INSTITUTE FOR CAPACITY DEVELOPMENT

Workshop 1: Introduction to Dynare and The RBC Model

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Course on Monetary and Fiscal Policy Analysis with DSGE Models (OT26.08)

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How to Solve a DSGE Model?

- In L-1, we described the RBC model
- How to solve a DSGE model such as the RBC model
  - By hand, with some specific functional forms for the utility and production functions
  - Write your own computer code
  - Use Dynare

Outline

- Introduce Dynare
- Code, solve, and simulate the RBC model in Dynare

What is Dynare?

- Dynare is a free software platform for handling a wide class of economic models, in particular DSGE and overlapping generations (OLG) models
- Developed by a team led by Michel Julliard
- Now used widely by academic and policy institutions

What You Need to Do

- Download Dynare from http://www.dynare.org and https://www.dynare.org/release/windows-7z/
- Once downloaded, configure MATLAB with Dynare (version 4.5.7.) using the command window: ’addpath c:\dynare 4.5.7\matlab’
- Write your model in a “.mod” file, e.g., my_model.mod
- Run the mod file by typing in the MATLAB command window

  dynare my_model.mod

A Typical Dynare ".mod" File

- Declare endogenous variables

  var *[expressions];*

- Declare exogenous shocks

  varexo *[expressions];*

- Declare parameters

  parameters *[expressions];*

- Assign values to parameters ("calibration")

  parameter x = numerical value;

A Typical Dynare ".mod" File

- Describe the model

  model;
  [model equations, e.g., FOCs];
  end;

- Assign initial values to endogenous variables

  initval;
  [expressions];
  end;

- Define standard deviations of shocks

  shocks;
  [expressions];
  end;

Equilibrium Conditions of the RBC Model

Endogenous variables: $\{\tilde{c}_t, \tilde{\imath}_t, \tilde{k}_t, \tilde{y}_t, n_t, \widetilde{w}_t, r_t^K, z_t\}$

$$\left(\frac{\alpha}{1-\alpha}\right)\frac{\tilde{c}_t}{1-n_t} = \widetilde{w}_t$$

$$\frac{1+\gamma}{\tilde{c}_t} = \beta\mathbb{E}_t\left[\frac{1}{\tilde{c}_{t+1}}\left(r_{t+1}^K + 1 - \delta\right)\right]$$

$$(1+\gamma)(1+\eta)\tilde{k}_{t+1} = \tilde{\imath}_t + (1-\delta)\tilde{k}_t$$

$$\tilde{y}_t = e^{z_t}(\tilde{k}_t)^{\theta}(n_t)^{1-\theta}$$

$$r_t^K = \theta\frac{\tilde{y}_t}{\tilde{k}_t}$$

$$\widetilde{w}_t = (1-\theta)\frac{\tilde{y}_t}{n_t}$$

$$\tilde{y}_t = \tilde{c}_t + \tilde{\imath}_t$$

$$z_t = \rho z_{t-1} + \varepsilon_{t,} \;\; \varepsilon \sim \mathcal{N}(0, \sigma_\varepsilon^2)$$

Conventions

- **Conventions:** Write state variables with lags, e.g.,

$$(1+\gamma)(1+\eta)\tilde{k}_{t+1} = \tilde{\imath}_t + (1-\delta)\tilde{k}_t \longrightarrow (1+\gamma)(1+\eta)\tilde{k}_t = \tilde{\imath}_t + (1-\delta)\tilde{k}_{t-1}$$

- When the model variable is simply the level of the variable then the IRF will measure the difference between the variable and its steady state; e.g., if

$$\tilde{y}_t = \tilde{c}_t + \tilde{\imath}_t$$

then IRF measures $\tilde{y}_t - y$

- When the model variable measures percentages (e.g., log deviations from steady state) the IRF will show the percentage deviation from steady state; e.g., if

$$\exp(\widetilde{yy}_t) = \exp(\widetilde{cc}_t) + \exp(\widetilde{ii}_t)$$

then IRF measures

$$\widetilde{yy}_t = \log\left(\frac{\tilde{y}_t}{y}\right) \simeq \frac{\tilde{y}_t - y}{y}$$

