Macroeconomics II Part II, Lecture VI: The New-Keynesian Model: Policy

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Recap

- Basic NK model = RBC model + monopolistic competition and sticky prices
- In contrast to RBC, NK predicts inefficient fluctations, and a role for monetary policy to affect the equilibrium
- Today: when and how should be monetary policy be used to adress fluctuations in the NK model?

Agenda

1. Ineffiencies in the NK model
2. Optimal monetary policy with TFP shocks
3. Optimal monetary policy with Cost-push shocks
   - Discretion
   - Commitment
4. Quantitative NK models: A helicopter view (time permitting)

Ineffiencies in the NK model

Ineffiencies in the NK model

- Before we think about policy, let's think about why decentralized outcomes might be suboptimal
- The basic NK model has two frictions
  1. Monopolistic competition
  2. Frictional (Calvo) price setting
- Monopolistic competition: creates a (constant) labor wedge between MRS and MRT
- Frictional price setting: implies
  1. time-varying labor wedge due to time-varying markups
  2. time varying efficiency wedge due to time-varying price dispersion

Planner's problem

- The Planner maximizes utility subject to resource constraints
- No capital $\Rightarrow$ completely static problem

$$\begin{aligned}
\max_{C_t, N_{it}} \quad & \log C_t - \theta \frac{N_t^{1+\varphi}}{1+\varphi} \\
\text{s.t.} \quad & C_t = \left(\int_0^1 (A_t N_{it})^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}} \\
& N_t = \int_0^1 N_{it} di
\end{aligned}$$

- Set up Lagrangian and take F.O.C.'s - you'll find:

$$\begin{aligned}
\frac{\theta N^{\varphi}}{C^{-1}} &= A_t \quad \left(\text{i.e., } MRS = -\frac{V'(N)}{U'(C)} = MRT = F'(N) \right) \\
N_{it} &= N_t \\
C_t &= A_t N_t
\end{aligned}$$

Inefficiences with flexible prices

- Consider the decentralized equilibrium with flexible prices
- With flexible prices, all firms set the same price, $P_{it} = P_t$ for all i, and the markup is constant and given by $M = \frac{\epsilon}{\epsilon - 1}$. Household and firm optimality:

$$\begin{aligned} \frac{\theta N^{\varphi}}{C^{-1}} &= \frac{W_t}{P_t} \\ P_t &= M \frac{W_t}{A_t} \end{aligned}$$

- Therefore, in steady state,

$$\frac{\theta N^{\varphi}}{C^{-1}} = \frac{A_t}{M}$$

- Higher markup $\Rightarrow$ lower real wages $\Rightarrow$ lower production
- This is a *static* distorition, has nothing to do with the dynamic response to shocks
- Going forward, we eliminate the static distortion with lump-sum financed firm subsidy $(1 - \tau)$, implying firm F.O.C.

$$(1 - \tau) P_t = M \frac{W_t}{A_t}$$

Inefficiency with sticky prices I: time-varying average markup

- Calvo-pricing implies time-varying average markup $\mathcal{M}_t$:

$$\mathcal{M}_t \equiv \frac{(1-\tau)P_t}{MC_t^{nom}} = \frac{(1-\tau)P_t A_t}{W_t}$$

where P_t is the price level

- With $1-\tau = \mathcal{M}$, we can write

$$P_t = \frac{\mathcal{M}_t}{\mathcal{M}} \frac{W_t}{A_t}$$

implying that

$$\frac{\theta N^{\varphi}}{C^{-1}} = \frac{\mathcal{M}_t}{\mathcal{M}} A_t$$

- Calvo pricing implies some firms cannot update prices, and the one that do update do not set $P_{it} = \mathcal{M} * MC_t^{nom} \Rightarrow$ fluctuations in $\mathcal{M}_t$
  - These fluctuations are inefficient, even if average markup is zero (as with the firm subsidy)
  - Note: This inefficiency creates fluctuations in the labor wedge

