New Keynesian Model: Extensions

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$$\underset{\text{loan rate}}{R_t^L} = \underset{\text{deposit rate}}{R_t^D} = \underset{\text{policy rate}}{R_t}$$

- Real marginal costs paid by firms

$$MC_t^r = (1-\alpha)\frac{W_t^r}{Z_t} + \alpha\frac{W_t^r}{Z_t}R_t \tag{1}$$

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$$\hat{x}_t = E_t\hat{x}_{t+1} - \delta\left(\hat{r}_t - E_t\hat{\pi}_{t+1} - \hat{rr}_t^n\right) \tag{2}$$

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- AS directly affected by the interest rate

$$\begin{aligned} \hat{\pi}_t &= \beta E_t \hat{\pi}_{t+1} + \kappa \widehat{mc}_t^r + \hat{u}_t \\ &= \beta E_t \hat{\pi}_{t+1} + \kappa_x \hat{x}_t + \kappa_r \hat{r}_t + \hat{u}_t \end{aligned} \tag{3}$$

NOTE: for $\alpha = 0 \Longrightarrow \kappa_r = 0$ (baseline model)

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  - larger contraction in output

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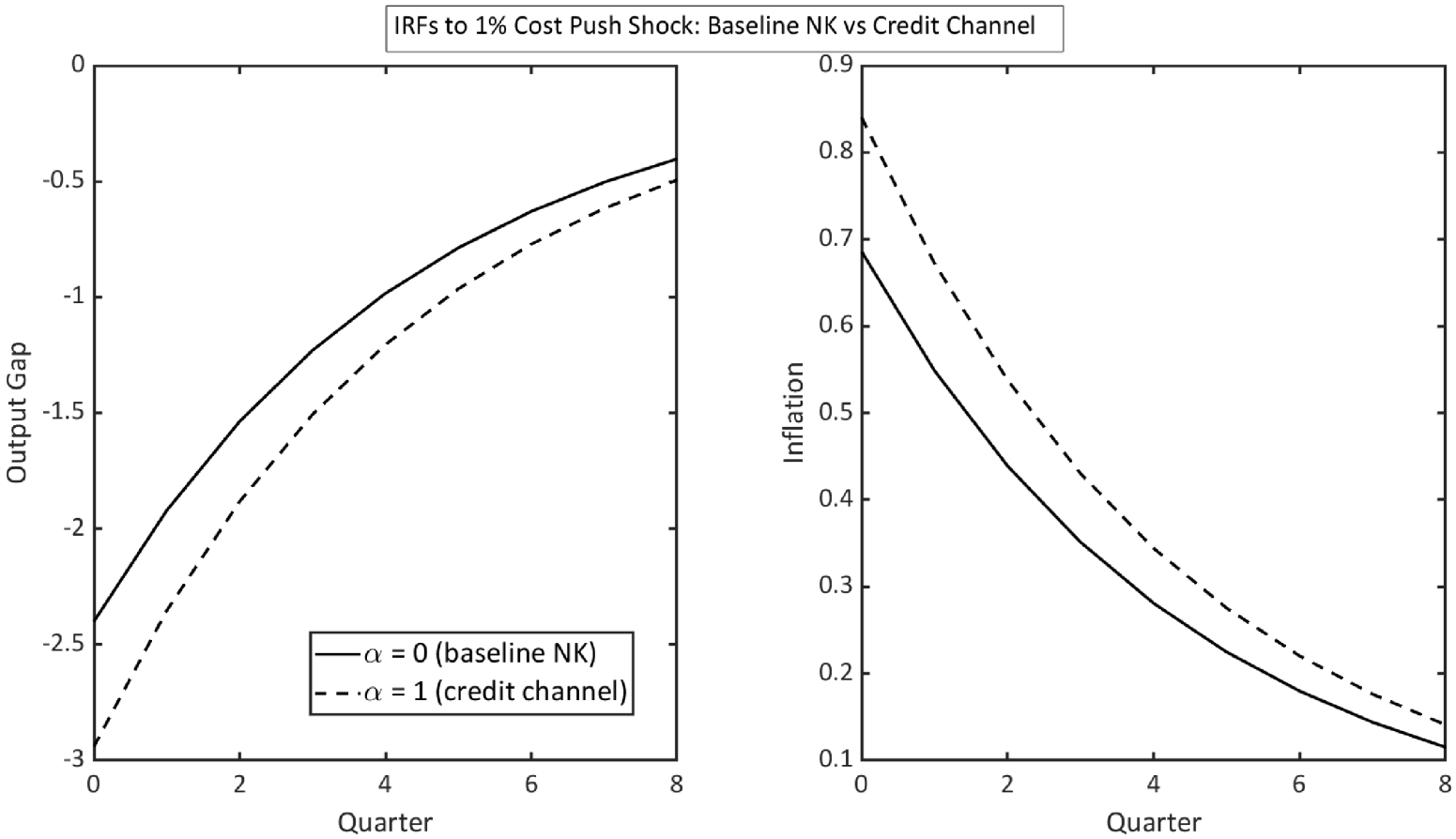