Solving the RBC Model

- Use Dynare
- Run the code by typing in the MATLAB command window

  dynare rbc.mod

- Dynare (log)linearizes the model and rewrites it as

$$x_t = B\mathbb{E}_t x_{t+1} + D x_{t-1} + N\varepsilon_t$$

- For the RBC model, even with the additional equations, the model can be written

$$x_t = \Lambda\mathbb{E}_t x_{t+1} + \Xi\varepsilon_t$$

B,D,N, Λ, and Ξ are matrices

Solving the RBC Model

The steady state where there is no shock ε_t and $X_t = X_{t+1} = X_{t-1} = X$

```
STEADY-STATE RESULTS:

z         0
k         24.694
c         1.33036
n         0.313068
i         0.466114
y         1.79647
w         3.44296
r         0.0290997
```

Solving the RBC Model

The Blanchard-Kahn Rank Condition: The role of the eigenvalues of Λ in $x_t = \Lambda \mathbb{E}_t x_{t+1} + \Xi \varepsilon_t$ for the equilibrium determinacy

# of explosive eigenvalues = # of jump variables ⇒Unique equilibrium

Jump (forward-looking) variables: $\tilde{c}_{t+1}$, r_{t+1}; State (predetermined) variables: $\tilde{k}_{t-1}$, z_{t-1}

```
EIGENVALUES:
         Modulus              Real         Imaginary

            0.95              0.95                 0
          0.9663            0.9663                 0
           1.045             1.045                 0
       2.519e+18        -2.519e+18                 0


There are 2 eigenvalue(s) larger than 1 in modulus
for 2 forward-looking variable(s)

The rank condition is verified.
```

Solving the RBC Model

- Dynare finds the solution

$$x_t^c = \Omega x_{t-1}^s + \mathrm{P}\varepsilon_t \qquad and \qquad x_t^s = \Upsilon x_{t-1}^s + \Phi\varepsilon_t$$

  - x_t^c is a vector of control (jump or non-predetermined) variables
  - x_t^s is a vector of state (predetermined) variables
  - Ω, P, Υ, and Φ are matrices

POLICY AND TRANSITION FUNCTIONS

	z	k	c	n	i	y	w	r
Constant	0	24.694026	1.330358	0.313068	0.466114	1.796471	3.442963	0.029100
z(-1)	0.950000	2.077583	0.416777	0.232938	2.091867	2.508644	2.246123	0.040636
k(-1)	0	0.966272	0.033176	-0.003197	-0.015085	0.018091	0.069835	-0.000885
e	1.000000	2.186929	0.438713	0.245198	2.201965	2.640678	2.364340	0.042774

$$\tilde{c}_t - 1.330 = 0.033(\tilde{k}_{t-1} - 24.694) + 0.417(z_{t-1} - 0) + 0.439 e_t$$