Inefficiency with sticky prices II: price dispersion

- Lecture IV: Aggregation yields

$$Y_t = A_t D_t N_t$$

where

$$D_t = \int_0^1 \left(\frac{P_{it}}{P_t}\right)^{-\epsilon} di$$

- In response to a shock, Calvo implies $P_{it} \neq P_{jt} \Rightarrow D_t$ lower
  - D_t lower, as $(\cdot)^{-\epsilon}$ is a convex function (Jensen's inequality)

- Price dispersion generates an ineffiency due to missallocation

- Note: missallocation induces an efficiency wedge

Optimal monetary policy with TFP shocks

Achieving the first best

- Consider the NK model subject to TFP shocks
- Suppose that in period $t = -1$, $P_i = P_{-1}$ for all i
- Suppose optimal $P_t^* = P_{-1}$ for all resetters in $t = 0, 1, 2, ...$
- Then, no price disperion, and no time-varying markup $\Rightarrow$ first-best attained
- $\Rightarrow$ the socially optimal allocation is achieved if all price setters stay with the initial price
- Could (in theory) be implemented with time-varying subsidy to resetters
- Could also (in theory) be implemented by time-varying taxes of household financial decisions $\Rightarrow$ ineffiency can be conceptaulized as arising from an aggregate-demand externality (Farhi-Werning, Ectmra 2016; see also Correia-Farhi-Nicolini-Teles, AER 2013)
- Could it be implemented with a suitable choice of $\hat{i}_t$?

Can monetary policy achieve the first best?

- Recall: Our system is

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

- We know that the efficient solution has $\pi_t = 0$ and $\tilde{y}_t = 0$
  - Zero inflation - not for it's own sake, but because it eliminates markup fluctuations and price dispersion
  - Output fluctuates due to TFP, but output gap is eliminated
- A socially optimal interest rate makes sure the real interest rate tracks the natural real interest rate

How can monetary policy implement first best? part I

- Suppose the monetary policy sets interest rates according to the rule

$$\hat{i}_t = \hat{r}_t^n$$

- In that case, the equilibrium system becomes

$$\begin{aligned} \text{DIS curve:} \qquad & \tilde{y}_t = -(E_t \pi_{t+1}) + E_t \tilde{y}_{t+1} \\ \text{Phillips curve:} \qquad & \pi_t = \beta E_t \pi_{t+1} + \kappa \tilde{y}_t \end{aligned}$$

- One solution: $\pi_t = \tilde{y}_t = 0$

- But, both eigenvalues are not inside unit circle (check this at home!) $\Rightarrow$ indeterminacy

- Ergo, this rule does not garantuee that the first best is achieved

How can monetary policy implement first best? part II

- Suppose instead that the monetary policy rule is

$$\hat{i}_t = \hat{r}_t^n + \phi \pi_t$$

- In that case, the equilibrium system becomes

$$\begin{aligned} \text{DIS curve:} \qquad & \tilde{y}_t = -(\phi \pi_t - E_t \pi_{t+1}) + E_t \tilde{y}_{t+1} \\ \text{Phillips curve:} \qquad & \pi_t = \beta E_t \pi_{t+1} + \kappa \tilde{y}_t \end{aligned}$$

- Same determinacy condition as before: $\phi > 1$ acheives determinacy: $\pi_t = 0$, $\tilde{y}_t = 0$ is the unique bounded solution

- With TFP shocks, sound monetary policy in the NK model boils down to tracking the natural real interest rate, and making credible threats to exclude other equilibria

Comments

- In practice: secular movements in r_t^n can perhaps be computed, but $\hat{r}_t^n$ is unobserved
  - However, in theory: simple policy rules, e.g., $\hat{i}_t = \phi\pi_t$ effectively mitigates welfare losses if ϕ is sufficiently high
- TFP shocks does not generate a trade-off for monetary policy decisions
  - If you stabilize inflation, you also stablize the output gap
  - Sometimes called the divine coincide
  - No rationale for a dual mandade
- Other shocks do...

