Macroeconomics II Part II, Lecture V: The New-Keynesian Model: Shocks & Propagataion

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Recap

- Basic NK model = RBC model + monopolistic competition and sticky prices
- Last lecture: Setup, derivations and determinacy
- Today: What are the predictions of the NK model?

Agenda

1. Monetary Policy shocks
2. TFP shocks
3. Cost-push shocks

Monetary Policy shocks

The 3-equation representation

- The log-linearized equilibrium can be characterized by

$$\begin{aligned} \text{DIS curve:} \quad & \hat{y}_t = -(\hat{i}_t - E_t\pi_{t+1}) + E_t\hat{y}_{t+1} \\ \text{Phillips curve:} \quad & \pi_t = \beta E_t\pi_{t+1} + \kappa\hat{y}_t \\ \text{Policy rule:} \quad & \hat{i}_t = \phi\pi_t + \nu_t \end{aligned}$$

- 3 equations in 3 unknowns: $\{\hat{y}_t, \hat{i}_t, \pi_t\}$!

- This is how the model is usually presented in the literature

- **Warning!:** Although very convenient, these equations mix multiple equilibrium relationships $\Rightarrow$ hard to extract a precise intuition about model mechanisms

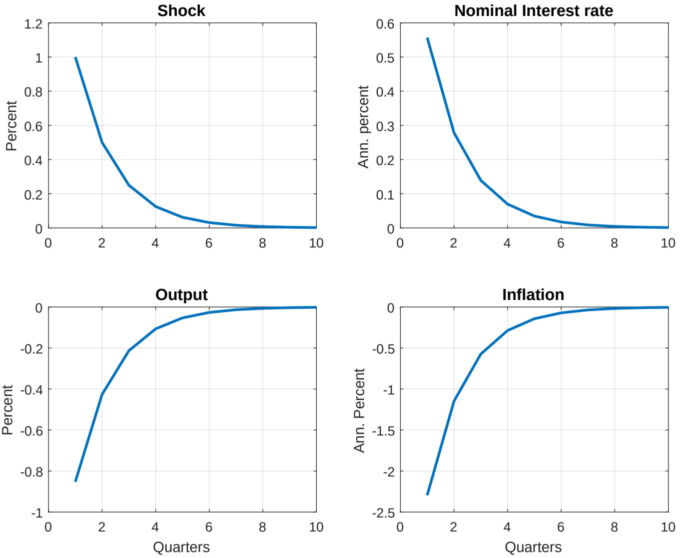
Calibration

- Quarterly frequency
- For the recurrent parameters, let's stick with we used for our RBC model
  - $\beta = 0.99$
  - $\varphi = 1$
- The new ones:
  - $\theta = 2/3$ to match average price duruation of three quarters (Galí-Lopéz-Salido EER 2001)
  - $\epsilon = 6$ to match average markup of 20%
  - $\phi = 1.5$ to match Fed reaction function during Greenspan era
- The shock process:

$$\nu_t = \rho_\nu \nu_{t-1} + \epsilon_t$$

with $\rho_\nu = 0.5$ to generate a "moderately" persistent shocks, as we saw in the empirical IRFs

IRFs to monetary policy shock



Comments I

- In contrast to the vanilla RBC model, there are no humps and bumps here
- This is the because the model has no state variable - dynamics are completely forward-looking:

$$\begin{aligned} \text{DIS curve:} \quad & \hat{y}_t = -(\hat{i}_t - E_t\pi_{t+1}) + E_t\hat{y}_{t+1} \\ \text{Phillips curve:} \quad & \pi_t = \beta E_t\pi_{t+1} + \kappa\hat{y}_t \\ \text{Policy rule:} \quad & \hat{i}_t = \phi\pi_t + \nu_t \end{aligned}$$

- This means that the policy function for any variable $x_t \in \{\hat{y}_t, \pi_t, \hat{i}_t\}$

$$x_t = \sum_{s=0}^{t} a^x_{t-s}\nu_s$$

has $a_{t-s} = 0$ for all $s < t$, i.e.,

$$x_t = a^x_0\nu_t.$$

- An implication is that you can solve for the IRFs analytically, see problem set 6.