The constant is the steady state level of a variable

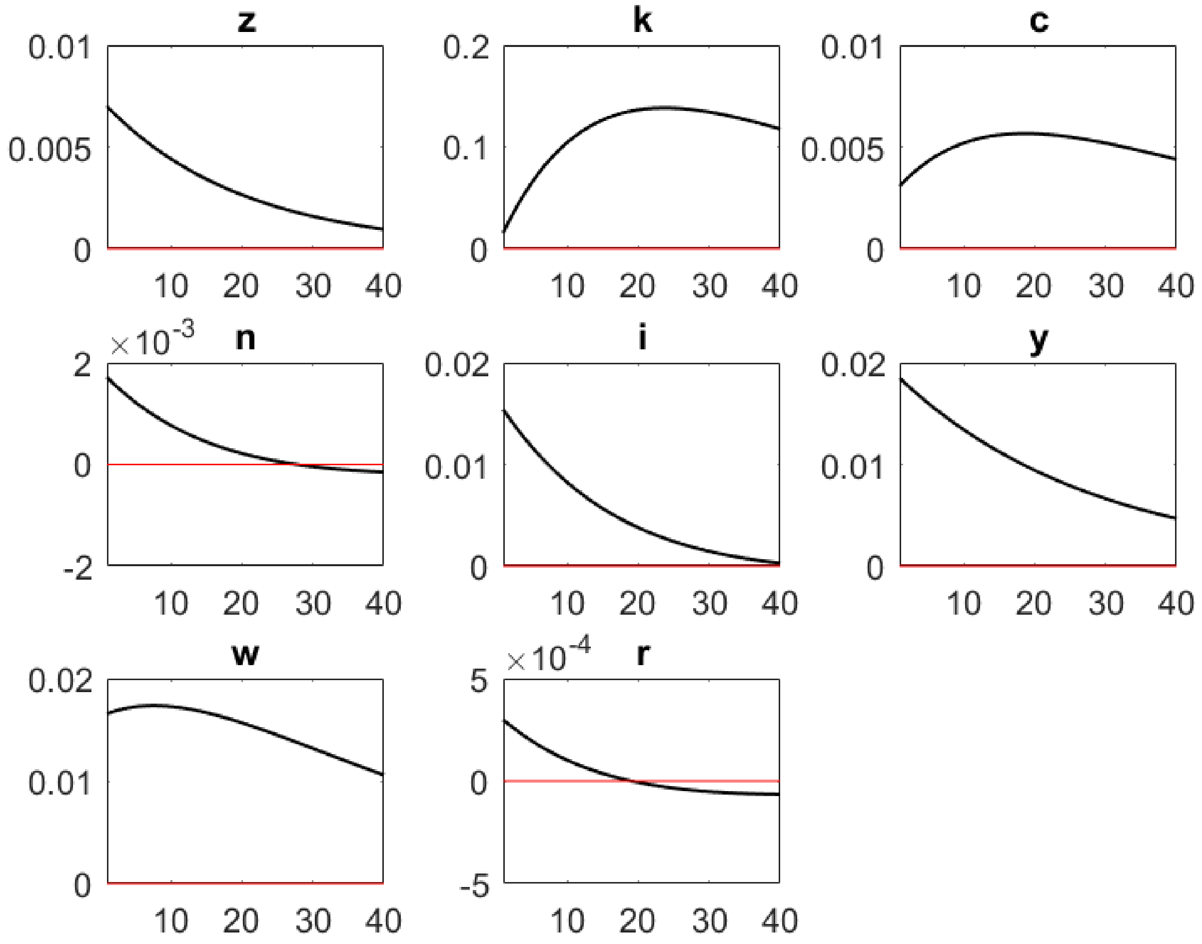
Business Cycles: Model vs. Data

	Model		Data	
Variable	SD (%)	Corr(var, y)	SD (%)	Corr(var, y)
y	1.34	1.00	1.72	1.00
c	0.35	0.88	1.27	0.83
i	4.32	0.99	8.24	0.91
n	0.72	0.99	1.69	0.92
y/n	0.64	0.98	0.73	0.34

$$\frac{1.34}{1.72} = 0.78$$

Impulse Responses: we use '<u>rbc.mod</u>' file

The impulse responses to one-time shock in z_t, i.e., $\varepsilon_t \uparrow$ by one std 0.007 at $t = 0$ and then $\varepsilon_t = 0, \forall t \geq 1$. Variables expressed as deviations from SS levels



Impulse Responses

Analyze the impulse responses using the equilibrium conditions. For simplicity ignore $\mathbb{E}_t(.)$