Optimal monetary policy with cost-push shocks

The policy problem

- With TFP shocks, there are no trade-offs and policy analysis is easy
- Cost-push shocks create an interesting trade-off, and also a time inconsistency problem
- With cost-push shocks, we need some more technique to get at optimal policy
- In general, the policy problem is to set a sequence $\{\hat{i}_t\}$ such to maximize some social objective function, subject to that the allocation is an equilibrium:

$$\begin{aligned} \max_{\hat{i}_t} \quad & \text{Objective function} \\ \text{s.t.} \quad & x_t = -(\hat{i}_t - E_t\pi_{t+1} - \hat{r}_t^e) + E_t x_{t+1} \ \forall t \\ & \pi_t = \beta E_t \pi_{t+1} + \kappa x_t + u_t \ \forall t \end{aligned}$$

  where $x_t = y_t - y_t^e$

- Which objective function?

The objective function

- If the policy maker has the same preferences as the social planner, the objective function is the welfare of the representative household: $E_0 \sum U(C_t, N_t)$
- To put the welfare function on par with the equilibrium expressed in terms of a log-linear appoximation around steady state, we need to approximate it
- A linear approximation does not work - why?
- Woodford (Book 2003): Let's consider a second-order approximation

$$U_t - U = U_c C\left(\hat{y}_t + \frac{1-\sigma}{2}\hat{y}_t^2\right) + \frac{U_N N}{1-\alpha}\left(\hat{y}_t + \frac{\epsilon}{2\Theta}\int_0^1 p_{it}^2 di + \frac{1+\varphi}{2}(\hat{y}_t)\right)$$

using that

$$N_t = \int_0^1 \frac{Y_t}{A}\left(\frac{P_{it}}{P_t}\right)^{-\epsilon} di, \text{and } \hat{c}_t = \hat{y}_t = \hat{n}_t$$

- With a bit of work, one can show that, in equilibrium, the welfare loss amounts to

$$E_0 \sum_{t=0}^{\infty} \beta^t (\pi_t^2 + \alpha_x x_t^2)$$

with $\alpha_x = \frac{\kappa}{\epsilon}$

The policy problem, again

- The policy problem is thus

$$\begin{aligned}
\max_{\{\hat{i}_t\}} \quad & E_0 \sum_{t=0}^{\infty} \beta^t(\pi_t^2 + \alpha_x x_t^2) \\
\text{s.t.} \quad & x_t = -(\hat{i}_t - E_t\pi_{t+1} - \hat{r}_t^e) + E_t x_{t+1} \ \forall t \\
& \pi_t = \beta E_t \pi_{t+1} + \kappa x_t + u_t \ \forall t
\end{aligned}$$

- There is clearly a trade-off in setting the interest rate path here

- We can split the policy problem in two
  1. Find the equilibrium allocation that maximizes welfare

$$\begin{aligned}
\max_{x_t, \pi_t} \quad & E_0 \sum_{t=0}^{\infty} \beta^t(\pi_t^2 + \alpha_x x_t^2) \\
\text{s.t.} \quad & \pi_t = \beta E_t \pi_{t+1} + \kappa x_t + u_t \ \forall t
\end{aligned}$$

  2. Given a solution $\{x_t^*, \pi_t^*\}$, find the interest rate path that implements this allocation by solving

$$x_t^* = -(\hat{i}_t - E_t\pi_{t+1}^* - \hat{r}_t^e) + E_t x_{t+1}^* \ \forall t$$

