

# The Dynare Macro-processor

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# Outline

- 1 Overview
- 2 Syntax
- 3 Typical usages

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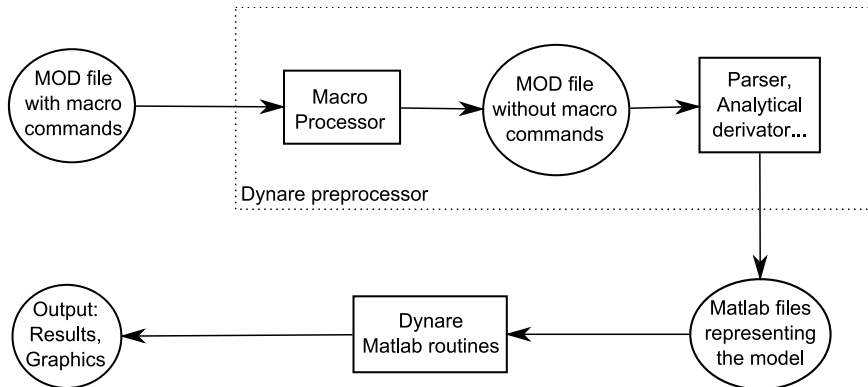
# Motivation

- The **Dynare language** (used in MOD files) is well suited for many economic models
- However, as such, it lacks some useful features, such as:
  - ▶ a loop mechanism for automatically repeating similar blocks of equations (such as in multi-country models)
  - ▶ an operator for indexed sums or products inside equations
  - ▶ a mechanism for splitting large MOD files in smaller modular files
  - ▶ the possibility of conditionally including some equations or some runtime commands
- The **Dynare Macro-language** was specifically designed to address these issues
- Being flexible and fairly general, it can also be helpful in other situations

# Design of the macro-language

- The Dynare Macro-language provides a new set of **macro-commands** which can be inserted inside MOD files
- Language features include:
  - ▶ file inclusion
  - ▶ loops (*for* structure)
  - ▶ conditional inclusion (*if/else* structures)
  - ▶ expression substitution
- The macro-processor transforms a MOD file with macro-commands into a MOD file without macro-commands (doing text 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)

# Design of Dynare



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# Macro Directives

- Directives begin with an at-sign followed by a pound sign (@#)
- A directive produces no output, but gives instructions to the macro-processor
- Main directives are:
  - ▶ file inclusion: `@#include`
  - ▶ definition a variable of the macro-processor: `@#define`
  - ▶ conditional statements (`@#if/@#ifdef/@#ifndef/@#else/@#endif`)
  - ▶ loop statements (`@#for/@#endfor`)
- 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.



# Variables

- The macro processor maintains its own list of variables (distinct of model variables and of MATLAB/Octave variables)
- Macro-variables can be of four types:
  - ▶ integer
  - ▶ character string (declared between *double* quotes)
  - ▶ array of integers
  - ▶ array of strings
- No boolean type:
  - ▶ false is represented by integer zero
  - ▶ true is any non-null integer

# Macro-expressions (1/2)

It is possible to construct macro-expressions, using standard operators.

## Operators on integers

- arithmetic operators: `+` `-` `*` `/`
- comparison operators: `<` `>` `<=` `>=` `==` `!=`
- logical operators: `&&` `||` `!`
- integer ranges: `1:4` is equivalent to integer array `[1,2,3,4]`

## Operators on character strings

- comparison operators: `==` `!=`
- concatenation: `+`
- extraction of substrings: if `s` is a string, then one can write `s[3]` or `s[4:6]`

# Macro-expressions (2/2)

## Operators on arrays

- dereferencing: if  $v$  is an array, then  $v[2]$  is its 2<sup>nd</sup> element
- concatenation:  $+$
- 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  
(example: `"b" in ["a", "b", "c"]` returns 1)

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

# Define directive

The value of a macro-variable can be defined with the `@#define` directive.

## Syntax

```
@#define variable_name = expression
```

## Examples

```
@#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)
```

# Expression substitution

## Dummy example

### Before macro-processing

```
@#define x = [ "B", "C" ]  
@#define i = 2
```

```
model;  
    A = @{x[i]};  
end;
```

### After macro-processing

```
model;  
    A = C;  
end;
```

# Inclusion directive (1/2)

- This directive simply includes the content of another file at the place where it is inserted.

## Syntax

```
@#include "filename"
```

## Example

```
@#include "modelcomponent.mod"
```

- 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)

## Inclusion directive (2/2)

- The filename can be given by a macro-variable (useful in loops):

### Example with variable

```
@#define fname = "modelcomponent.mod"  
@#include fname
```

- Files to include are searched for in current directory. Other directories can be added with `@includepath` directive, `-I` command line option or `[paths]` section in config file.