Comments II

- Basic NK model qualitatively matches the evidence: a surprise increase in the policy rate leads to a fall in y
- Quantitatively, it is way off, we'll get back to this in Lecture VI
- To understand the mechanism, let's go back to the full 8-equation system, where we have more clean interpretations of the equilibrium equations

Reminder: Full system looks like...

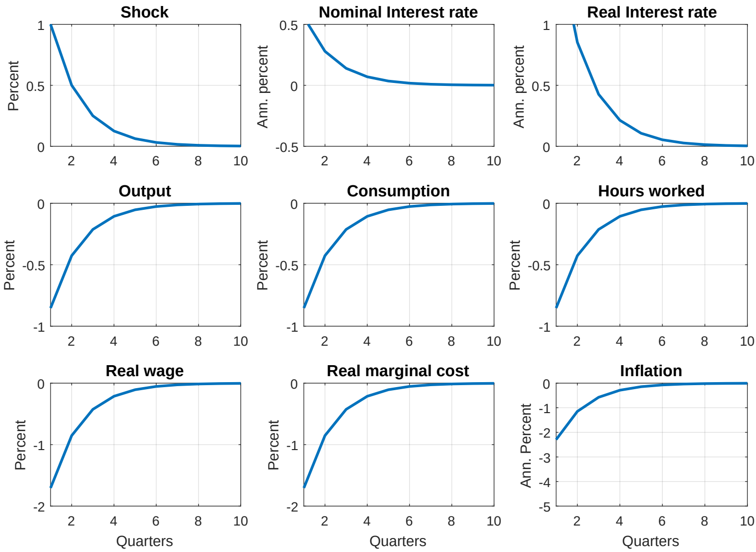
- The log-linearized equilibrium is characterized by

$$\begin{aligned} \text{Intratemporal hh optimality:} \quad & \hat{\omega}_t = \hat{c}_t + \varphi \hat{n}_t \\ \text{Intertemporal hh optimality:} \quad & \hat{c}_t = -(\hat{i}_t - E_t \pi_{t+1}) + E_t \hat{c}_{t+1} \\ \text{Firm optimality:} \quad & \pi_t = \beta E_t \pi_{t+1} + \lambda \widehat{mc}_t \\ \text{Marginal cost:} \quad & \widehat{mc}_t = \hat{\omega}_t \\ \text{Goods clearing:} \quad & \hat{c}_t = \hat{y}_t \\ \text{Labor clearing:} \quad & \hat{y}_t = \hat{n}_t \\ \text{Policy:} \quad & \hat{i}_t = \phi \pi_t + \nu_t \end{aligned}$$

where $\hat{\omega}_t = \hat{w}_t - p_t$ is log deivations in the real wage

- Note: Real interest rate given by $\hat{r}_t = \hat{i}_t - E_t \pi_{t+1}$

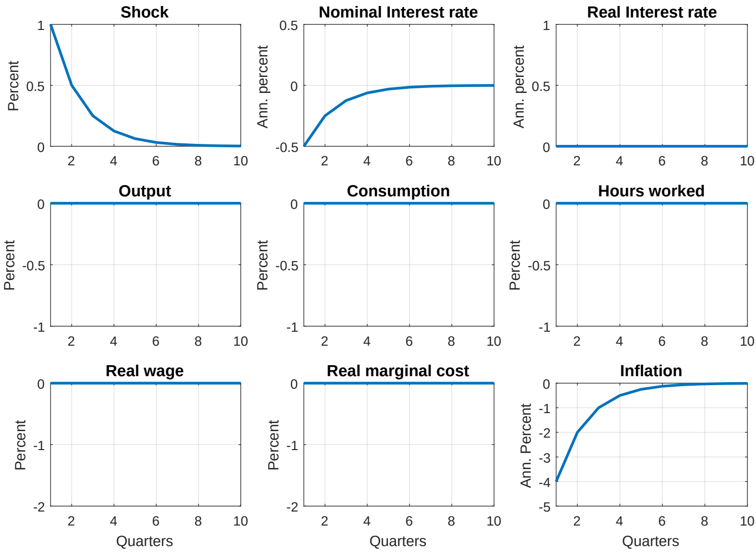
IRFs to monetary policy shock: full system