- Note: $\hat{r}_t^e$ is exogenous to the policy problem

Discrition vs. commitment

- Suppose the central bank cannot commit to future interest rates $\{i_{t+s}\}_{s=1}^{\infty}$ when setting the interest rate today i_t
- Then, the central bank knows that tomorrow, it will set an interest rate path that solves

$$\begin{aligned} \max_{x_{t+s},\pi_{t+s}} \quad & E_{t+1}\sum_{s=1}^{\infty}\beta^s(\pi_{t+s}^2+\alpha_x x_{t+s}^2) \\ \text{s.t.} \quad & \pi_{t+s}=\beta E_t\pi_{t+s+1}+\kappa x_{t+s}+u_{t+s}\ \forall s>0 \end{aligned}$$

  resulting in some path $\{x_{t+s}^*,\pi_{t+s}^*\}_{s=1}^{\infty}$

- This means that when setting the interest rate today, the central bank can take the future allocation as given $\{x_{t+s}^*,\pi_{t+s}^*\}_{t=s}^{\infty}$
- $\Rightarrow$ The maximization problem today is static!

$$\begin{aligned} \max_{x_t,\pi_t} \quad & \pi_t^2+\alpha_x x_t^2 \\ \text{s.t.} \quad & \pi_t=\beta E_t\pi_{t+1}^*+\kappa x_t+u_t \end{aligned}$$

- Note: this result stems from that the equilibrium has no state variable

Optimal discretionary policy

- The maximization problem

$$\max_{x_t,\pi_t} \quad \pi_t^2 + \alpha_x x_t^2$$
$$\text{s.t.} \quad \pi_t = \beta E_t \pi_{t+1}^* + \kappa x_t + u_t$$

- F.O.C.

$$\pi_t : \quad 2\pi_t - \lambda = 0$$
$$x_t : \quad 2\alpha_x x_t - \lambda\kappa = 0$$

- Combine to get

$$x_t = -\frac{\kappa}{\alpha_x}\pi_t$$

- Higher inflation $\Rightarrow$ optimal policy features engineering an "inefficient" recession

Implication and Implementation

- Combine with Phillips curve to get path of inflation under this policy:

$$\pi_t = \beta E_t \pi_{t+1} - \frac{\kappa^2}{\alpha_x}\pi_t + u_t$$

- $\Rightarrow$ solves for some policy function $\pi_t = \Phi_\pi u_t$

- Combine with DIS curve to get path of interest rate under this policy:

$$\frac{\kappa}{\alpha_x}\pi_t = (\hat{i}_t - E_t \pi_{t+1} - \hat{r}_t^e) + \frac{\kappa}{\alpha_x} E_t \pi_{t+1}$$

- $\Rightarrow$ solves for some policy function $i_t = \hat{r}_t^e + \Phi_i u_t$

- Implemented as unique equilibrium with rule $i_t = \hat{r}_t^e + \Phi_i u_t + \phi(\pi_t - \Phi_\pi u_t)$ for large enough ϕ

Optimal policy with commitment

- Suppose instead the central bank can commit. The policy problem is

$$\begin{aligned} \max_{\{x_t,\pi_t\}} \quad & E_0 \sum_{t=0}^{\infty} \beta^t (\pi_t^2 + \alpha_x x_t^2) \\ \text{s.t.} \quad & \pi_t = \beta E_t \pi_{t+1} + \kappa x_t + u_t \ \forall t \end{aligned}$$

- Let $\{\lambda_t\}$ be the sequence of Lagrange multipliers. F.O.C is

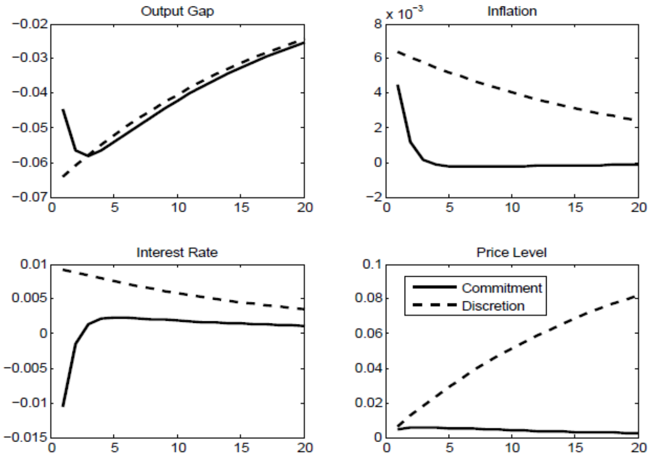
$$\begin{aligned} \pi_t : \quad & \pi_t + \lambda_t - \lambda_{t-1} = 0 \\ x_t \quad & \alpha_x x_t - \kappa \lambda_t = 0 \end{aligned}$$