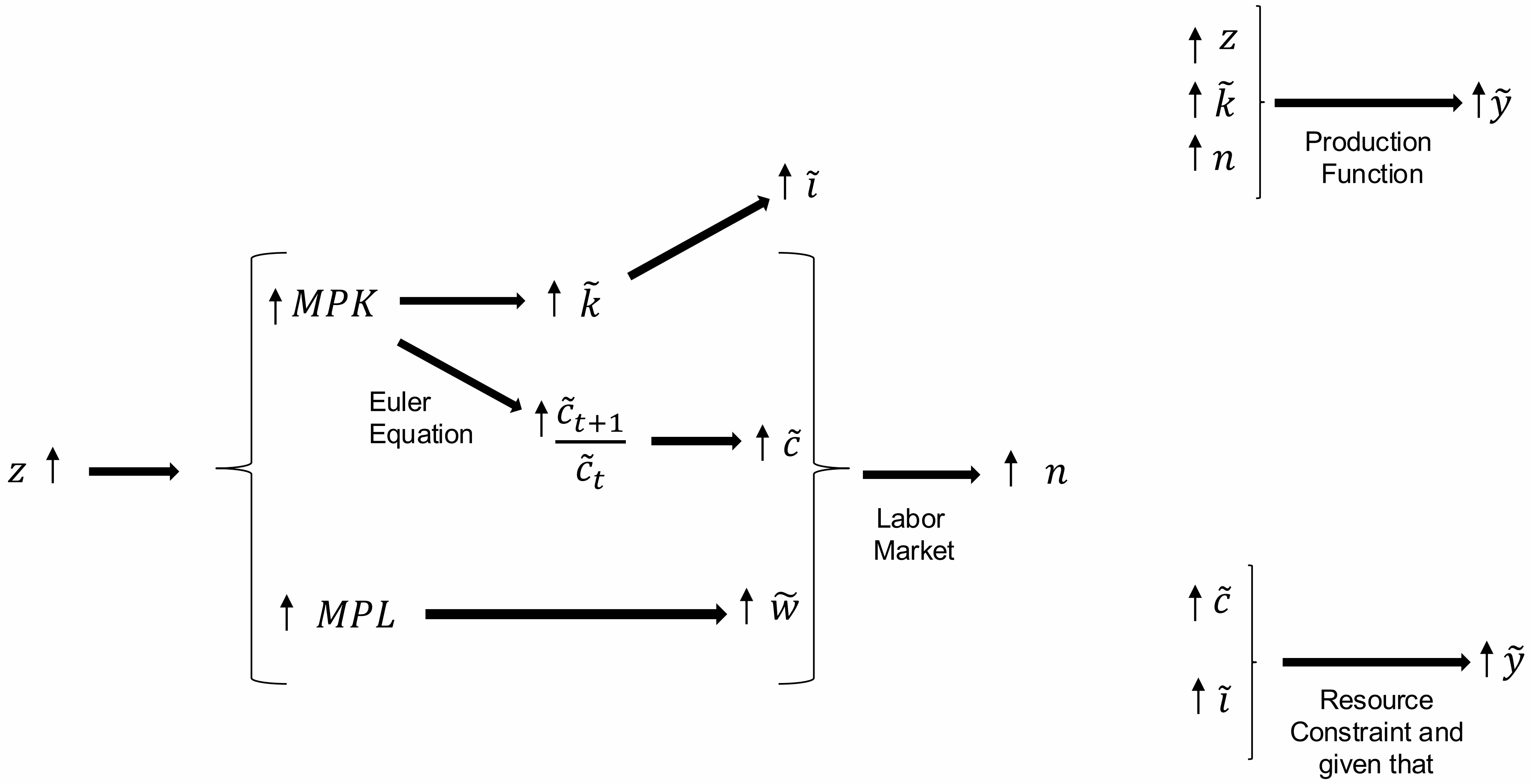
$$\frac{\tilde{c}_{t+1}}{\tilde{c}_t} = \frac{\beta}{1+\gamma}(MPK_{t+1} + 1 - \delta) \quad with \quad MPK_{t+1} = \theta \frac{\tilde{y}_{t+1}}{\tilde{k}_{t+1}} = r_{t+1}^K$$

$$\tilde{w}_t = \left(\frac{\alpha}{1-\alpha}\right)\left(\frac{\tilde{c}_t}{1-n_t}\right) \quad Labor \quad Supply$$