# Loop directive

## Syntax

```
@#for variable_name in array_expr  
    loop_body  
@#endfor
```

## Example: before macro-processing

```
model;  
@#for country in [ "home", "foreign" ]  
    GDP_{country} = A * K_{country}^a * L_{country}^{(1-a)};  
@#endfor  
end;
```

## Example: after macro-processing

```
model;  
    GDP_home = A * K_home^a * L_home^{(1-a)};  
    GDP_foreign = A * K_foreign^a * L_foreign^{(1-a)};  
end;
```



# Conditional inclusion directives (1/2)

## Syntax 1

```
@#if integer_expr  
    body included if expr != 0  
@#endif
```

## Syntax 2

```
@#if integer_expr  
    body included if expr != 0  
@#else  
    body included if expr == 0  
@#endif
```

## Example: alternative monetary policy rules

```
@#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;
```

## Conditional inclusion directives (2/2)

### Syntax 1

```
@#ifdef variable_name  
    body included if variable  
defined  
@#endif
```

### Syntax 2

```
@#ifdef variable_name  
    body included if variable  
defined  
@#else  
    body included if variable not  
defined  
@#endif
```

There is also `@#ifndef`, which is the opposite of `@#ifdef` (*i.e.* it tests whether a variable is *not* defined).

# Echo and error directives

- The echo directive will simply display a message on standard output
- The error directive will display the message and make Dynare stop (only makes sense inside a conditional inclusion directive)

## Syntax

```
@#echo string_expr
```

```
@#error string_expr
```

## Examples

```
@#echo "Information message."
```

```
@#error "Error message!"
```

# Saving the macro-expanded MOD file

- For **debugging or learning** purposes, it is possible to save the output of the macro-processor
- This output is a valid MOD file, obtained after processing the macro-commands of the original MOD file
- Just add the `savemacro` option on the Dynare command line (after the name of your MOD file)
- If MOD file is `filename.mod`, then the macro-expanded version will be saved in `filename-macroexp.mod`
- You can specify the filename for the macro-expanded version with the syntax `savemacro=mymacroexp.mod`

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# 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
  - `simulate.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 `simulate.mod` and `estim.mod`
- But it makes no sense to run it on `modeldesc.mod`
- Advantage: no need to manually copy/paste the whole model (at the beginning) or changes to the model (during development)

# Indexed sums or products

Example: moving average

## Before macro-processing

```
@#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

```
var x MA_x;
...
model;
...
MA_x = 1/5*(
    +x(-2)
    +x(-1)
    +x(0)
    +x(1)
    +x(2)
);
...
end;
```

# Multi-country models

## MOD file skeleton example

```
@#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;
```



# Endogeneizing parameters (1/4)

- When doing the steady-state calibration of the model, it may be useful to consider a parameter as an endogenous (and vice-versa)
- Example:

$$y = \left( \alpha^{\frac{1}{\xi}} \ell^{1-\frac{1}{\xi}} + (1 - \alpha)^{\frac{1}{\xi}} k^{1-\frac{1}{\xi}} \right)^{\frac{\xi}{\xi-1}}$$

$$lab\_rat = \frac{w\ell}{py}$$

- In the model,  $\alpha$  is a (share) parameter, and  $lab\_rat$  is an endogenous variable
- We observe that:
  - ▶ calibrating  $\alpha$  is not straightforward!
  - ▶ on the contrary, we have real world data for  $lab\_rat$
  - ▶ it is clear that these two variables are economically linked

# Endogeneizing parameters (2/4)

- Therefore, when computing the steady state:
  - ▶ we make  $\alpha$  an endogenous variable and *lab\_rat* a parameter
  - ▶ we impose an economically relevant value for *lab\_rat*
  - ▶ the solution algorithm deduces the implied value for  $\alpha$
- We call this method “variable flipping”

# Endogeneizing parameters (3/4)

## Example implementation

- File `modeqs.mod`:
  - ▶ contains variable declarations and model equations
  - ▶ For declaration of `alpha` and `lab_rat`:

```
@#if steady
  var alpha;
  parameter lab_rat;
@#else
  parameter alpha;
  var lab_rat;
@#endif
```

# Endogeneizing parameters (4/4)

## Example implementation

- File `steadystate.mod`:
  - ▶ begins with `@#define steady = 1`
  - ▶ then with `@#include "modeqs.mod"`
  - ▶ initializes parameters (including `lab_rat`, excluding `alpha`)
  - ▶ computes steady state (using guess values for endogenous, including `alpha`)
  - ▶ saves values of parameters and endogenous at steady-state in a file, using the `save_params_and_steady_state` command
- File `simulate.mod`:
  - ▶ begins with `@#define steady = 0`
  - ▶ then with `@#include "modeqs.mod"`
  - ▶ loads values of parameters and endogenous at steady-state from file, using the `load_params_and_steady_state` command
  - ▶ computes simulations

# MATLAB/Octave loops vs macro-processor loops (1/3)

Suppose you have a model with a parameter  $\rho$ , 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
```

- The loop is not unrolled
- MATLAB/Octave manages the iterations
- Interesting when there are a lot of iterations

## MATLAB/Octave loops vs macro-processor loops (2/3)

### 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
```

- Very similar to previous example
- Loop is unrolled
- Dynare macro-processor manages the loop index but not the data array (rhos)

# MATLAB/Octave loops vs macro-processor loops (3/3)

## With a macro-processor loop (case 2)

```
@#for rho_val in [ "0.8", "0.9", "1"]  
    rho = @{rho_val};  
    stoch_simul(order=1);  
@#endfor
```

- Advantage: 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)
- Inconvenient: can not reuse an array stored in a MATLAB/Octave variable

# Thanks for your attention!

## Questions?



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