which gives us

$$\begin{aligned} x_0 &= -\frac{\kappa}{\alpha_x}\pi_0 \\ x_t &= x_{t-1} - \frac{\kappa}{\alpha_x}\pi_t \end{aligned}$$

- Still qualitatively similar tradeoff between output and inflation, but now optimal policy features some degree of smoothing: A high x_{t-1} implies a high value of x_t

Optimal policies in response to an AR(1) cost-push shock



- From Eric Sims' lecture notes

Quantitative NK models: A helicopter view

Quantitative NK models

- The simple 3-equation model is too stylized for much quantitative analysis
- To make serious quantitative predictions about the response to shocks and policy, we need to incorporate more frictions
- Key questions for quantitative NK models: which extensions are most important, and how to discipline the (often many) model parameters?
  - Which data moments should we target?
- Resarch program initiated by Christiano-Eichenbaum-Evans (JPE 2005) and Smets-Wouters (JEDC 2003; AER 2007)
- Quantitative NK models are used by many central banks to make forecast and analyze policy interventions
  - Sveriges Riksbank's model: RAMSES II

Quantitative NK models:ingredients

- Typical ingredients:
  1. Capital and investment adjustment costs
  2. Variable capacity utilization
  3. Financial frictions
  4. Price indexation (and positive steady-state inflation)
  5. Consumption habits
  6. Rigid wages
- Other ingredients too, but these are the most common (I think...)
- Let's quickly look at the last two

Consumption habits

- Macro aggregates, in particular aggregate consumption, tend to respond sluggishly to shocks
- One way to capture this: consumption habits
- Change utility function to

$$U(C_t, C_{t-1}) = u(C_t - bC_{t-1})$$

$\Rightarrow$ utility penalty from changing consumption too fast

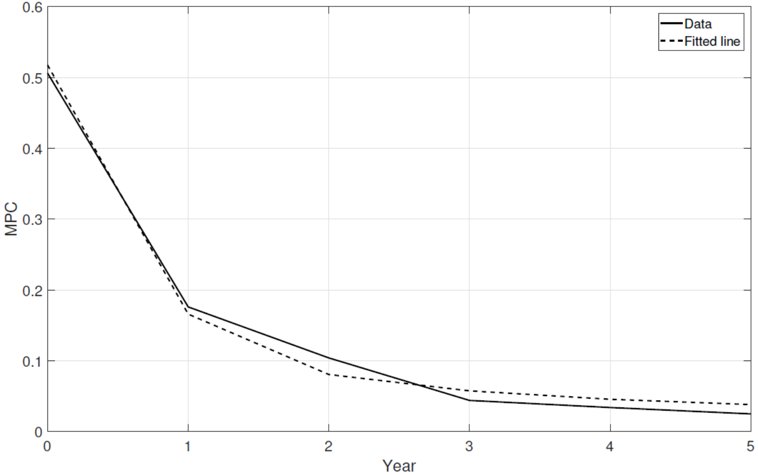
- Changes household F.O.C. to

$$\lambda_t = \beta^t u'(C_t - bC_{t-1}) - \beta^{t+1} b u'(C_{t+1} - bC_t)$$

$\Rightarrow$ adjust Euler equation and intratemporal optimality condition accordingly