IRFs to monetary policy shock: mechanism

- How can we explain the equilibrium responses?
- Simplify, simplify, simplify
- Let's start with flexible prices: $\theta \to 0$

IRFs to monetary policy shock under flexible prices



Mechanism under flexible prices

- Last lecture, we showed that under flexible prices, system collapses to

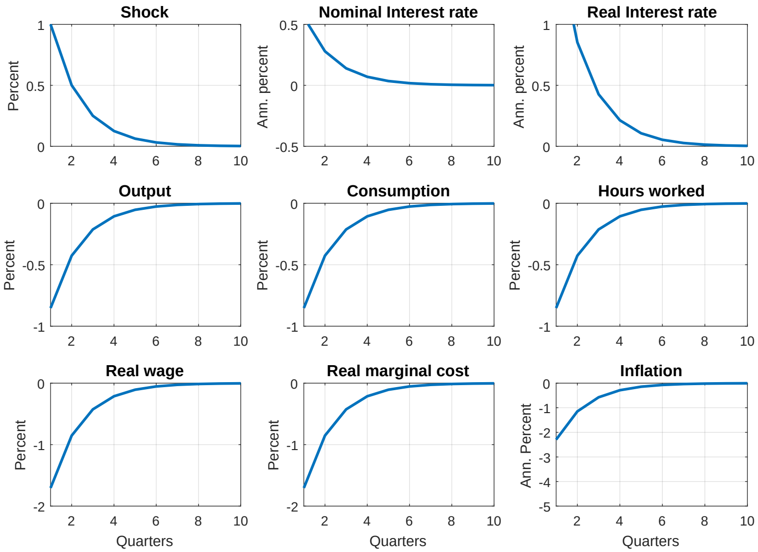
$$\begin{aligned} \text{DIS curve:} \qquad & \hat{i}_t = E_t \pi_{t+1} \\ \text{Policy rule:} \qquad & \hat{i}_t = \phi \pi_t + \nu_t \end{aligned}$$

- 0 response of all real variables, i.e., monetary neutraility
- We also showed that the unique solution has

$$\pi_t = -\sum_{s=0}^{\infty} \frac{1}{\phi^{s+1}} \nu_{t+s}$$

- Inflation falling in response to “contractionary” monetary policy shock has nothing to do with sticky prices or other frictions, simply a consequence of a Taylor and rational expectations
- Inflation response so strong that interest rate falls in response to positive shock!

Back to sticky prices



Mechanism

- Sticky price $\rightarrow$ smaller inflation response
- With smaller inflation response, nominal interest rate actually increases
- As a consequence, the real interest rate increases:

$$\hat{r}_t = \hat{i}_t - E_t \pi_{t+1}$$

- Monetary non-neutraility!
- Given that the real interest rate increases, we can back out the response of all other variables
- In so doing, recall that we have assumed that we only search for bounded solutions!

Mechanism cont'd

- Take as given that $\hat{r}_t$ increases, then

$$\text{Intertemporal hh optimality:} \qquad \hat{c}_t = -(\hat{r}_t) + E_t \hat{c}_{t+1}$$

  implies $\Delta E_t c_{t+1}$ is positive

- $\Delta E_t c_{t+1} > 0$ + Bounded solution $\Rightarrow \{\hat{c}_{t+s}\}$ must converge to some steady state
- But the steady state is unique, so we know $\{\hat{c}_{t+s}\}$ must converge to $\hat{c}_{t+s} = 0$
- Therefore, we must have that $\hat{c}_t < 0$!

Mechanism cont'd

- Take as given that $\hat{c}_t < 0$
- Market clearing $\hat{c}_t = \hat{y}_t = \hat{n}_t < 0$
  - $\Rightarrow$ we may think of the output drop as being caused by drop in aggregate demand
- How is this consistent with optimal labor supply? Intratemporal optimality condition:

$$\text{Intratemporal hh optimality:} \qquad \hat{\omega}_t = \hat{c}_t + \varphi \hat{n}_t$$

- $\hat{n}_t < 0$ only if $\hat{\omega}_t < \hat{y}_t < 0$
  - Wages need to respond more than output (and profits less)!
- Is the fall in inflation consistent with the Phillips curve?
  - $\hat{\omega}_t < 0 \Rightarrow \hat{m}c_t < 0 \Rightarrow \beta E_t \pi_{t+1} - \pi_t \approx \Delta\pi_{t+1} > 0$ from the Phillips curve
  - Again, bounded solution + unique steady state $\Rightarrow \hat{\pi}_t < 0$

