Money and Finance	**Fall Semester, 2005**
Exercise session 1: September 19	
Lecturer: Michal Kejak	*TA: František Brázdik*

1.1 Uhlig's toolkit - A Tool for simulations

Often, researchers wish to analyze nonlinear dynamic discrete-time stochastic models. Uhlig's toolkit provides a device for solving such models easily, building on log-linearizing the necessary equations characterizing the equilibrium and solving for the recursive equilibrium law of motion with the method of undetermined coefficients.

You can find information on Prof. Harald Uhlig, Ph.D. at `http://www.wiwi.hu-berlin.de/wpol/index.html` and more information on toolkit is presented in paper *"A toolkit for analyzing nonlinear economic dynamic models easily: MATLAB programs."* by Prof. Harald Uhlig and you can download this paper at: `http://www.wiwi.hu-berlin.de/wpol/html/toolkit.htm`

We need for simulations of RBC models:

- Matlab
- Installed toolkit
- Log–linearized RBC model
- .m file that describes model and sets up parameters for simulations

From simulations we get:

- Impulse responses to shocks
- Impulse responses to deviation of state variables from steady state
- Moments + Standard deviations
- Autocorrelation Table

1.1.1 Installing toolbox

Run Matlab and type do_it to see if toolkit is installed. If you see this message

```
>> do_it
??? Undefined function or variable 'do_it'.
```

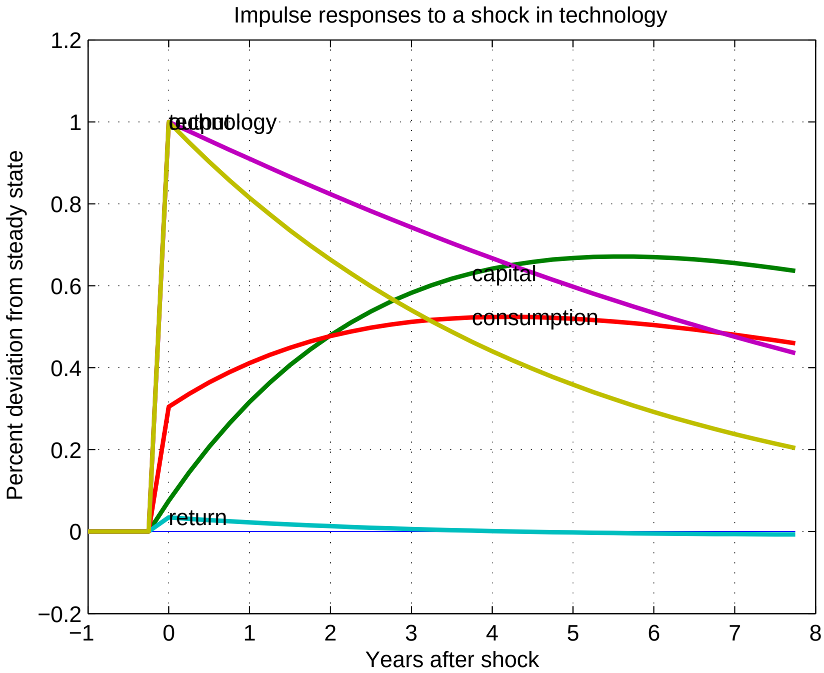

Figure 1.1: Impulse response to shock

it means that toolkit is not installed. And you have to install it in following way:

1. Download toolkit at
`http://www.wiwi.hu-berlin.de/wpol/html/toolkit/version4_1/Toolkit4_1.zip`
and extract the .m files into directory

2. Add path to this directory into the Matlab's path: File→Set Path

3. Type do_it at Matlab's command line again and you see this message

```
>> do_it
??? Undefined function or variable "AA".
Error in ==> do_it at 10
[l_equ,m_states] = size(AA);
```

This means that toolkit is installed but the description of model is missing.