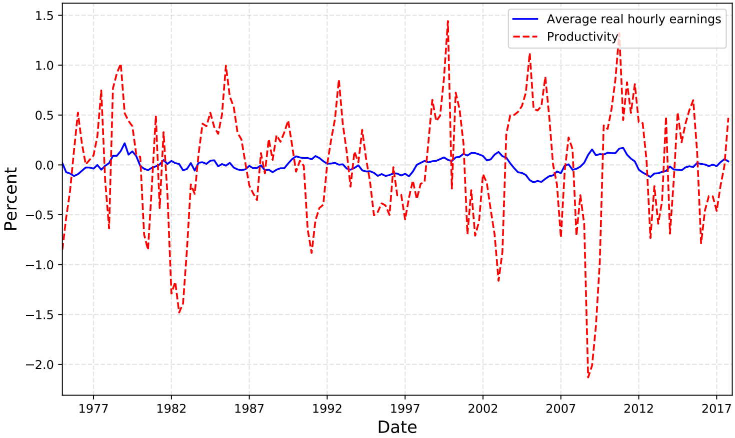
- Is this reasonable?
  - Some form of consumption habit formation seems plausible
  - Helps explaining some asset pricing puzzles (See, e.g., Campbell-Cochrane, JPE 1999)
  - Hard to square with micro evidence on consumption response to transitory income shocks (Carroll-Crawley-Slacalek-Tokuoka-White, AEJmacro 2020; Auclert-Rognlie-Straub, 2020)
  - Alternative: sticky expecations (Mankiw-Reis, QJE 2002)

Fagereng-Holm-Natvik (AEJmacro 2020): Consumption response to lottery gains using Norwegian administrative data



Notes: The solid line is the estimated dynamic consumption responses from Figure 2. The dashed line is the fitted consumption response using the approach described above.

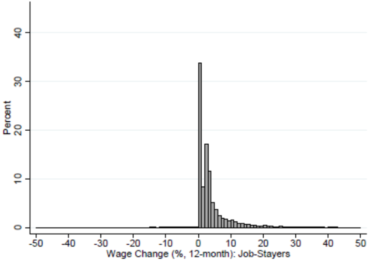
Rigid wages? Aggregate data



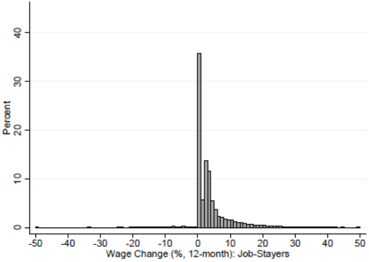
Detrended (HP-filtered) quarterly data. OECD estimate of total labor productivity. Average hourly earnings for total private sector excluding supervisory employees, deflated with PCE. Source: FRED and own calculations.

Rigid wages? Micro data

Figure 2: 12-Month Nominal Base Wage Change Distribution, Job-Stayers



Panel A: Hourly Workers



Panel B: Salaried Workers

Notes: Figure shows the annual change in nominal base wages for workers in our employee sample (including commission workers) who remain employed on the same job for 12 consecutive months.

- From Grigsby-Hurst-Yildirmaz (AER 2021), using micro data from the largest US payroll processing company

Rigid wages

- Data indicative of wage rigidities
  - Average wage rate not very volatile, although hours worked and productivity is
  - Micro data suggest: some of low aggregate volatility is due to selection, some due to rigidness
- Wage rigidity can be modelled analogously to Calvo-style price rigidity (Erceg-Henderson-Levin, JME 2000)
  - Assumption 1: each household provides a differentiated labor service $\Rightarrow$ workers have monopoly power and set their wages accordingly
  - Assumption 2: each household belongs to a union $\Rightarrow$ consumption insurance
  - Assumption 3: constant probability $(1-\theta_w)$ of resetting wage
- Optimality condition to resetter's problem + aggregation yields