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- From Euler equation for consumption, with $\hat{r}_t = \phi_\pi \hat{\pi}_t$

$$\hat{c}_t = \underbrace{E_t \hat{c}_{t+1}}_{\text{fixed}} - \delta \underbrace{(\phi_\pi - 1)\varepsilon^\pi}_{\text{real interest rate}}$$

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- For given $E_t \hat{c}_{t+1}$,

$$\hat{c}_t \begin{cases} > 0 \text{ (higher consumption)} & \text{if} \quad \phi_\pi < 1 \text{ (dovish Fed)} \\ < 0 \text{ (lower consumption)} & \text{if} \quad \phi_\pi > 1 \text{ (hawkish Fed)} \end{cases}$$

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- **Result**. Since $\beta \approx 1$, inflation increases by less than expected ($\hat{\pi}_t < \varepsilon^\pi$), or even declines ($\hat{\pi}_t < 0 < \varepsilon^\pi$): the initial belief of higher inflation is NOT *self-fulfilled*

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  $\Longrightarrow$ the initial belief of higher inflation is *self-fulfilled*
- With a credit channel, we need a **modified Taylor Principle**
  $\Longrightarrow$ to rule out self-fulfilling expectations, the Fed should set ϕ_π below a certain upper bound

$$1 < \phi_\pi < \bar{\phi}_\pi$$

where $\bar{\phi}_\pi$ is strictly decreasing in α (the extent of the credit friction).

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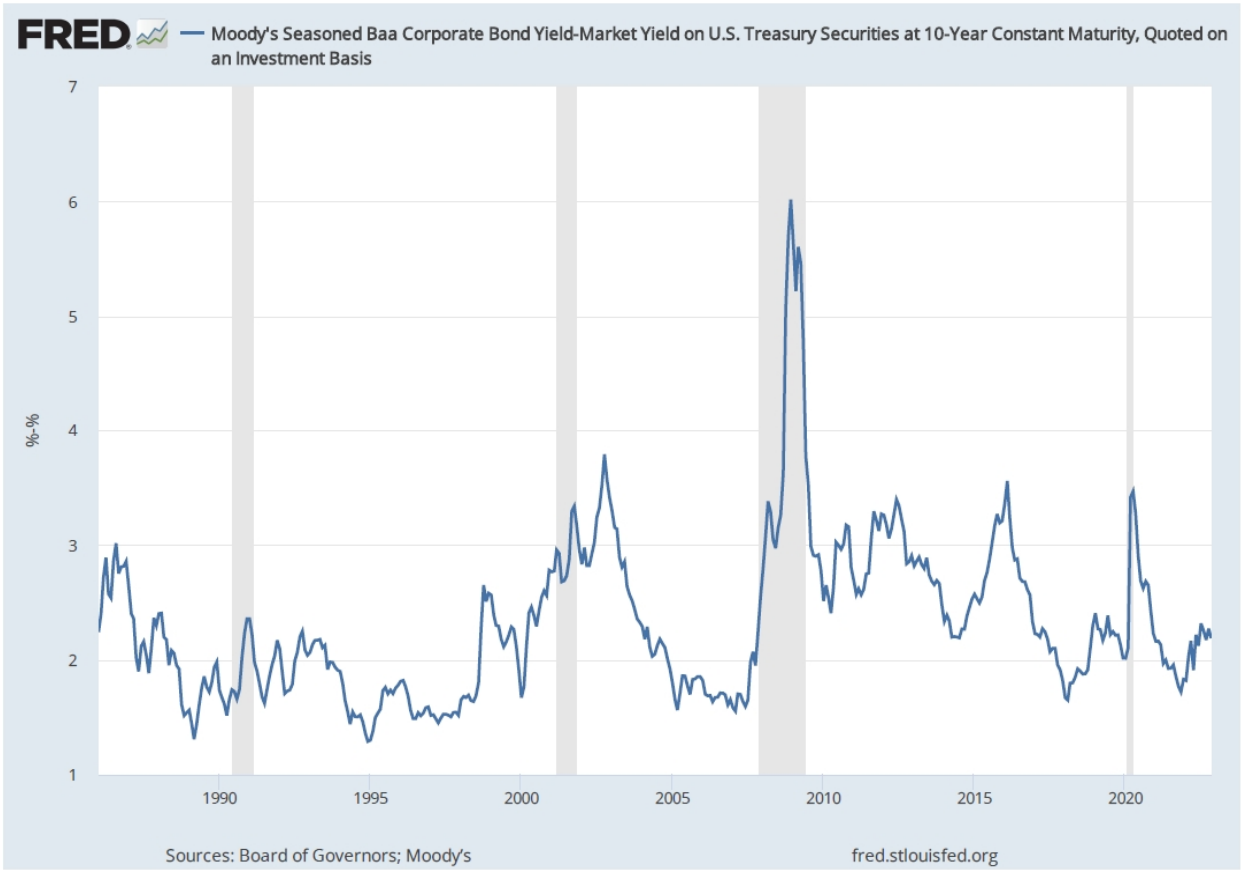
  - pro-longed duration of credit crisis