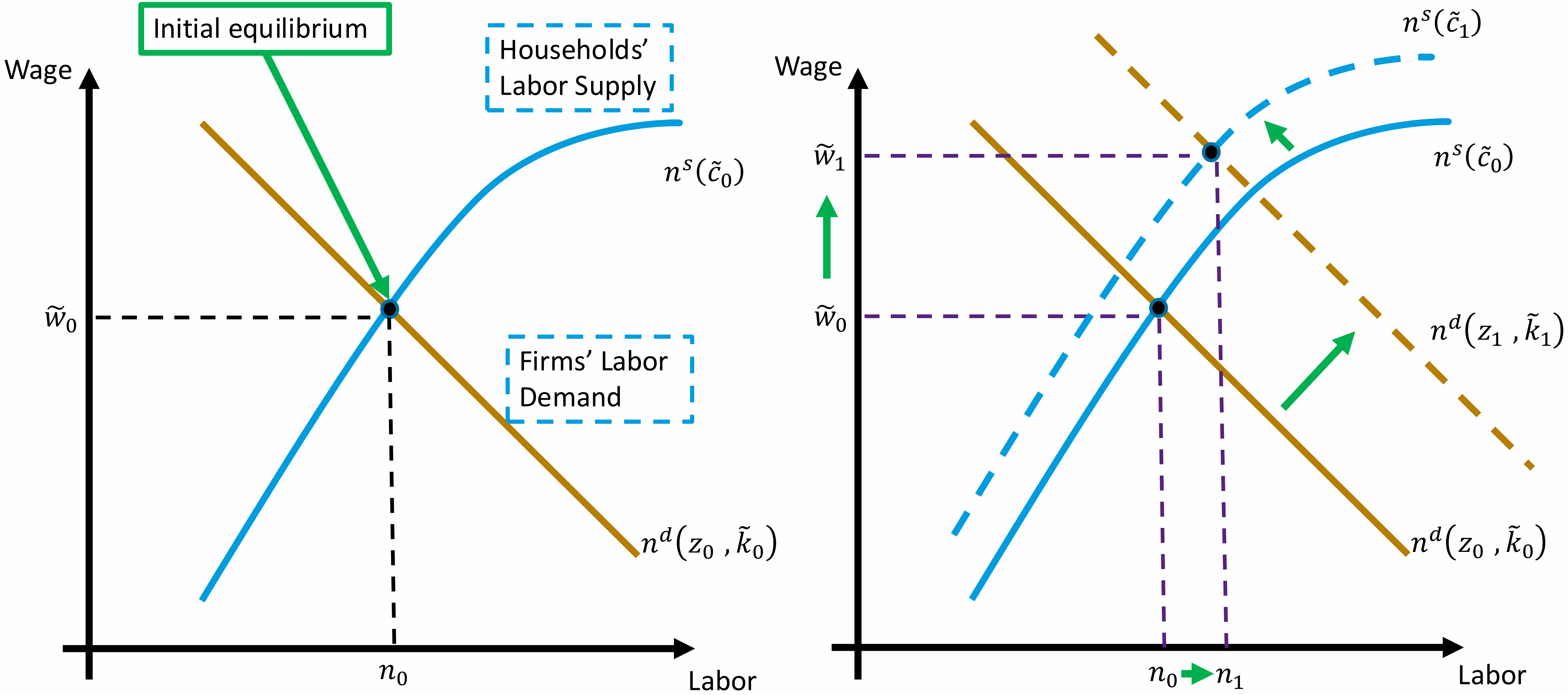
$$\tilde{w}_t = (1-\theta)e^{z_t}\left(\frac{\tilde{k}_t}{n_t}\right)^{\theta} \quad LaborDemand$$

$$\tilde{y}_t = e^{z_t}\tilde{k}_t^{\theta} n_t^{1-\theta} \quad and \quad \tilde{c} + \tilde{\imath}_t = \tilde{y}_t$$

Transmission Mechanism



Labor Market Adjustment



$\tilde{c}_1 > \tilde{c}_0 \quad z_1 > z_0 \quad \tilde{k}_1 > \tilde{k}_0$

Sensitivity Analysis: we use ‘main_comparison.m’ file

- Exercise 1: Change the share of leisure in utility from its benchmark value 0.64 to 0.5 or to 0.9. What would happen?
- Exercise 2: Change the capital θ from its benchmark value 0.4 to 0.35. What would happen?
- Exercise 3: Change the standard deviation σ of the TFP shock from its benchmark value 0.007 to 0.07. What would happen?

Shock persistence: we use ‘main_comparison.m’ file

- Exercise 4: Change the shock persistence ρ from its benchmark value 0.95 to 0.99 or to 0.2. What would happen?

Shock process: we use ‘rbc_news_shock.mod’ file

- Exercise 5: Change the shock process to

$$z_t = \rho z_{t-1} + \varepsilon_{t-8,} \;\; \varepsilon \sim \mathcal{N}(0, \sigma_\varepsilon^2)$$

The shock was anticipated eight quarters ago but only realized today. We call it ”news shock” (Beaudry and Portier 2004 JME).