Monetary policy shock equivalent to demand shock

- Recall: DIS curve stems from household Euler equation

$$c_t = -(i_t - E_t\pi_{t+1} - \xi) + E_t c_{t+1}$$

  where $\xi = -\log\beta$

- Suppose there are shocks to discount factor β
  - Specifically, assume $\xi_t = \rho_\xi \xi_{t-1} + \epsilon_{\xi,t}$
  - $=$ shock to the marginal value of current consumption - a "demand shock"

- Then, 3-equation system becomes

$$\begin{aligned} \text{DIS curve:} \quad & \hat{y}_t = -(\hat{i}_t - E_t\pi_{t+1} - \xi_t) + E_t\hat{y}_{t+1} \\ \text{Phillips curve:} \quad & \pi_t = \beta E_t\pi_{t+1} + \kappa\hat{y}_t \\ \text{Policy rule:} \quad & \hat{i}_t = \phi\pi_t + \nu_t \end{aligned}$$

  or

$$\begin{aligned} \text{DIS curve + Policy rule:} \quad & \hat{y}_t = -(\phi\pi_t - E_t\pi_{t+1}) + E_t\hat{y}_{t+1} + \xi_t - \nu_t \\ \text{Phillips curve:} \quad & \pi_t = \beta E_t\pi_{t+1} + \kappa\hat{y}_t \end{aligned}$$

- $\Rightarrow$ Positive monetary policy shocks are equivalent to negative demand shocks

TFP shocks

TFP shocks

- So far: focus on monetary policy shocks
- Naturally, we are interested in how sticky prices and the behavior of monetary policy affect response to non-policy shocks
- Let's consider TFP shocks
- Assume that $a_t \equiv \log A_t$ follows

$$a_t = \rho_a a_{t-1} + \epsilon_t^a$$

- Which equations in our equilibrium system are affected?

$$\begin{aligned}
\text{Intratemporal hh optimality:} \quad & \hat{\omega}_t = \hat{c}_t + \varphi \hat{n}_t \\
\text{Intertemporal hh optimality:} \quad & \hat{c}_t = -(\hat{i}_t - E_t \pi_{t+1}) + E_t \hat{c}_{t+1} \\
\text{Firm optimality:} \quad & \pi_t = \beta E_t \pi_{t+1} + \lambda \widehat{mc}_t \\
\text{Marginal cost:} \quad & \widehat{mc}_t = \hat{\omega}_t \\
\text{Goods clearing:} \quad & \hat{c}_t = \hat{y}_t \\
\text{Labor clearing:} \quad & \hat{y}_t = \hat{n}_t \\
\text{Policy:} \quad & \hat{i}_t = \phi \pi_t + \nu_t
\end{aligned}$$

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Intratemporal hh optimality:	$\hat{\omega}_t = \hat{c}_t + \varphi \hat{n}_t$
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Firm optimality:	$\pi_t = \beta E_t \pi_{t+1} + \lambda \widehat{mc}_t$
Marginal cost:	$\widehat{mc}_t = \hat{\omega}_t$
Goods clearing:	$\hat{c}_t = \hat{y}_t$
Labor clearing:	$\hat{y}_t = \hat{n}_t$
Policy:	$\hat{i}_t = \phi \pi_t + \nu_t$

Incorporating TFP shocks

- Marginal cost:

$$MC_t = \frac{W_t}{A_t P_t} \quad \Rightarrow \hat{m}c_t = \hat{\omega}_t - a_t$$