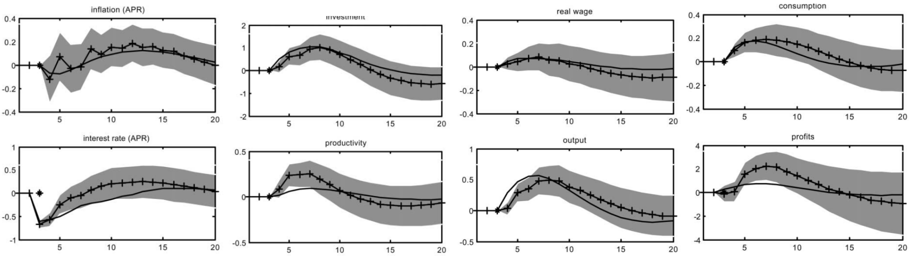
$$\pi_t^w = \beta E_t \pi_{t+1}^w - \lambda_w(\hat{\omega}_t - (\hat{c}_t + \varphi \hat{n}_t)) \quad \text{instead of } \omega_t = c_t + \varphi n_t$$

- A good starting point, but not very compelling assumptions
- Broer-Harmenberg-Krusell-Öberg (AER:insights 2023) offer another framework for modelling wage rigidity maintaining competitive markets

How to pick parameter values?

- Cristiano-Eichenbaum-Evans: Set parameters values to minimize distance of model IRF to data IRF to monetary policy shocks
  1. Pick some parameter values
  2. Compute IRFs
  3. Calculate squared distance
  4. Update parameters, iterate
- Smets-Wouters: set parameters (including shock process parameters) so that model matches unconditional time series on macro aggregates
  - Often done with Bayesian estimation techniques
  - This means specifying a prior distribution of parameter values, and then update according to Bayes law when model is confronted with data
- Contrast this approach with RBC-style calibration

Christiano-Eichenbaum-Evans (JPE 2005): model fit



(a) (b) (c) (d)

$+$: empirical IRFs with CI-bands, $-$: estimated model IRFs. Y-axis: percentage points. X-axis: quarters. US data.

- Empirical IRFs estimated using recursive ordering
- CEE show that rigid wages is the key friction needed to match these moments

Summing up

- NK models: RBC with monopolistic competition and sticky prices
- Inefficient business cycles due to time-varying markups and price dispersion
- When flex price equilibrium is optimal: policy can mitigate efficiency loss, both in terms of inflation and output, by implementing natural real interest rate
- When shocks distort flex-price equilibrium: policy trade-off in terms of stabilizing inflation and output, and also a time-inconsistency problem
- With a reasonable set of model extensions, NK model can match empirical IRFs to monetary policy shocks in quite some detail

New-Keynesian theory: a very incomplete history

- **Wicksell (1898): Interest and Prices**
  - Natural rate hypothesis; interest-rate gap as cause of inflation and real fluctuations
- Keynes (1936): The General Theory
- 40-60s: "Neoclassical synthesis", i.e., Keynesian equilibrium models (e.g. IS-LM)
  - Hicks, Samuelson, Mogiliani, Tobin etc.
- **Patinkin (1956): Money, Interest and Prices**
- Phelps (Economica 1967; JPE 1968): forward-looking Phillips curve based on firm's price setting behavior
  - Taylor (JPE 1980): staggered price-setting; Calvo (JME 1983): random price-setting
- 1980's: theoretical insights regarding interplay of "aggregate demand", price stickiness and monopoly power
  - Akerlof-Yellen (QJE 1985); Mankiw (QJE (1985); Blanchard-Kiyotaki (AER 1987); Ball-Romer (ReStud 1990)
- 1990's: "New neoclassical synthesis", i.e., the integration of sticky prices in micro-founded (RBC-style) business cycle models
  - Yun (JME 1996); Rotemberg-Woodford (NBER 1997); Goodfriend-King (NBER 1997); Clarida-Galí-Gertler (JEL 1999)
- **Woodford (2003): Interest and Prices**