1.1.2 Simple Model

To demonstrate the usage of Uhlig's toolbox, let's simulate the simple model he stochastic neoclassical growth model of indivisible labor given by following problem:

$$\max_{K_t,C_t} \sum_0^\infty E\left(\beta^t \frac{C^{1-\eta}-1}{1-\eta}\right) \tag{1.1}$$

$$s.t.$$

$$C_t + K_t = Z_t K_t^\alpha N_t^{1-\alpha} + (1-\delta)K_{t-1} \tag{1.2}$$

$$log Z_t = (1-\phi) log \bar{Z} + \phi Z_{t-1} + \varepsilon_t, \tag{1.3}$$

where $0 < \beta < 1$ is discount factor, $0 < \alpha < 1$ is capital share, $\eta > 0$ is relative risk aversion coefficient, $0 < \delta < 1$ is depreciation rate and N_t is normalized to 1.

Finally, $0 < \phi < 1$ and $\bar{Z}$ are parameters of technology evolution process. To solve the model, we have following necessary conditions (F.O.C.):

$$C_t = Z_t K_{t-1}^\alpha + (1-\delta)K_{t-1} - K_t \tag{1.4}$$

$$1 = \beta E[\left(\frac{C_t}{C_{t+1}}\right)^\eta R_{t+1}] \tag{1.5}$$

$$log Z_t = (1-\phi) log \bar{Z} + \phi Z_{t-1} + \varepsilon_t, \tag{1.6}$$

and variables can be divided into these groups:
Endogenous state variables: K_t
Exogenous state variables: Z_t
Endogenous variables: C_t, R_t, Y_t

Solving for steady state gives:

$$\beta = \frac{1}{\bar{R}} \tag{1.7}$$

$$\bar{K} = \left(\frac{\rho \bar{Z}}{\bar{R} - 1 + \delta}\right)^{\frac{1}{1-\rho}} \tag{1.8}$$

$$\bar{Y} = \bar{Z}\bar{K}^\rho \tag{1.9}$$

$$\bar{C} = \bar{Y} - \delta \bar{K}, \tag{1.10}$$

when we denote $variable = log(\overline{variable}) - log(variable_t)$ and log–linearize necessary conditions we get following equations:

$$0 = -(1-\beta(1-\delta))(1-\rho)k_{t-1} + (1-\beta(1-\delta))z_t - r_t \tag{1.11}$$

$$0 = -\frac{\bar{K}}{\bar{C}}k_t + \frac{\bar{K}}{\beta\bar{C}}k_{t-1} + (1+\delta\frac{\bar{K}}{\bar{C}})z_t - c_t \tag{1.12}$$

$$0 = -y_t + z_t + \rho k_{t-1} \tag{1.13}$$
$$0 = E_t[-\eta c_{t+1} + r_{t+1} + \eta c_t] \tag{1.14}$$
$$z_{t+1} = \psi z_t + \varepsilon_{t+1} \tag{1.15}$$

1.1.3 Creating .m file used for simulation

The .m file used for running simulations has the usually the following structure:

- Setting parameters: this section also, often includes calculations of the steady state values of variables that are used in log–linearizated equations as parameters.
- Declaring the matrices - Description of the model
  - Deterministic Equations
  - Expectational Equations
  - Exogenous processes
- Setting the options for toolkit
- Starting the calculations

Parameters are set in usual way:

```
Z_bar     = 1;    % Normalization
rho       = .36;  % Capital share
...
Y_bar   = Z_bar*K_bar^rho; % Steady state value of output
...
```

For declaring the matrices that describe model, at first we identify the names of variables in the the following order: 1) Endogenous state variables (in following text denoted as x), 2) Exogenous state variables - (y), and 3) Endogenous variables (z)

```
  VARNAMES = ['capital    ',
              'consumption',
              'return     ',
              'output     ',
              'technology '];
```

To describe the model the following generalized structure is used:

Deterministic equations:
$$0 = AAx_t + BBx_{t-1} + CCu_t + DDe_t$$
Expectational equations:
$$0 = E_t[FFx_{t+1} + GGx_t + HHx_{t-1} + JJu_{t+1} + KKu_t + LLe_{t+1} + MMe_t]$$
Exogenous processes:
$$e_{t+1} = NNe_t + \varepsilon_{t+1}$$
Shocks variance matrix:
$$Sigma = Var(u)$$