- Labor market clearing:

$$N_t = \frac{Y_t}{A_t} D_t \quad \Rightarrow \hat{n}_t = \hat{y}_t - a_t$$

- Again, here we have that $\hat{a}_t = a_t$

Full system with TFP shocks

- The log-linearized equilibrium is characterized by

$$\begin{aligned}
\text{Intratemporal hh optimality:} &\quad \hat{\omega}_t = \hat{c}_t + \varphi \hat{n}_t \\
\text{Intertemporal hh optimality:} &\quad \hat{c}_t = -(\hat{i}_t - E_t \pi_{t+1}) + E_t \hat{c}_{t+1} \\
\text{Firm optimality:} &\quad \pi_t = \beta E_t \pi_{t+1} + \lambda \widehat{mc}_t \\
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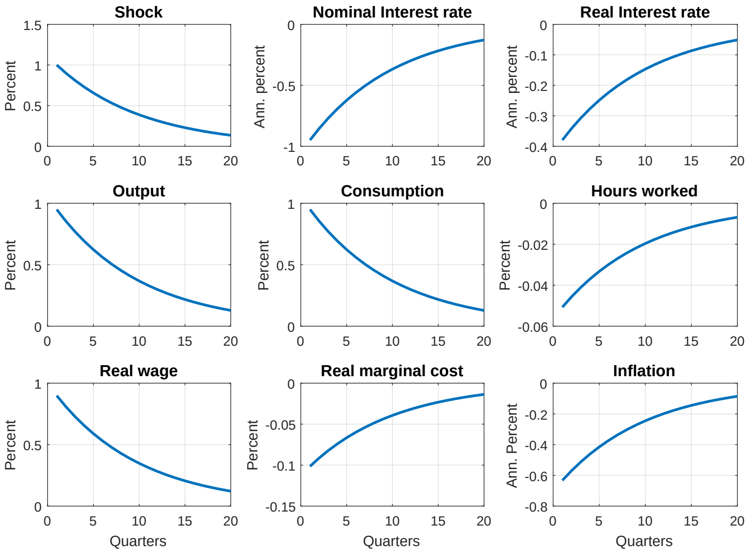
\text{Goods clearing:} &\quad \hat{c}_t = \hat{y}_t \\
\text{Labor clearing:} &\quad \hat{y}_t = \hat{n}_t + a_t \\
\text{Policy:} &\quad \hat{i}_t = \phi \pi_t + \nu_t
\end{aligned}$$

where $\hat{\omega}_t = \hat{w}_t - p_t$ is log deivations in the real wage

- Also, the law of motion for exogenous shocks:

$$\begin{aligned}
\nu_t &= \rho_\nu \nu_{t-1} + \epsilon_t \\
a_t &= \rho_a a_{t-1} + \epsilon_t^a
\end{aligned}$$

IRFs to a TFP shock



Mechanism

- Again, no hump shapes like in the vanilla RBC model.
  - Again, without capital, there is no state variable.
- Recall, in RBC without capital, hours worked did not respond at all
- Here, hours worked falls
  - Galí (AER 1999) and Basu-Fernald-Kimball (AER 2006) argue this is consistent with the data
- What role does sticky prices and monetary policy play for this response?
- Again, let's go back to flexible prices (which is just the RBC model with no capital (and monopolistic competition))
- With flexible prices, firm optimality is

$$\begin{aligned} P_{it} &= M\psi_t \\ \frac{P_{it}}{P_t} &= M\frac{\psi_t}{P_t} \quad \Rightarrow \widehat{mc}_t = 0 \end{aligned}$$

- All other relationships are unaffected

Equilibrium system with flexible prices

- The log-linearized equilibrium is characterized by

$$\begin{aligned}
\text{Intratemporal hh optimality:} \quad & \hat{\omega}_t = \hat{c}_t + \varphi \hat{n}_t \\
\text{Intertemporal hh optimality:} \quad & \hat{c}_t = -(\hat{i}_t - E_t \pi_{t+1}) + E_t \hat{c}_{t+1} \\
\text{Firm optimality:} \quad & \widehat{mc}_t = 0 \\
\text{Marginal cost:} \quad & \widehat{mc}_t = \hat{\omega}_t - a_t \\
\text{Goods clearing:} \quad & \hat{c}_t = \hat{y}_t \\
\text{Labor clearing:} \quad & \hat{y}_t = \hat{n}_t + a_t \\
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\end{aligned}$$

where $\hat{\omega}_t = \hat{w}_t - p_t$ is log deivations in the real wage

- Also, the law of motion for exogenous shocks:

$$\begin{aligned}
\nu_t &= \rho_\nu \nu_{t-1} + \epsilon_t \\
a_t &= \rho_a a_{t-1} + \epsilon_t^a
\end{aligned}$$