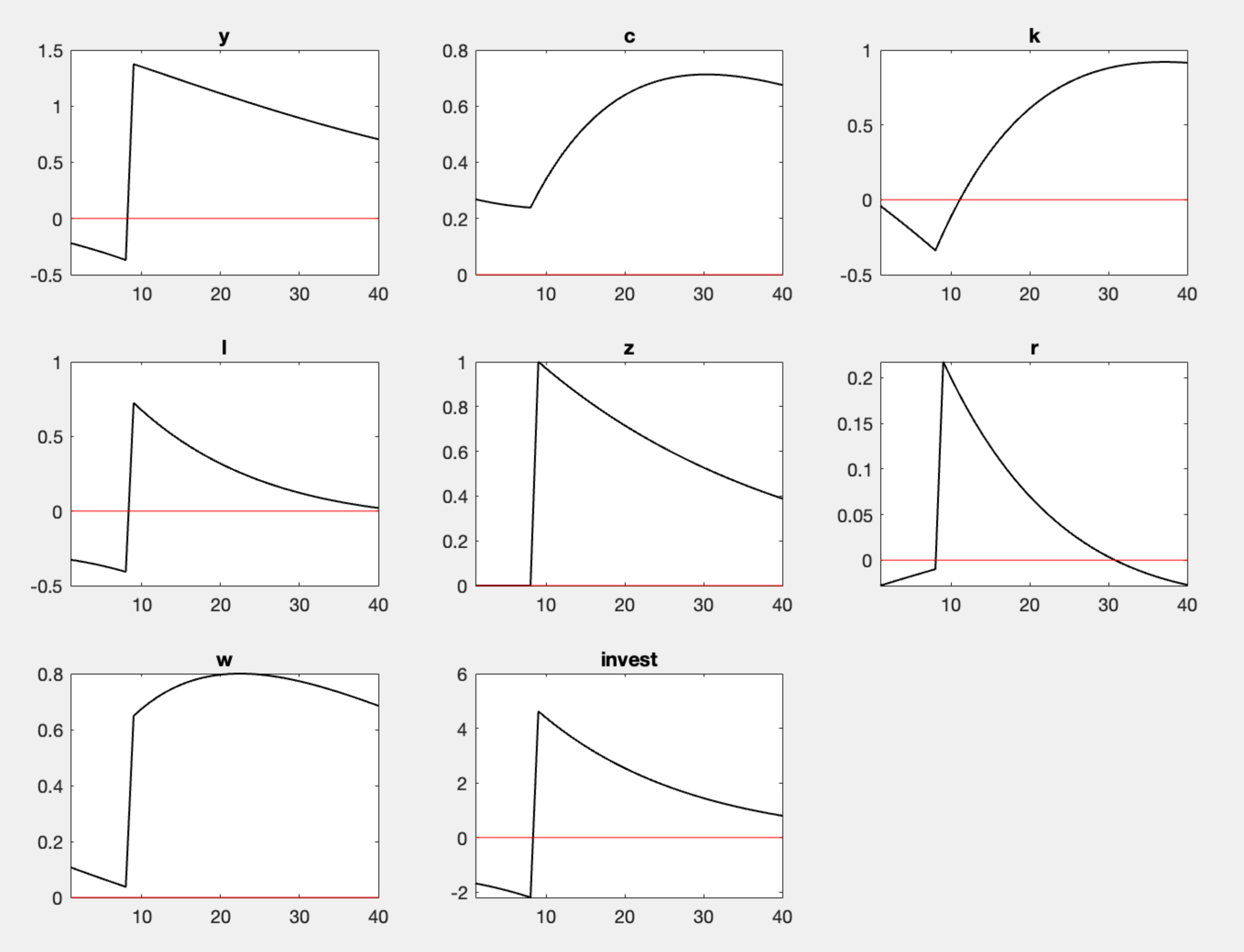
Impact of News Shock: IRF

Mechanism

- Good news (TFP ↑ in eight quarters) makes output and investment ↓ but consumption ↑
- Why? "Wealth effect" makes agents believe they are richer, hence consumption ↑ and leisure ↑ (hours worked ↓.
- Good news create recessions, which is at odds with data and intuition.

How to fix it?