In our case we have $x(t) = [k(t)]$, $u(t) = [c(t), r(t), y(t)]$ and $e(t) = [z(t)]$ and we can define matrices in following way:

```
AA = [ 0
       - K_bar/C_bar
       0             ];
...
CC = [     0,   -1,    0
          -1,    0,    0
           0,    0,   -1 ];
...
HH = [ 0 ];
JJ = [    -eta,     1 ,  0     ];
...
NN = [psi];
Sigma = [ sigma_eps^2  ];
```

1.1.4 Options for toolbox

Options are passed to different subroutines of Uhlig's toolbox to control outputs of the simulation. First, it is necessary to include these options:

```
  PERIOD     = number of periods per year, i.e. 4 for quarterly;
  GNP_INDEX  = Index of output variable in VARIABLES array;
```

Also there are many other options that help to control the simulation flow. Following table contains the list of the most interesting options for toolkit.

Option name	**Description**
Simulation options	
DO_IMPRESP = 1	if you want to calculate impulse responses.
DO_MOMENTS = 0	Turn on, if you want to do fourier-transforms-based calculations of moments
DO_SIMUL = 0	Turn on, if you want to do simulations or simulation-based calculations of moments
Statistics options	
DO_HP_FILTER= 1	Set to = 1, if you want moments and simulations with HP-filter. Set to = 0, if you want moments and simulations without HP-filter.
HP_LAMBDA=1600*(PERIOD/4)^4	The lambda parameter for the HP-Filter
HP_SELECT = 1:(m_states+n_endog+k_exog)	Selecting the variables for the HP Filter calculations
N_LEADS_LAGS = 6	calculate autocorr table up to N_LEADS_LAGS-1 leads and lags
SIM_MODE = 1	Set to = 1, if you just want one simulated time series Set to = 2, if you want to do simulation-based calculation of moments
SIM_LENGTH = 100	Length of time series to be simulated
SIM_RANDOM_START = 1	= 1, if you want a random start, = 0, if you want predetermined start
SIM_X_START = zeros(m_states,1)	if predetermined start, SIM_X_START should be a vector of length m, setting the initial values for the endogenous state variables x
SIM_Z_START = zeros(k_exog,1)	if predetermined start, SIM_Z_START should be a vector of length k, setting the initial values for the exogenous state variables z
SIM_GIVEN_EPS = 0	set = 1, if you want to choose the shocks epsilon yourself In that case, declare them beforehand as given_eps which needs to be a matrix of size k_exog x SIM_LENGTH ONLY RELEVANT FOR SIM_MODE = 2
SIM_N_SERIES = 50	number of simulated series for the calculations of moments
SIM_TRACK_N = 1	Prints a little message at the start of each simulation
SIM_TRACK_LENGTH = 1	Prints a little message every simulation
Graphics options	
DO_SHOCK_RESP = 1	=1, if impulse responses to shocks shall be calculated
SELECT_SHOCKS = 1 : k_exog	select the shocks to which impulse responses should be plotted
DO_STATE_RESP = 1	= 1, if impulse responses to deviations of state variables should be calculated
SELECT_STATES = 1 : m_states	select the state variables to which impulse responses should be plotted
INIT_DATE = 4	Number of periods prior to shock. Default = 4
HORIZON = 32	how far out should the impulse responses be calculated. Default = 32
DO_PLOTS = 1	If impulse response plots should be made, = 0, if not