Equilibrium system with flexible prices: solution

- The log-linearized equilibrium is characterized by

$$
\begin{aligned}
\text{Intratemporal hh optimality:} \quad & \hat{\omega}_t = \hat{c}_t + \varphi \hat{n}_t \\
\text{Intertemporal hh optimality:} \quad & \hat{c}_t = -(\hat{i}_t - E_t \pi_{t+1}) + E_t \hat{c}_{t+1} \\
\text{Firm optimality:} \quad & \widehat{mc}_t = 0 \\
\text{Marginal cost:} \quad & \widehat{mc}_t = \hat{\omega}_t - a_t \\
\text{Goods clearing:} \quad & \hat{c}_t = \hat{y}_t \\
\text{Labor clearing:} \quad & \hat{y}_t = \hat{n}_t + a_t \\
\text{Policy:} \quad & \hat{i}_t = \phi \pi_t + \nu_t
\end{aligned}
$$

- Work it through to find the natural interest rate: (Do on whiteboard)

$$
\begin{aligned}
\hat{r}_t^n &= \hat{i}_t - E_t \pi_{t+1} \\
&= -(1 - \rho_a) a_t
\end{aligned}
$$

- Key result: positive TFP shocks cause a decline in the natural real interest rate

- Mechanism: $a_t > 0 \Rightarrow \Delta E_t a_{t+1} < 0 \Rightarrow \Delta E_t c_{t+1} < 0 \Rightarrow \hat{r}_t^n < 0$

Sticky-price equilibrium in gaps

- Let's turn back to the sticky-price equilibrium
- We linearized the equilibrium around the steady state $\hat{x} = x_t - x_{ss}$, for any x
- Let's instead consider a linearization around the flexible-price equilibrium or, using another terminology, the natural equlibrium
- We'll go directly at the 3-equation system
- Define "gaps" as $\tilde{x}_t = x_t - x_t^n$
- Note $\tilde{x}_t = (x_t - x_{ss}) - (x_t^n - x_{ss}) = \hat{x}_t - \hat{x}_t^n$

Sticky-price equilibrium in gaps II

- DIS curve: not affected by a_t, simply subtract natural equilibrium to find

$$\begin{aligned} & \hat{y}_t = -(\hat{i}_t - E_t\pi_{t+1}) + E_t\hat{y}_{t+1} \\ \Leftrightarrow \quad & \hat{y}_t - \hat{y}_t^n = -(\hat{i}_t - E_t\pi_{t+1} - \hat{r}_t^n) + E_t\hat{y}_{t+1} - E_t\hat{y}_{t+1}^n \\ \Leftrightarrow \quad & \tilde{y}_t = -(\hat{i}_t - E_t\pi_{t+1} - \hat{r}_t^n) + E_t\tilde{y}_{t+1} \end{aligned}$$

- Phillips curve:
  - Start with firm optimality:

$$\pi_t = \beta E_t\pi_{t+1} + \lambda\widehat{mc}_t$$

  - Flexible prices: $\widehat{mc}_t^n = 0 \Rightarrow \widehat{mc}_t = \widetilde{mc}_t$
  - Work through the flex-price equations to find $\widetilde{mc}_t = (1+\varphi)\tilde{y}_t$, hence

