Macro II - Business cycle fluctuations, Lecture 3

David Vestin

Sveriges Riksbank

April 29, 2016

Todays Agenda

- Solving rational expectations models - general method
- Solving the NK model
- Optimal monetary policy design in the NK model - simple rules

The setup

$$\begin{bmatrix} x_{1,t+1} \\ E_t x_{2,t+1} \end{bmatrix} = A \begin{bmatrix} x_{1,t} \\ x_{2,t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{t+1} \\ 0 \end{bmatrix} \tag{1}$$

- The objective is to find "a solution" to this system.
- That is: given initial condition $x_{1,0}$ and $\{\varepsilon_t\}_1^\infty$, what is $\{x_{1,t}\}_1^\infty$ and $\{x_{2,t}\}_1^\infty$?

Example

A reduced form of the NK model. Consider the NK Phillips curve, but for simplicity assume that the output-gap follows an exogenous process:

$$\begin{aligned} \pi_t &= \beta E_t \pi_{t+1} + \kappa x_t \\ x_t &= \rho x_{t-1} + \varepsilon_t \end{aligned}$$

We rewrite this model to fit the notation above:

$$\begin{bmatrix} x_{t+1} \\ E_t \pi_{t+1} \end{bmatrix} = \begin{bmatrix} \rho & 0 \\ -\beta^{-1}\kappa & \beta^{-1} \end{bmatrix} \begin{bmatrix} x_t \\ \pi_t \end{bmatrix} + \begin{bmatrix} \varepsilon_{t+1} \\ 0 \end{bmatrix}.$$

Method of undetermined coefficients (Gali)

- Guess and verify approach, guess that

$$\pi_t = cx_t$$

- Then $E_t \pi_{t+1} = cE_t x_{t+1} = c\rho x_t$
- Insert into Phillips-curve to find

$$\pi_t = (\beta c\rho + \kappa)\, x_t$$

- Comparing with the guess, we see that $c = \beta c\rho + \kappa$, or that

$$c = \frac{\kappa}{1 - \beta\rho}$$

- This can be generalized to system form, but is inefficient. Instead we look at another much better way of solving.

Solving RE models using the Schur decomposition

Theorem

Given a system of forward difference equations

$$\begin{bmatrix} x_{1,t+1} \\ E_t x_{2,t+1} \end{bmatrix} = A \begin{bmatrix} x_{1,t} \\ x_{2,t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{t+1} \\ 0 \end{bmatrix}$$

with initial condition $x_{1,0}$, and where x_1 contains n_1 state variables and x_2 contains n_2 jump variables. Let Z, T be the ordered Schur decomposition of A such that $A = ZTZ^H$. If and only if the number of eigenvalues with modulus smaller than unity equals n_1, the unique stable solution to the system is given by

$$\begin{aligned} x_{1,t+1} &= Mx_{1,t} + \varepsilon_{t+1} \\ x_{2,t} &= Cx_{1,t}, \end{aligned}$$

$M = Z_{ss} T_{ss} Z_{ss}^{-1}$, $C = Z_{es} Z_{ss}^{-1}$, $T_{ss} = T(1 : n_1, 1 : n_1)$,
$Z_{es} = Z(n_1 + 1 : n, 1 : n_1)$, $Z_{ss} = Z\left(1 : n_1, 1 : n_1\right)$

Equilibrium

- New Keynesian Phillips curve (NKPC)

$$\pi_t = \beta E_t \left[\pi_{t+1}\right] + \kappa \tilde{y}_t \tag{2}$$

where

$$\kappa = \lambda \left(\sigma + \varphi\right)$$

Note that, with decreasing returns ($Y_t\left(i\right) = A_t\left(N_t\left(i\right)\right)^{1-\alpha}$), the NKPC is qualitiatively identical to above, but with $\kappa = \lambda \left(\sigma + \frac{\varphi+\alpha}{1-\alpha}\right)$ and $\lambda = \frac{1-\alpha}{1-\alpha+\alpha\epsilon}\left(1-\beta\theta\right)\frac{1-\theta}{\theta}$.