Option name	**Description**
IMP_SUBPLOT = 0	Set =1, if impulse respones should be plotted in a subplot
IMP_SUB_FONT = 6	Size of the title and labels in the subplots
IMP_JOINT = 0	Set =1, if all responses should be plotted in one graph, =0, if not
IMP_SINGLE = 1	If each response should be plotted in a separate graph, =0 if not
IMP_SELECT = 1:(m_states+n_endog+k_exog)	a vector containing the indices of the variables to be plotted
DO_NO_ZERO_RESPONSE = 0	Set = 1 to avoid plotting responses near zero
ZERO_RESPONSE_LEVEL = 0.0001	Defining near zero to be the interval [-ZERO_RESPONSE_LEVEL,ZERO_RESPONSE_LEVEL]
DO_ENLARGE = 0	=1, if you need large letter sizes for overheads, say If set to 1, letter size will be manipulated by ENLARGE M
DO_THICK_LINES = 1	If you set DO_ENLARGE = 1, then you will also get thick lines with DO_THICK_LINES = 1
PRINT_FIG = 0	Set = 1, if you want to sent figures directly to printer
SIM_GRAPH = 1	Set to = 1 to see plots of the simulated series
SIM_SUBPLOT=0	Set =1, if simulated series should be plotted in a subplot
SIM_JOINT=1	If all simulated series should be plotted in one graph, =0, if not
SIM_SINGLE=0	set =1, if each simulated series should be plotted in one graph
SIM_SUB_FONT=6	Size of the title and labels in the subplots
SIM_MAX = 200	Maximal number of dates to be used for the plots
SIM_SELECT = 1:(m_states+n_endog+k_exog)	Selecting the variables for the graphics of simulations
SIM_DATE0 = 0	Set to the initial date of the simulated series
Only relevant if DO_MOMENTS = 1:	
DO_HP_GRAPH=1	To plots pectral densities
MOM_SUBPLOT=0	Set =1, if spectral densities should be plotted in a subplot
MOM_JOINT=1	If all spectral densities should be plotted in one figure, =0, if not
MOM_SINGLE=0	Set =1, if spectral densities should be plotted in separate figures
MOM_SUB_FONT=6	Size of the title and labels in the subplots
MOM_PLOT_RAW=0	If you like non-HP-filtered spectral density plots

1.1.5 Simulation

Finally, we need to do some simulations with command:

```
do_it;
```

and we receive results like this figure:

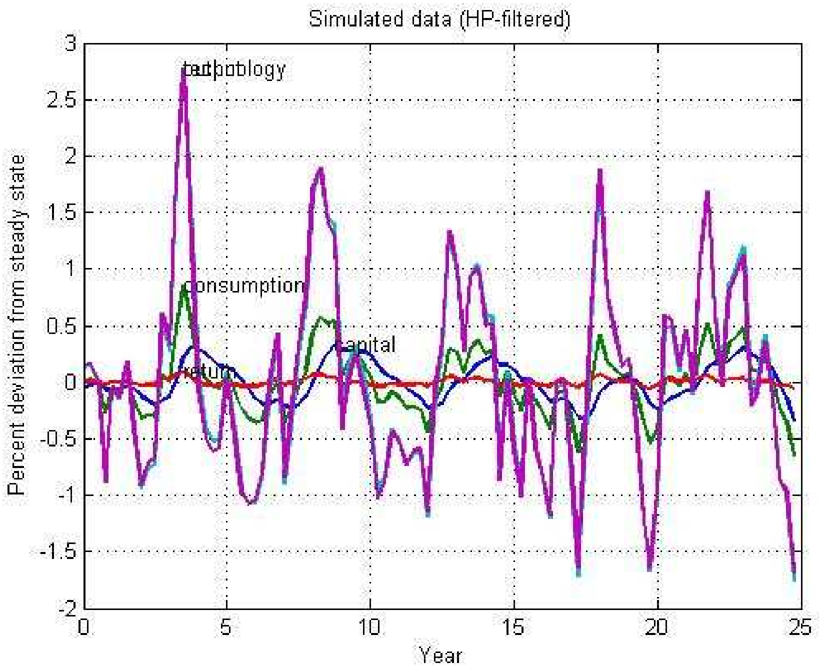

Figure 1.2: Results of simulations

1.1.6 Useful data structures

Uhlig's toolkit also produce useful data structures that contains results of simulations.

1.2 Preparing simulation files easily

SimulEditor creates a MATLAB m-file for your model which is written in the format required by Uhlig (1999), so you can simulate your model using Uhlig Toolkit. The m-file of your model is created in four intuitive steps in a user-friendly environment.