$$\pi_t = \beta E_t\pi_{t+1} + \kappa\tilde{y}_t$$

    where $\kappa = \lambda(1+\varphi)$

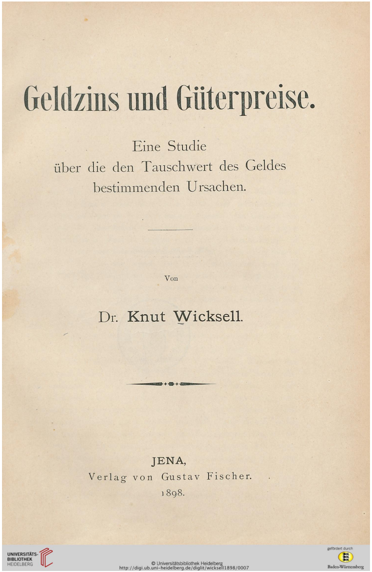
Sticky-price equilibrium in gaps III

- Putting it together, the equilibrium can be summarized as

$$\begin{aligned} \text{DIS curve:} \quad & \tilde{y}_t = -(\hat{i}_t - E_t\pi_{t+1} - \hat{r}_t^n) + E_t\tilde{y}_{t+1} \\ \text{Phillips curve:} \quad & \pi_t = \beta E_t\pi_{t+1} + \kappa\tilde{y}_t \\ \text{Policy rule:} \quad & \hat{i}_t = \phi\pi_t + \nu_t \\ \text{Natural real interest rate:} \quad & \hat{r}_t^n = -(\rho_a - 1)a_t \end{aligned}$$

- $\tilde{y}_t$ measures fluctuations that are inefficient
- Model captures two central assertions of the prevailing Neo-Wicksellian view of business cycles
  1. Monetary factors does not affect the natural real interest
  2. Inefficient fluctuations are linked by deviations in the real interest rate from the natural real interest rate

Intermezzo: The Great Knut Wicksell



Geldzins und Güterpreise.

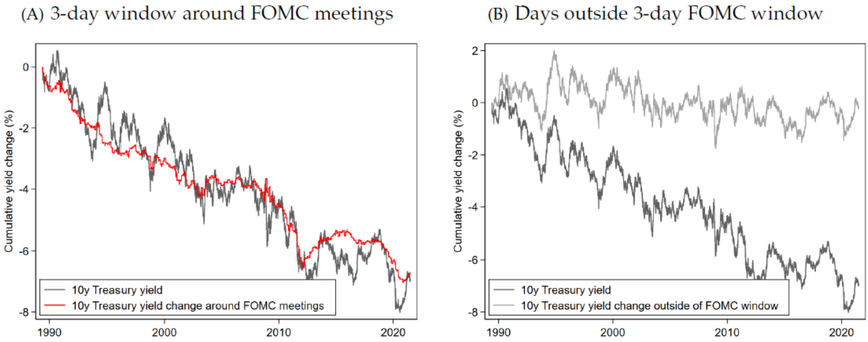
Eine Studie
über die den Tauschwert des Geldes
bestimmenden Ursachen.

Von

Dr. Knut Wicksell.

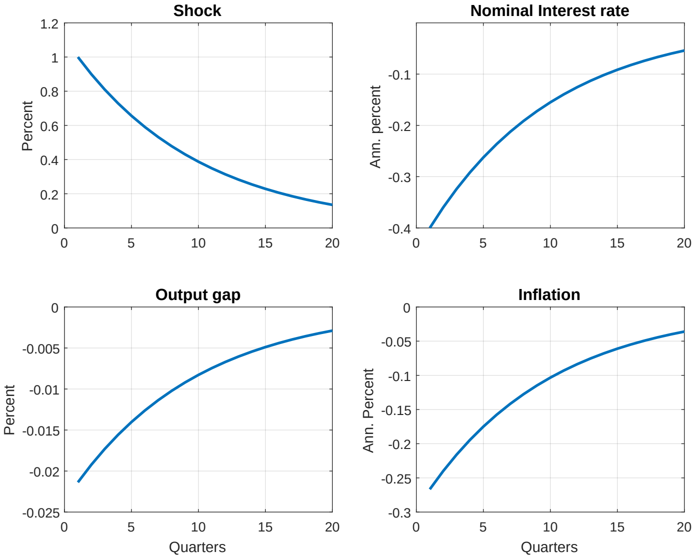
JENA,
Verlag von Gustav Fischer.
1898.

Intermezzo: is the natural-rate hypothesis correct?



From Hillenbrand (2023)

IRFs to a TFP shock: Gaps



IRFs to a TFP shock: comments

- A positive TFP shocks leads to "gap" recession
- This reflects that monetary policy is not doing a good job
- Mehcanism: TFP $\uparrow \Rightarrow$ Marginal cost $\downarrow \Rightarrow$ inflation $\downarrow \Rightarrow$ Interest rate $\downarrow$
  - Monetary policy "stimulates" the economy...
  - ... but not enough to raise consumption to its efficient level
  - In the "natural equilibrium", real interest rate is even lower, and hours worked are constant
  - Therefore, hours decline in the observed equilibrium
- Ineffiency not surprising: the policy rule was specified in a completely ad hoc manner