- Solving forward

$$\pi_t = E_t \sum_{k=0}^{\infty} \beta^k \left(\kappa \tilde{y}_{t+k}\right)$$

- Inflation proportional to the weighted sum of current and expected future output gaps

Equilibrium

- Euler or (Dynamic) IS equation

$$\tilde{y}_t = E_t\left[\tilde{y}_{t+1}\right] - \frac{1}{\sigma}\left(i_t - E_t\left[\pi_{t+1}\right] - r_t^n\right) \quad (3)$$

where r_t^n is the natural rate of interest

$$r_t^n = \rho + \sigma E_t\left[y_{t+1}^n - y_t^n\right]$$

Equilibrium

- Note that solving the IS equation forward assuming effects of nominal rigidities vanish asymptotically $\lim_{T\to\infty} E_t\left(\tilde{y}_{t+T}\right) = 0$ yields

$$\tilde{y}_t = -E_t \sum_{k=0}^{\infty} \frac{1}{\sigma}\left(i_{t+k} - \pi_{t+k+1} - r^n_{t+k}\right) = -E_t \sum_{k=0}^{\infty} \frac{1}{\sigma}\left(r_{t+k} - r^n_{t+k}\right)$$

- The output gap is proportional to the sum of current and expected deviations between the real interest rate and the natural counter part
- Simple recursive structure
- To close the model the NKPC and IS Equation need to be supplemented with a description of how i_t evolves over time. Thus, with sticky prices real variables cannot be determined independently of monetary policy - Monetary policy is non-neutral.

Monetary Policy

- Interest rate rule
$$i_t = \rho + \phi_\pi \pi_t + \phi_y \tilde{y}_t + v_t \tag{4}$$
- Using (3) and (4) to eliminate the interest rate, and combine with (2) to get
$$\begin{bmatrix} \tilde{y}_t \\ \pi_t \end{bmatrix} = A_T \begin{bmatrix} E_t\left[\tilde{y}_{t+1}\right] \\ E_t\left[\pi_{t+1}\right] \end{bmatrix} + B_T\left(r_t^n - \rho - v_t\right) \tag{5}$$
where
$$\begin{aligned} A_T &\equiv \Omega \begin{bmatrix} \sigma & 1 - \beta\phi_\pi \\ \sigma\kappa & \kappa + \beta\left(\sigma + \phi_y\right) \end{bmatrix} \\ B_T &= \Omega \begin{bmatrix} 1 \\ \kappa \end{bmatrix} \end{aligned}$$
and
$$\Omega = \frac{1}{\sigma + \phi_y + \kappa\phi_\pi}$$

- Recall first lecture

$$\pi_t = \frac{1}{\phi_\pi} E_t \pi_{t+1} + \frac{1}{\phi_\pi} \hat{r}_t$$

with solution

$$\pi_t = E_t \sum_{k=0}^{\infty} \left(\frac{1}{\phi_\pi} \right)^{(k+1)} \hat{r}_{t+k}$$

when $\phi_\pi > 1$. Eigenvalue of stochastic differential equation is $\frac{1}{\phi_\pi}$

- Conditions for unique solution with sticky prices
- Eigenvalues of A_T less than one (compare with classical model).
- Messy to check - See Bullard and Mitra (2002) JME. Result, given that ϕ_y and ϕ_π are nonnegative,

$$\kappa\left(\phi_\pi - 1\right) + \left(1 - \beta\right)\phi_y > 0$$

- Note: If $\phi_\pi > 1$ and $\phi_y > 0$ the above expression holds.

Monetary policy shock

- Set $r_t^n - \rho = 0$ ($a_t = 0$)
- Assume v_t follows

$$v_t = \rho_v v_{t-1} + \varepsilon_t^v$$

- Calibration as before
- Sticky prices: $\theta = \frac{2}{3}$. Prices last for nine months (also try $\theta = \frac{4}{5}$)
- $\phi_y = 0.5/4$ and $\phi_\pi = 1.5$
- Use undetermined coefficient method to solve: Assume that solution is given by

$$\begin{aligned} \tilde{y}_t &= \psi_{yv} v_t \\ \pi_t &= \psi_{\pi v} v_t \end{aligned}$$

- Plug solution into the system (5) to get

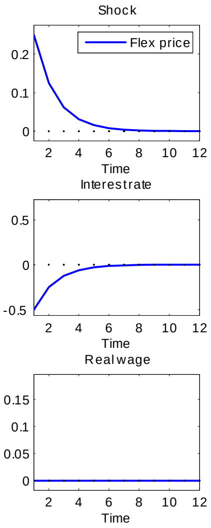
$$\begin{aligned}
\begin{bmatrix} \tilde{y}_t \\ \pi_t \end{bmatrix} &= \begin{bmatrix} \psi_{yv} v_t \\ \psi_{\pi v} v_t \end{bmatrix} = A_T \begin{bmatrix} E_t \left[\psi_{yv} v_{t+1} \right] \\ E_t \left[\psi_{\pi v} v_{t+1} \right] \end{bmatrix} + B_T \left(-v_t \right) \\
&= A_T \begin{bmatrix} \psi_{yv} \\ \psi_{\pi v} \end{bmatrix} \rho_v v_t + B_T \left(-v_t \right)
\end{aligned}$$

