The Dynare Macro-processor

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Outline

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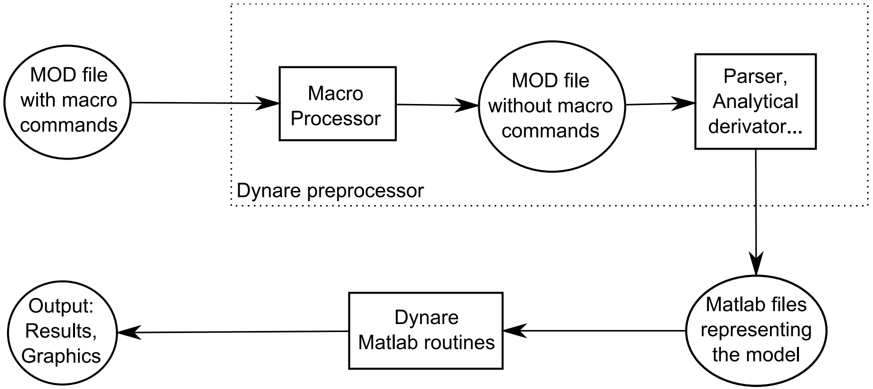
Motivation

- 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


MOD file with macro commands
Macro Processor
MOD file without macro commands
Parser, Analytical derivator...
Dynare preprocessor
Matlab files representing the model
Dynare Matlab routines
Output: Results, Graphics

Outline

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 2nd 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`

Outline

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, α is a (share) parameter, and *lab_rat* is an endogenous variable
- We observe that:
  - calibrating α is not straigthforward!
  - 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 α 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 α
- 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 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
```

- 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?