** block is followed by the command **steady**, it is not necessary to provide exact values for the endogenous variables. **steady** will use the values provided in the **endval** block as initial guess in the non-linear equation solver and computes exact values for the endogenous variables at the steady state. The steady state is defined by keeping constant the value of the exogenous variables.

#### 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  $x=2$ .

## 2.4 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 is 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**. Note that, starting with version 2.5.2, the direct specification of the **internal** matrix *Sigma\_e*-, prone to errors, is discouraged.

### 2.4.1 shocks

**shocks;** [Command]

```
SHOCK STATEMENT
[SHOCK STATEMENT]
...
end;
```

**In deterministic context:**  
 SHOCK STATEMENT:  
**var** VARIABLE NAME;  
**periods** PERIOD STATEMENT;  
**values** VALUE STATEMENT;

PERIOD STATEMENT: NUMBER[:NUMBER] or LIST OF NUMBERS  
 VALUE STATEMENT: EXPRESSION

The VALUE STATEMENT must be a valid expression returning a scalar value or a vector when the shock applies to a range of periods and takes a different values in each of these periods.

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

#### Example

```

shocks;
var e;
periods 1;
values 0.5;
var u;
periods 4:5;
values 0;
end;

```

**In stochastic context, syntax 1:**

SHOCK STATEMENT:

**var** VARIABLE NAME[,VARIABLE NAME] = expression ;

For stochastic simulations (available only in the MATLAB or SCILAB versions), the `shocks` block specifies the non zero elements of the covariance matrix of the shocks.

**Example**

```

shocks;
var e = 0.000081;
var e,u = phi*0.009*0.009;
var u = 0.000081;
end;

```

**In stochastic context, syntax 2:**

SHOCK STATEMENT:

**var** VARIABLE NAME;

**stderr** expression;

Alternatively, when the shocks are uncorrelated, it is possible to specify only the standard errors with a slightly different syntax (for consistency with previous versions).

**Example**

```

shocks;
var e;
stderr 0.009;
var u;
stderr 0.009;
end;

```

## 2.4.2 Sigma\_e

**Sigma\_e** [Command]

SIGMA\_E = [ MATRIX ELEMENT [,] MATRIX ELEMENT [,] ... ; MATRIX ELEMENT ... ];

MATRIX ELEMENT = (expression) or NUMBER

The matrix of variance-covariance of the shocks can be directly specified as a upper (or lower) triangular matrix. Dynare builds the corresponding symmetrix matrix. Each row of the triangular matrix, except the last one, must be terminated by a semi-colon

’;’. For a given element, an expression using predefined parameters is allowed but must be placed between parentheses. THE ORDER OF THE COVARIANCES IN THE MATRIX IS THE SAME AS THE ONE USED IN THE VAREXO DECLARATION. NOTE: In previous versions, it was possible to directly set Dynare’s internal covariance matrix *Sigma\_e*. This is still possible for compatibility with older .mod files, but STRONGLY DISCOURAGED as too prone to error. When setting *Sigma\_e* directly, the order of the exogenous shocks is the ALPHABETICAL order of their names.

#### Example

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

where the variance of *u* is 0.81, the variance of *e*, 0.000081, and the correlation between *e* and *u* is *phi*.

## 2.5 Computations and simulations

DYNARE has special commands for the computation of the static equilibrium of the model (**steady**), of the eigenvalues of the linearized model (**check**) for dynamics local analysis, of a deterministic simulation (**simul**) and for stochastic simulations (**stoch\_simul**).

### 2.5.1 steady

**steady;** [Command]

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.

#### Examples

See **initval** and **endval**.

### 2.5.2 check

**check;** [Command]

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.

### 2.5.3 simul

**simul;** [Command]  
 Triggers the computation of a deterministic simulation of the model for the number of periods set in the **periods** instruction.