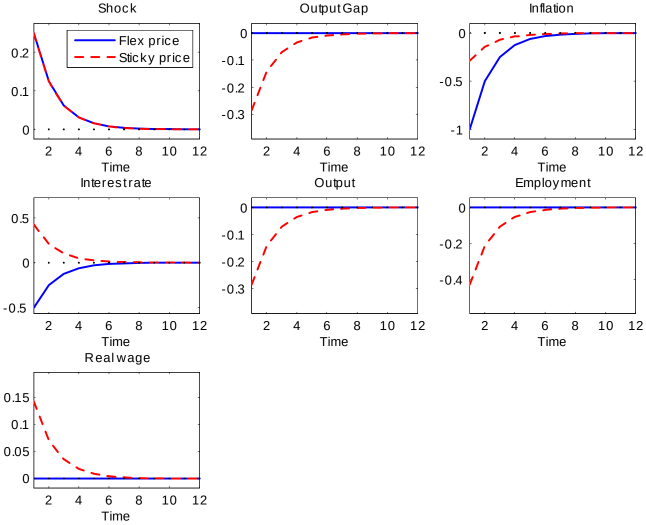
Equation system in coefficients. Divide through by v_t to get

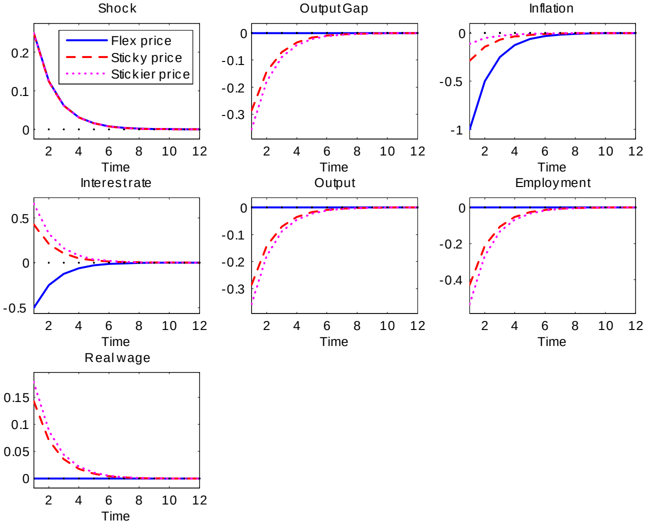
$$\begin{bmatrix} \psi_{yv} \\ \psi_{\pi v} \end{bmatrix} = A_T \begin{bmatrix} \psi_{yv} \\ \psi_{\pi v} \end{bmatrix} \rho_v - B_T$$

or

$$\left(I - A_T \rho_v \right) \begin{bmatrix} \psi_{yv} \\ \psi_{\pi v} \end{bmatrix} = -B_T \iff \begin{bmatrix} \psi_{yv} \\ \psi_{\pi v} \end{bmatrix} = -\left(I - A_T \rho_v \right)^{-1} B_T$$


Shock
Flex price
0.2
0.1
0
2 4 6 8 10 12
Time
OutputGap
0
-0.1
-0.2
-0.3
Time
Inflation
0
-0.5
-1
Time
Interestrate
0.5
0
-0.5
Time
Output
0
-0.1
-0.2
-0.3
Time
Employment
0
-0.2
-0.4
Time
Realwage
0.15
0.1
0.05
0
Time

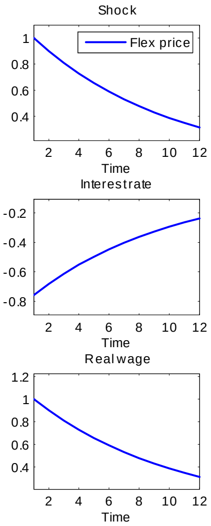

Shock
Flex price
Sticky price
0.2
0.1
0
2 4 6 8 10 12
Time
OutputGap
0
-0.1
-0.2
-0.3
Inflation
0
-0.5
-1
Interestrate
0.5
0
-0.5
Output
Employment
-0.2
-0.4
Realwage
0.15
0.1
0.05