- Jaimovich and Rebelo (2009 AER) propose to create expectations-driven business cycles in a rather standard RBC model with three features:
  - GHH preferences (eliminate wealth effect)
  - Adjustment cost to investment
  - Capital utilization

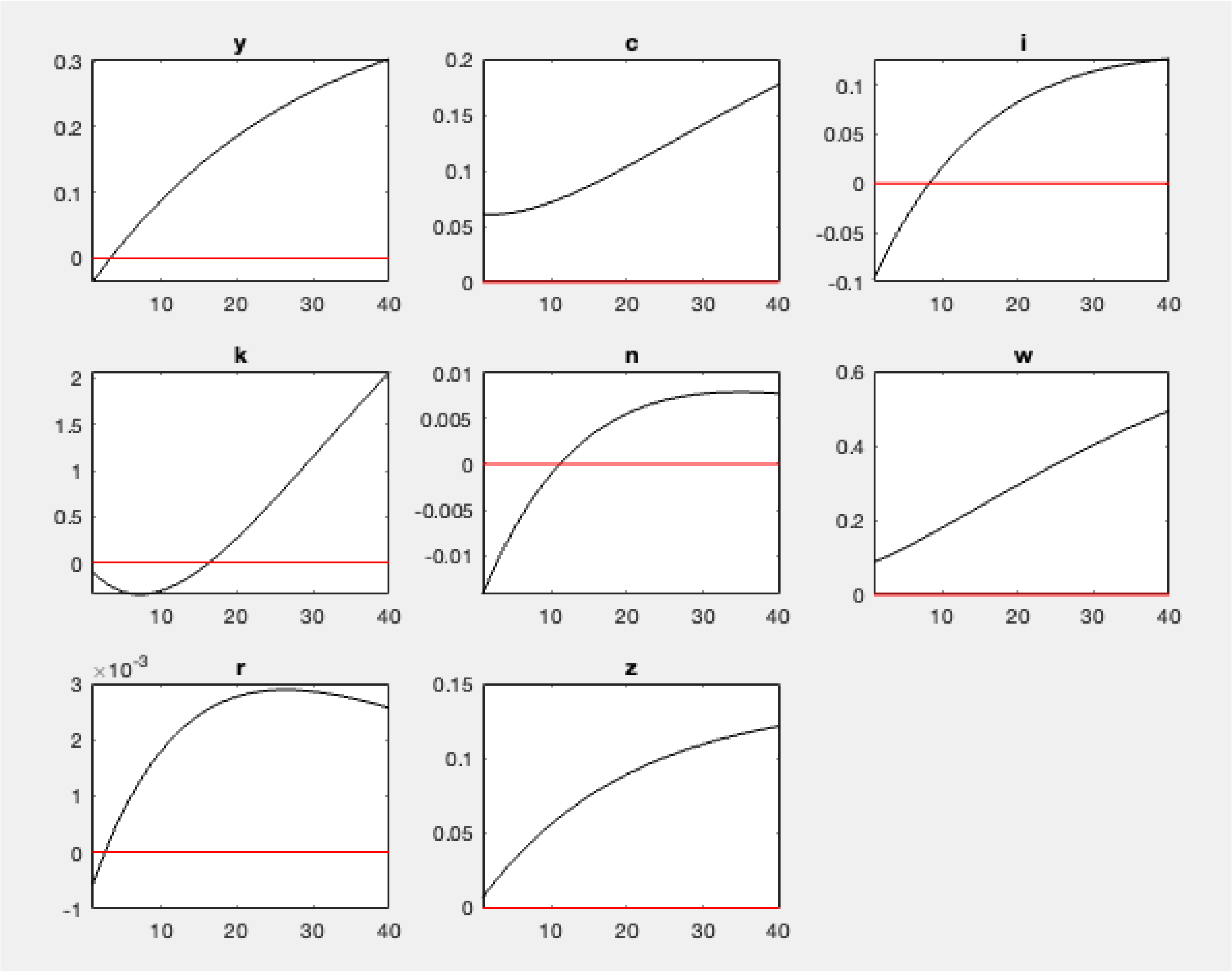


Shock process: we use ‘rbc_z.mod’ file

- Exercise 6: Change the shock process to a growth process

$$\Delta z_{t+1} = \rho \Delta z_t + \varepsilon_{t+1}, \;\; \varepsilon \sim \mathcal{N}(0, \sigma_\varepsilon^2)$$

Shock process: IRF



Take-Aways

- Dynare is a simple, user-friendly software platform for solving DSGE models
- Provided step-by-step instructions to put the RBC model in Dynare
- Explained how to interpret Dynare output, tested the sensitivity of the model and checked the potential issues with RBC

Thank you!