Simuleditor creates m–file in following four steps:

1. Select the exact number and names of variables that model has.

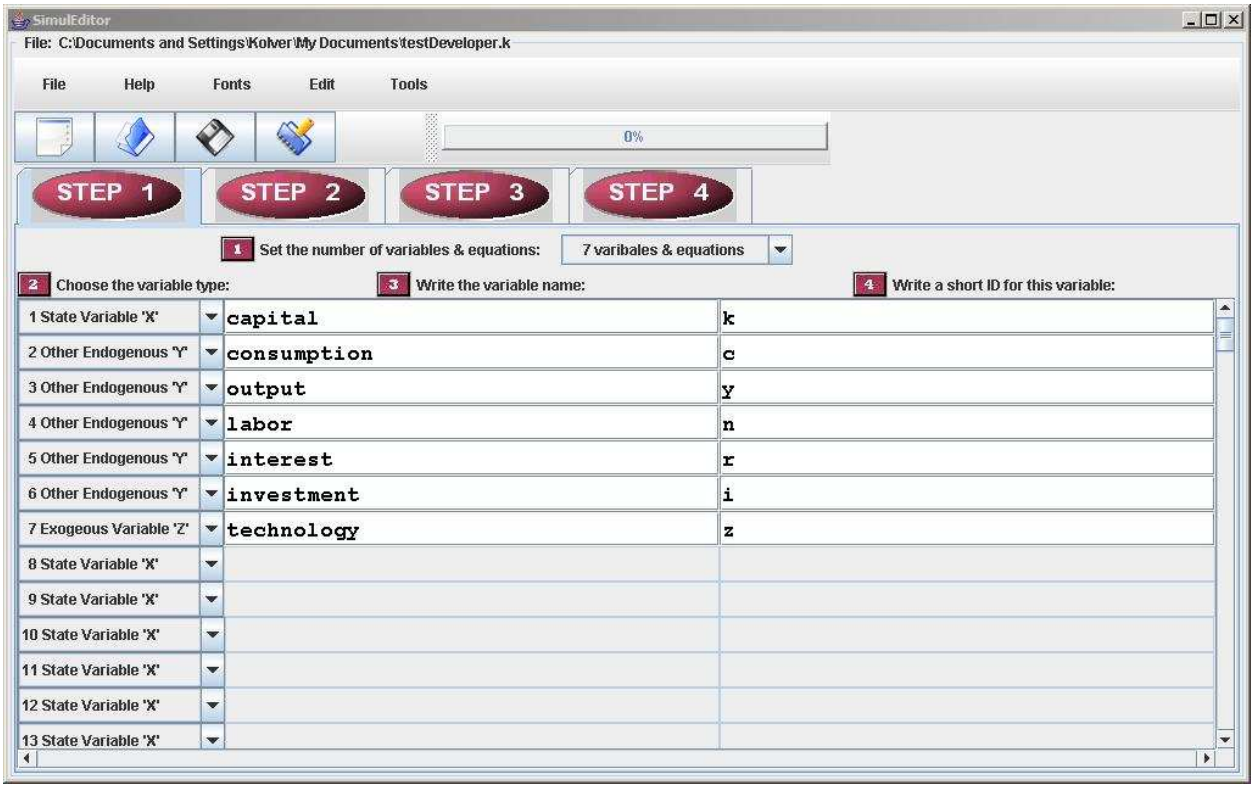

Figure 1.3: Environment of SimulEditor

2. Declare all the parameters in the model and their values (includes steady state relations)
3. Write the equations and select its type.
4. Create m-file:
   (a) Checks for consistency - the number of exogenous equations equals the number of exogenous variables declared
   (b) Finds some spelling errors - equations use only terms of the variables' ID,
   (c) Checks for the proper format of the equations and creates the m-file
   (d) Export the m-file" button

To use the Simuleditor you have to:

- Install Java's(TM) 2 Runtime Environment, Standard Edition
  check with command 'java' typed in the windows command line, if you receive unrecognized command message download Java at:
  `http://java.sun.com/j2se/downloads/index.html`

- Download Simuleditor and unpack Simuleditor files from
  `http://copland.udel.edu/ kolver/simuleditor/simul_m.html#download`
- Set path to Simuleditor directory in Matlab
  Matlab→File→Set Path ...
- Run Simuleditor
  - From Matlab's command line:

    ```
    >> ! java simuleditor &
    ```

  - From command line:

    ```
    ..\path to simuleditor directory>java simuleditor
    ```

For more downloads and help on Simuleditor go to:
`http://copland.udel.edu/ kolver/simuleditor/`

1.3 Sources

An extended textbook-chapter-like version of the paper, which explains in particular everything in great detail for the stochastic neoclassical growth model. Available at:
`http://www.wiwi.hu-berlin.de/wpol/html/toolkit/toolkit.pdf`