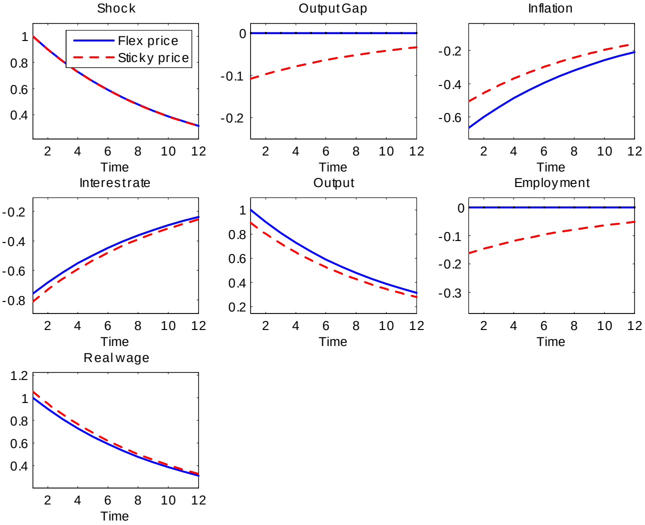

Shock
Flex price
Sticky price
Stickier price
0.2
0.1
0
2 4 6 8 10 12
Time
Output Gap
0
-0.1
-0.2
-0.3
Time
Inflation
0
-0.5
-1
Time
Interest rate
0.5
0
-0.5
Time
Output
0
-0.1
-0.2
-0.3
Time
Employment
0
-0.2
-0.4
Time
Real wage
0.15
0.1
0.05
0
Time

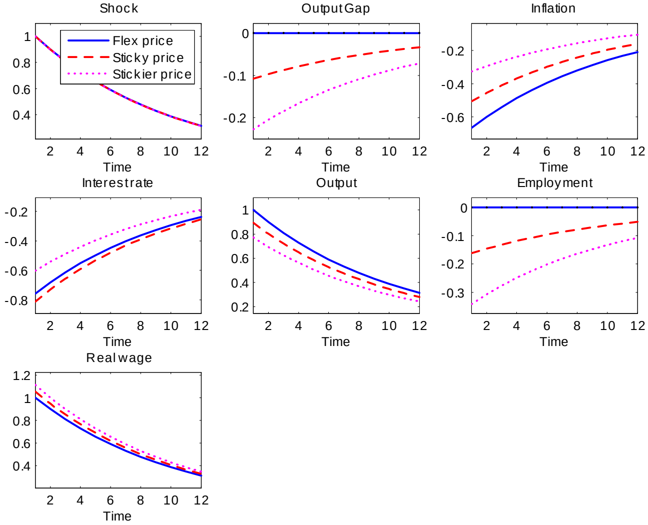
- Flexible prices: Inflation and interest rate moves in the same way
- Sticky prices: Inflation and interest rate moves in opposite directions
- Sticky prices: Output and interest rate moves in opposite directions

Productivity shocks

- From empirical evidence - Employment should initially responds negatively


Shock
Flex price
1
0.8
0.6
0.4
2
4
6
8
10
12
Time
OutputGap
0
-0.1
-0.2
Time
Inflation
-0.2
-0.4
-0.6
Time
Interestrate
-0.2
-0.4
-0.6
-0.8
Time
Output
1
0.8
0.6
0.4
0.2
Time
Employment
0
-0.1
-0.2
-0.3
Time
Realwage
1.2
1
0.8
0.6
0.4
Time


Shock
Flex price
Sticky price
OutputGap
Inflation
Interestrate
Output
Employment
Realwage
Time



Shock
Flex price
Sticky price
Stickier price
1
0.8
0.6
0.4
2 4 6 8 10 12
Time
Output Gap
0
-0.1
-0.2
Inflation
-0.2
-0.4
-0.6
Interest rate
-0.2
-0.4
-0.6
-0.8
Output
1
0.8
0.6
0.4
0.2
Employment
0
-0.1
-0.2
-0.3
Real wage
1.2
1
0.8
0.6
0.4

- Employment responds negatively
- Real wages still problem
- Inflation responds less (also output responds less but change not as big as for inflation)

Other ways of modelling monetary non-neutrality

- Other types of price-setting frictions
  - Taylor (1979) AER - Cohorts sets prices/wages in overlapping contracts
  - Rotemberg (1982) JPE - Quadratic cost of price adjustment
  - Calvo /Taylor / Rotemberg gives rise to same shaped NKPC - See Roberts (1995) JMCB.
  - Menu costs - Golosov and Lucas (2007) JPE (much older idea) - Fix adjustment cost - Firms chose optimally to adjust or not (State-dependent pricing) In menu cost models the degree of monetary non-neutrality varies with the set up - Midrigan (2010) Econometrica Karadi and Reiff (2014).