Cost-push shocks

Cost-push shocks

- TFP shocks is an example of a *supply shock*
- Due to sticky prices, TFP shocks create a wedge ("deviations") between the natural equilibrium and the actual equilibrium
- Because the fluctuations in the natural equilibrium are efficient, the policy problem tends be organized around how to undo the effect of price stickiness
- Another class of supply shocks creates a wedge between the natural equilibrium and the efficient equilibrium, so called cost-push shocks
- Examples: shocks to firm's desired markup (greedflation?), shocks to distorionary taxes

Rewriting the system once more

- Written in deviations from the natural equilibrium, our system is

$$\begin{aligned} \text{DIS curve:} \quad & \tilde{y}_t = -(\hat{i}_t - E_t\pi_{t+1} - \hat{r}_t^n) + E_t\tilde{y}_{t+1} \\ \text{Phillips curve:} \quad & \pi_t = \beta E_t\pi_{t+1} + \kappa\tilde{y}_t \\ \text{Policy rule:} \quad & \hat{i}_t = \phi\pi_t + \nu_t \end{aligned}$$

- Define $x_t = y_t - y_t^e$, where y_t^e is the efficient equibrium path.

- We have that $\tilde{y}_t = x_t + (y_t^e - y_t^n)$

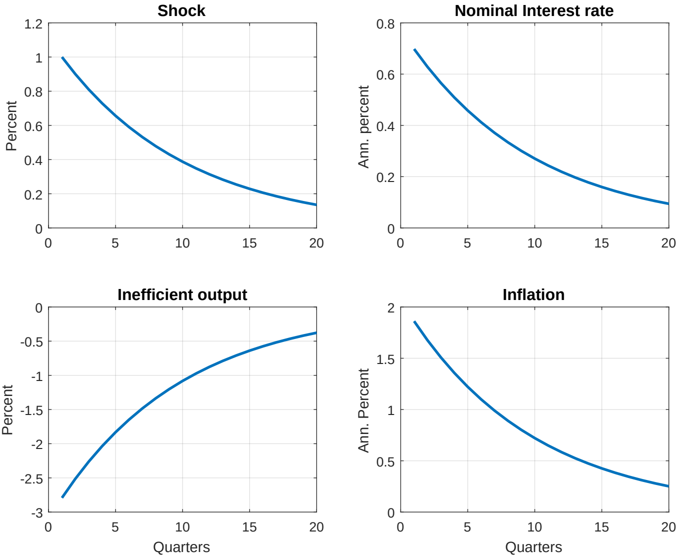
- We can write our system as

$$\begin{aligned} \text{DIS curve:} \quad & x_t = -(\hat{i}_t - E_t\pi_{t+1} - \hat{r}_t^e) + E_t x_{t+1} \\ \text{Phillips curve:} \quad & \pi_t = \beta E_t\pi_{t+1} + \kappa x_t + u_t \\ \text{Policy rule:} \quad & \hat{i}_t = \phi\pi_t + \nu_t \end{aligned}$$

where $u_t = \kappa(y_t^e - y_t^n)$ and $\hat{r}_t^e = E_t\Delta y_{t+1}^e$

- u_t is, in *reduced form*, a cost-push shock

IRFs to a cost-push shocks



Comments

- Cost-push shocks are interesting from a policy perspective
- These shocks increase inflation, but also cause an inefficient recession
  - A monetary authority can combat inflation, but this will lead an even deeper recession
- Contrast with a positive TFP shock: inefficient recession, but lowers inflation
  - Here, a monetary authority can seemingly adress two problems simoultaneously by stimulating the economy
- It seems like we need to think more systematically about the policy problem...

Summing up

- Basic NK model = RBC model + monopolistic competition and sticky prices
- In contrast to RBC, NK predicts inefficient fluctations, and a role for monetary policy
- In response to a positive shock, the NK model predicts that

Shock	$\hat{y}_t$	$\tilde{y}_t$	x_t	π_t
Monetary policy	down	down	down	down
TFP	up	down	down	down
Cost-push	—	—	down	up

- In line with the evidence on monetary policy (qualitatively, but not quantitatively)
- Next lecture, optimal policy in the NK model