### 2.5.4 stoch\_simul

**stoch\_simul**[(**OPTIONS**)] [*LIST OF VARIABLES*]; [Command]  
 (available currently only in the Matlab and the Scilab versions)  
**OPTIONS**:

**DR\_ALGO** = [0,1]  
 Specify the algorithm used for computing the quadratic approximation of the decision rules:

0: uses a “pure” perturbation approach as in Schmitt-Grohe and Uribe (2002) (default)  
 1: moves the point around which the Taylor expansion is computed toward the means of the distribution as in Collard and Juillard (2001)

**AR** = Integer  
 Order of autocorrelation coefficients to compute and to print (default = 5)

**NOCORR** Doesn’t print the correlation matrix (default = PRINT)

**DROP** = Integer  
 Number of points dropped at the beginning of simulation before computing the summary statistics (default = 100)

**IRF** = Integer  
 Number of periods on which to compute the IRFs (default = 40)

**NOFUNCTIONS**  
 Doesn’t print the coefficients of the approximated solution

**LINEAR** Indicates that the original model is linear

**NOMOMENTS**  
 Doesn’t print moments of the endogenous variables

**ORDER** = [1,2]  
 Order of Taylor approximation (default = 2)

**REPLIC** = Integer  
 Number of simulated series used to compute the IRFs (default = 1, if order = 1, and 50 otherwise)

When a **LIST OF VARIABLES** is specified, results are displayed only for these variables.

`stoch_simul` computes a Taylor approximation of the decision and transition functions for the model, 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 covariance matrix of the shocks is specified either with the `shocks` command or with the `Sigma_e` command.

#### 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(linear,irf=60) y k;
```

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

## 2.6 Displaying and saving results

DYNARE has comments to plot the results of a simulation and to save the results.

### 2.6.1 `rplot`

**RPLOT** *VARIABLE*; [command]  
Plots a variable

### 2.6.2 `dynatype`

**DYNATYPE** (*FNAME*) [*VARLIST*]; [command]

or

**DYNATYPE** *FNAME*;

**DYNATYPE** prints the variables included in *VARLIST* in a text file named *FNAME*. If *VARLIST* is missing, all endogenous variables are printed.

### 2.6.3 dynasave

**DYNASAVE** (*FNAME*) [*VARLIST*]; [command]

or

**DYNASAVE** *FNAME*;

**DYNASAVE** saves the variables included in **VARLIST** in a binary file named **FNAME**. If **VARLIST** is missing, all endogenous variables are saved.

In Matlab, variables saved with the **DYNASAVE** command can be retrieved by the **MATLAB** command **LOAD -MAT FNAME**.



## 3 Examples

Fabrice Collard (GREMAQ, University of Toulouse) has written a guide to stochastic simulations with DYNARE entitled "Dynare in Practice" which is in ‘`guide.pdf`’.

## 4 Bibliography

- Boucekkine, R. (1995) “An alternative methodology for solving nonlinear forward-looking models,” *Journal of Economic Dynamics and Control*, 19, 711–734.
- Collard, F. and M. Juillard (2001a) “Accuracy of stochastic perturbation methods: The case of asset pricing models,” *Journal of Economic Dynamics and Control*, 25, 979–999.
- Collard, F. and M. Juillard (2001a) “A Higher-Order Taylor Expansion Approach to Simulation of Stochastic Forward-Looking Models with an Application to a Non-Linear Phillips Curve,” *Computational Economics*, 17, 125–139.
- Fair, R.C and J. Taylor (1983) “Solution and Maximum Likelihood Estimation of Dynamic Nonlinear Rational Expectation Models.” *Econometrica*, 51, 1169–85.
- Judd, K.L. (1996) “Approximation, Perturbation, and Projection Methods in Economic Analysis,” in H.M. Amman, D.A. Kendrick and J. Rust (eds.) *Handbook of Computational Economics*. Amsterdam: North Holland Press, pp. 511–585.
- Juillard, M. (1996) DYNARE: A program for the resolution and simulation of dynamic models with forward variables through the use of a relaxation algorithm. Paris: CEPREMAP, Couverture Orange No. 9602.
- Laffargue, J.-P. (1990) “Rsolution d’un modle macroeconomique avec anticipations rationnelles,” *Annales d’Economie et Statistique*, 17, 97–119.
- Schmitt-Grohe, S. and M. Uribe (2002) Solving Dynamic General Equilibrium Models Using a Second-Order Approximation to the Policy Function. Working Paper, Rutgers University.