Other ways of modelling monetary non-neutrality

- Information frictions
  - Lucas (1972) JET
  - Sticky information - Mankiw and Reis (2002) QJE
  - Rational Inattention - Mackowiak and Wiederholt (2009) AER

Optimal monetary policy design: Introduction

- How should monetary policy be designed
- Optimal policy - Here objectives/criterions for optimal policy (implementation pushed into the background - See Galí Ch. 3 for a discussion)
- Using simple rules to get close to optimal policy - Rules that doesn't require full knowledge of the model and parameters

Optimal monetary policy in the flex-price eq

- In RBC model from Lecture 2: inflation does not matter at all for the real allocation
- Money-in-the-utility-function: downward-sloping function of the interest rate
- Conclusion: set $i_t = 0$ to maximize cash-holdings and let $\pi_t = -r_t$, the Friedman rule!
- With sticky prices and monopolistic competition, this is no longer true...

Efficiency

- Solve the central planners problem, given technology and preferences
- No transaction frictions
- No capital
- Planner solves

$$\max U\left(C_t, N_t\right)$$

subject to

$$C_t\left(i\right) = A_t\left(N_t\left(i\right)\right)^{1-\alpha}$$

where

$$\begin{aligned} N_t &= \int_0^1 N_t\left(i\right) di \\ C_t &= \left(\int_0^1 \left(C_t\left(i\right)\right)^{\frac{\varepsilon-1}{\varepsilon}} di\right)^{\frac{\varepsilon}{\varepsilon-1}} \end{aligned}$$

- The Lagrangian is

$$\begin{aligned} L &= U\left(\left(\int_0^1 (C_t(i))^{\frac{\varepsilon-1}{\varepsilon}} di\right)^{\frac{\varepsilon}{\varepsilon-1}}, \int_0^1 N_t(i)\, di\right) \\ &\quad - \int_0^1 \lambda_t(i)\left(C_t(i) - A_t(N_t(i))^{1-\alpha}\right) di \end{aligned}$$

- The first-order conditions are, with respect to $C_t(i)$ and $N_t(i)$,

$$\begin{aligned} U_c(C_t, N_t)\left(\int_0^1 (C_t(i))^{\frac{\varepsilon-1}{\varepsilon}} di\right)^{\frac{\varepsilon}{\varepsilon-1}-1} (C_t(i))^{\frac{\varepsilon-1}{\varepsilon}-1} - \lambda_t(i) &= 0 \\ U_n(C_t, N_t) + \lambda_t(i)(1-\alpha) A_t (N_t(i))^{-\alpha} &= 0 \end{aligned}$$

- The first-order conditions for $N_t(i)$ can be written as

$$U_n(C_t, N_t)\, N_t(i) = -\lambda_t(i)\,(1-\alpha)\, A_t\,(N_t(i))^{1-\alpha}$$

or

$$U_n(C_t, N_t)\left(\frac{C_t(i)}{A_t}\right)^{\frac{1}{1-\alpha}} = -\lambda_t(i)\,(1-\alpha)\, C_t(i)$$

- The first-order conditions for $C_t(i)$ can be written as

$$\begin{aligned} & U_c(C_t, N_t)\left(\int_0^1 (C_t(i))^{\frac{\varepsilon-1}{\varepsilon}}\, di\right)^{\frac{1}{\varepsilon-1}\frac{\varepsilon}{\varepsilon}} (C_t(i))^{-\frac{1}{\varepsilon}} \\ = \quad & U_c(C_t, N_t)\, C_t^{\frac{1}{\varepsilon}}\,(C_t(i))^{-\frac{1}{\varepsilon}} = \lambda_t(i). \end{aligned}$$

- Combining the above conditions gives

$$U_n\left(C_t, N_t\right)\left(\frac{C_t\left(i\right)}{A_t}\right)^{\frac{1}{1-\alpha}} = -U_c\left(C_t, N_t\right) C_t^{\frac{1}{\varepsilon}}\left(C_t\left(i\right)\right)^{-\frac{1}{\varepsilon}}\left(1-\alpha\right) C_t\left(i\right) \tag{6}$$

Since this holds for all $i \in [0,1]$ the solution for all $C_t\left(i\right)$ is the same for all i implying that $\lambda_t\left(i\right)$ and $N_t\left(i\right)$ is the same over firms and thus

$$N_t = N_t\left(i\right) \text{ and } \lambda_t = \lambda_t\left(i\right). \tag{7}$$

- The first-order condition with respect to $C_t\left(i\right)$ then simplifies to

$$U_c\left(C_t, N_t\right) = \lambda_t$$

and hence, using $\frac{\partial L}{\partial N}$,

$$\underbrace{-\frac{U_n\left(C_t, N_t\right)}{U_c\left(C_t, N_t\right)}}_{MRS_t} = \left(1-\alpha\right) A_t\left(N_t\right)^{-\alpha} = MPN_t \tag{8}$$

- Important lessons
  - Marginal rate of substitution between labor and consumption equal to marginal product (8)
  - Labor choices in different firms identical (7)
  - All goods produced in same amount (6)
- All these three violated in the basic New Keynesian model

Monopolistic competition violates (8)

- In model with flexible prices, we get from profit maximization

$$P_t = \mathcal{M} MC_t = \mathcal{M} \frac{W_t}{MPN_t} \tag{9}$$

- Since the labor market is perfectly competitive,

$$\underbrace{-\frac{U_{n,t}}{U_{c,t}}}_{MRS_t} = \frac{W_t}{P_t} \tag{10}$$

and hence

$$-\frac{U_{n,t}}{U_{c,t}} = \frac{1}{\mathcal{M}} MPN_t$$

- Although we do not have flexible prices, we are close to the flexible price equilibrium - we look at deviations from flexible price equilibrium
- Flexible price allocation inefficient due to markup (we require $-\frac{U_{n,t}}{U_{c,t}} = MPN_t$ for efficiency)

- Inefficiency can be eliminated through subsidy
- Suppose firms only pay $(1-\tau)$ times the consumer wage (modifying (9) but not (10)). Profit maximization now gives

$$P_t = \mathcal{M}\frac{(1-\tau)\,W_t}{MPN_t} \iff -\frac{U_{n,t}}{U_{c,t}} = \frac{1}{\mathcal{M}\,(1-\tau)}MPN_t$$

- Setting

$$(1-\tau) = \frac{1}{\mathcal{M}}$$

  eliminates distortions!
- Realistic?

Distortions associated with nominal rigidities

1. Markup variations. Average markup over marginal cost in economy

$$\mathcal{M}_t = \frac{P_t}{(1-\tau)\frac{W_t}{MPN_t}} = \frac{P_t}{\frac{W_t}{MPN_t}}\mathcal{M} \iff \frac{\mathcal{M}}{\mathcal{M}_t}MPN_t = \frac{W_t}{P_t} = -\frac{U_{n,t}}{U_{c,t}}$$

   Again (8) might be violated ($\frac{\mathcal{M}}{\mathcal{M}_t}$ not always unity).

2. In addition - Sticky prices leads to

$$P_t(i) \neq P_t(j)$$

   implying

$$C_t(i) \neq C_t(j) \text{ and } N_t(i) \neq N_t(j)$$

Welfare in model with price rigidities

- To find optimal policy, we need to compute welfare with sticky prices
- We use second-order approximation of utility around the efficient allocation (inefficiencies due to nominal rigidities)

Welfare in model with price rigidities

- Some tedious algebra (See Galí Appendix 4.1) gives welfare losses in terms of permanent consumption decline from deviating from the efficent allocation

$$-E_0 \sum_{t=0}^{\infty} \frac{U_t - U_t^n}{U_c C} \approx \frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t \left(\left(\sigma + \frac{\varphi + \alpha}{1 - \alpha} \right) (\tilde{y}_t)^2 + \frac{\epsilon}{\lambda} \pi_t^2 \right) \quad (11)$$

- Intuition for welfare losses: Firms have different prices $\Rightarrow$ different labor demand $\Rightarrow$ price distribution matters for welfare.
- High inflation in period t leads to high relative price in period t.
- First-order effects are eliminated due to efficiency, while second-order effects remain

Optimal policy

- Assume that we initially have no relative price distortions; $P_{-1}(i) = P_{-1}$ for all firms $i \in [0,1]$
- Also assume optimal employment subsidy
- One way to find optimal policy is to do the following:
- Social planner chooses sequences $\{\pi_t\}_{t=0}^{\infty}$, $\{\tilde{y}_t\}_{t=0}^{\infty}$ and $\{i_t\}_{t=0}^{\infty}$ to minimize

$$\frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t \left(\left(\sigma + \frac{\varphi + \alpha}{1-\alpha} \right) (\tilde{y}_t)^2 + \frac{\epsilon}{\lambda} \pi_t^2 \right)$$

subject to private sector optimization.

Optimal policy

- Private sector behavior can be summarized by

$$
\begin{aligned}
\tilde{y}_t &= E_t\left[\tilde{y}_{t+1}\right] - \frac{1}{\sigma}\left(i_t - E_t\left[\pi_{t+1}\right] - r_t^n\right) \\
\pi_t &= \beta E_t\left[\pi_{t+1}\right] + \kappa \tilde{y}_t
\end{aligned}
$$

where

$$
r_t^n = \rho + \sigma E_t\left[y_{t+1}^n - y_t^n\right]
$$

- Suppose planner chooses, for all t,

$$i_t = r_t^n \text{ and } \pi_t = 0 \text{ and } \tilde{y}_t = 0$$

- Satisfies constraints
- First-best achieved !

- Intuition: Planner can choose variables so that marginal costs for firms induce them to set optimal prices equal to previous prices,

$$P_t^* = P_{-1}(i) \Rightarrow \pi_t = 0$$

  Can be seen in Phillips curve by noting that $\tilde{y}_t = 0$ and expectation of $E_t[\pi_{t+1}] = 0$ implies that $\pi_t = 0$.
- If there is initial price distortion, the optimal policy converges to the one above - Yun (2005) AER

- Note

$$i_t = r_t^n$$

Thus, the equilibrium nominal interest rate (which is also the real rate since $\pi_t = 0$) in the model with sticky prices is equal to the flexible price real interest rate

- Implementation is tricky: $i_t = r_t^n$ is not a good choice as an interest rate rule - multiplicity in equilibria - add endogenous component to the rule to achive an unique equilibrium (Galí 4.3).

Simple Rules

- Above: r_t^n and $\tilde{y}_t$ depend on flexible price equilibrium, which we do not observe ("Optimal Policy Rules"). Use steady state value of output and real interest rate instead:
- Modified output gap

$$\hat{y}_t = y_t - \bar{y}$$

and

$$\hat{r}_t^n = -\sigma \psi_{ya}^n \left(1 - \rho_a\right) a_t$$

- Can try to find rules that are close to optimal

Simple Rules

- Taylor Rule, where $\hat{y}_t = y_t - \bar{y}$ which is observable

$$i_t = \rho + \phi_\pi \pi_t + \phi_y \hat{y}_t$$

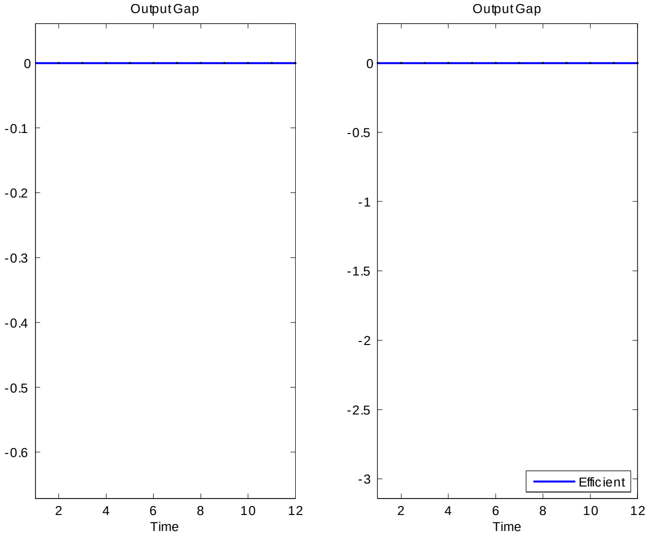
or, where we let $v_t = \phi_y \left(y_t^n - \bar{y} \right)$,

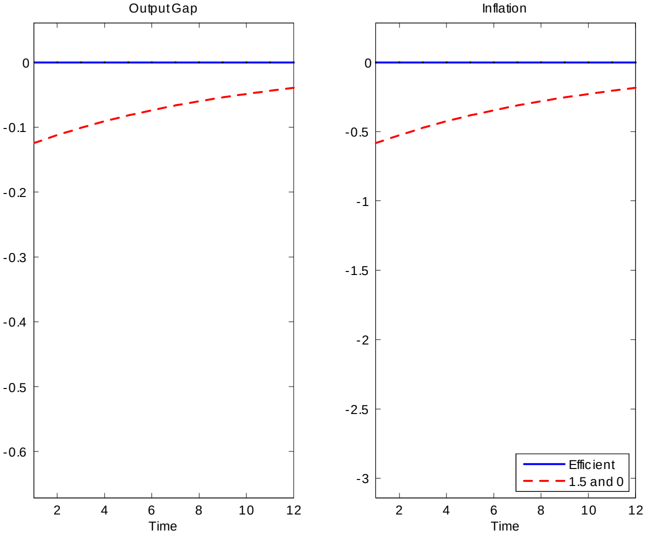
$$i_t = \rho + \phi_\pi \pi_t + \phi_y \tilde{y}_t + v_t$$

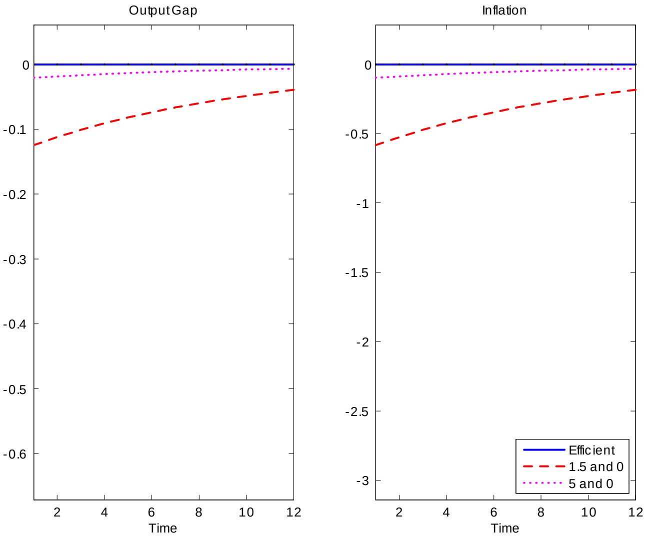
- System similar to before (reinterpreted shock)

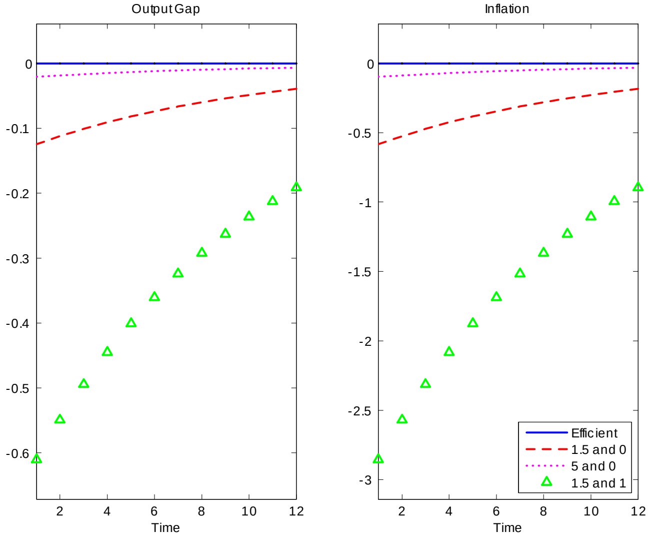
$$\begin{bmatrix} \tilde{y}_t \\ \pi_t \end{bmatrix} = \Omega \begin{bmatrix} \sigma & 1-\beta\theta_\pi \\ \sigma\kappa & \kappa+\beta\left(\sigma+\phi_y\right) \end{bmatrix} E_t \begin{bmatrix} \tilde{y}_{t+1} \\ \pi_{t+1} \end{bmatrix} + \Omega \begin{bmatrix} 1 \\ \kappa \end{bmatrix} (\hat{r}_t^n - v_t)$$

- Difference equation. Can be solved.
- Plug solution into welfare loss and evaluate
- Three cases,
  1. $\phi_\pi = 1.5$, $\phi_y = 0$
  2. $\phi_\pi = 5$, $\phi_y = 0$
  3. $\phi_\pi = 1.5$, $\phi_y = 1$


OutputGap
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
2
4
6
8
10
12
Time
OutputGap
0
-0.5
-1
-1.5
-2
-2.5
-3
Efficient
Time


Output Gap
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
2
4
6
8
10
12
Time
Inflation
0
-0.5
-1
-1.5
-2
-2.5
-3
2
4
6
8
10
12
Time
Efficient
1.5 and 0


Output Gap
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
2
4
6
8
10
12
Time
Inflation
0
-0.5
-1
-1.5
-2
-2.5
-3
2
4
6
8
10
12
Time
Efficient
1.5 and 0
5 and 0



Output Gap
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
2
4
6
8
10
12
Time
Inflation
0
-0.5
-1
-1.5
-2
-2.5
-3
2
4
6
8
10
12
Time
Efficient
1.5 and 0
5 and 0
1.5 and 1

Welfare Losses

	Taylor		
ϕ_π	1.5	1.5	5
ϕ_y	0	1	0
Welfare Loss	0.08	1.92	0.002