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- All these contributions emphasize the role of (endogenous) collateral/borrowing limits in credit markets

II. Heterogeneous Nominal Rigidities

Motivation I: Empirical

- Evidence: degree of price rigidity varies significantly across sectors
  Source: Bils and Klenow (J.Pol.Econ. '04)

TABLE 2
MONTHLY FREQUENCY OF PRICE CHANGES FOR SELECTED CATEGORIES

	Price Quotes with Price Changes (%) (1)	Price Quotes with Price Changes, Excluding Observations with Item Substitutions (%) (2)
All goods and services	26.1 (1.0)	23.6 (1.0)
Durable goods	29.8 (2.5)	23.6 (2.5)
Nondurable goods	29.9 (1.5)	27.5 (1.5)
Services	20.7 (1.5)	19.3 (1.6)
Food	25.3 (1.8)	24.1 (1.9)
Home furnishings	26.4 (1.8)	24.2 (1.8)
Apparel	29.2 (3.0)	22.7 (3.1)
Transportation	39.4 (1.8)	35.8 (1.9)
Medical care	9.4 (3.2)	8.3 (3.3)
Entertainment	11.3 (3.5)	8.5 (3.6)
Other	11.0 (3.3)	10.0 (3.3)
Raw goods	54.3 (1.9)	53.7 (1.7)
Processed goods	20.5 (.8)	17.6 (.7)

SOURCE.—U.S. Department of Labor (1997).

NOTE.—Frequencies are weighted means of category components. Standard errors are in parentheses. Durables, nondurables, and services coincide with U.S. NIPA classifications. Housing (reduced to home furnishings in our data), apparel, transportation, medical care, entertainment, and other are BLS major groups for the CPI.

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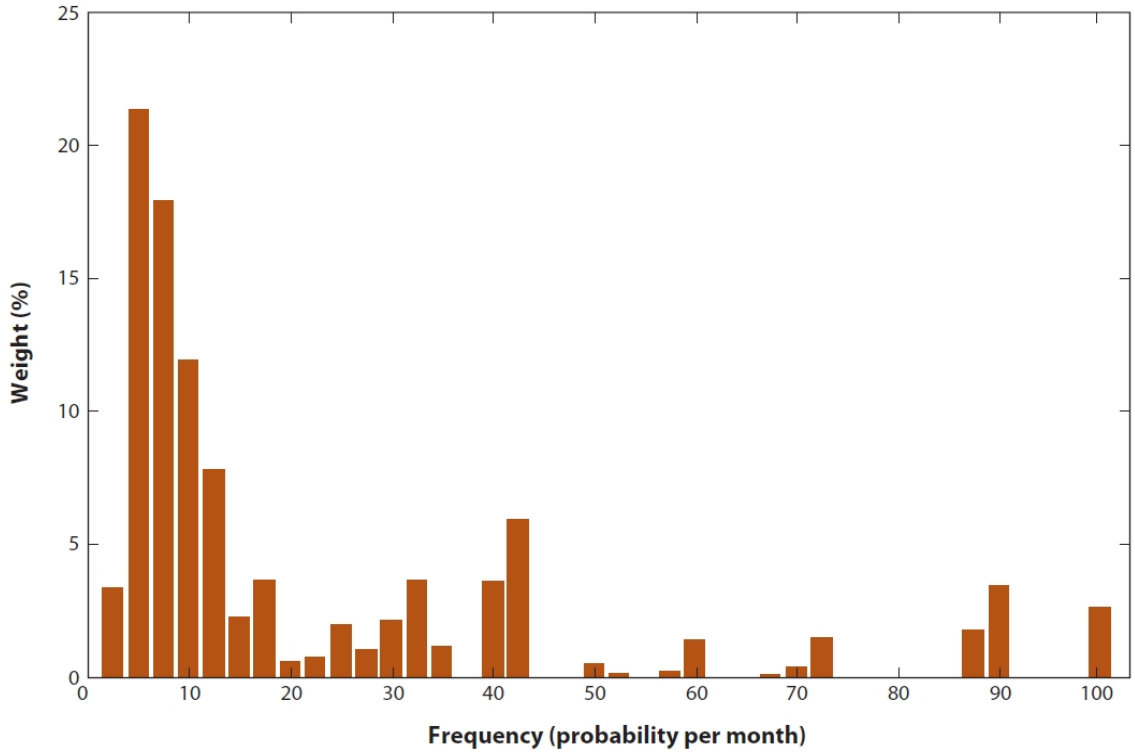

Figure 3

The expenditure weighted distribution of the frequency of regular price change (percent per month) across product categories (entry-leve items) in the US Consumer Price Index (CPI) for the period 1998–2005. Data taken from Nakamura & Steinsson (2008).

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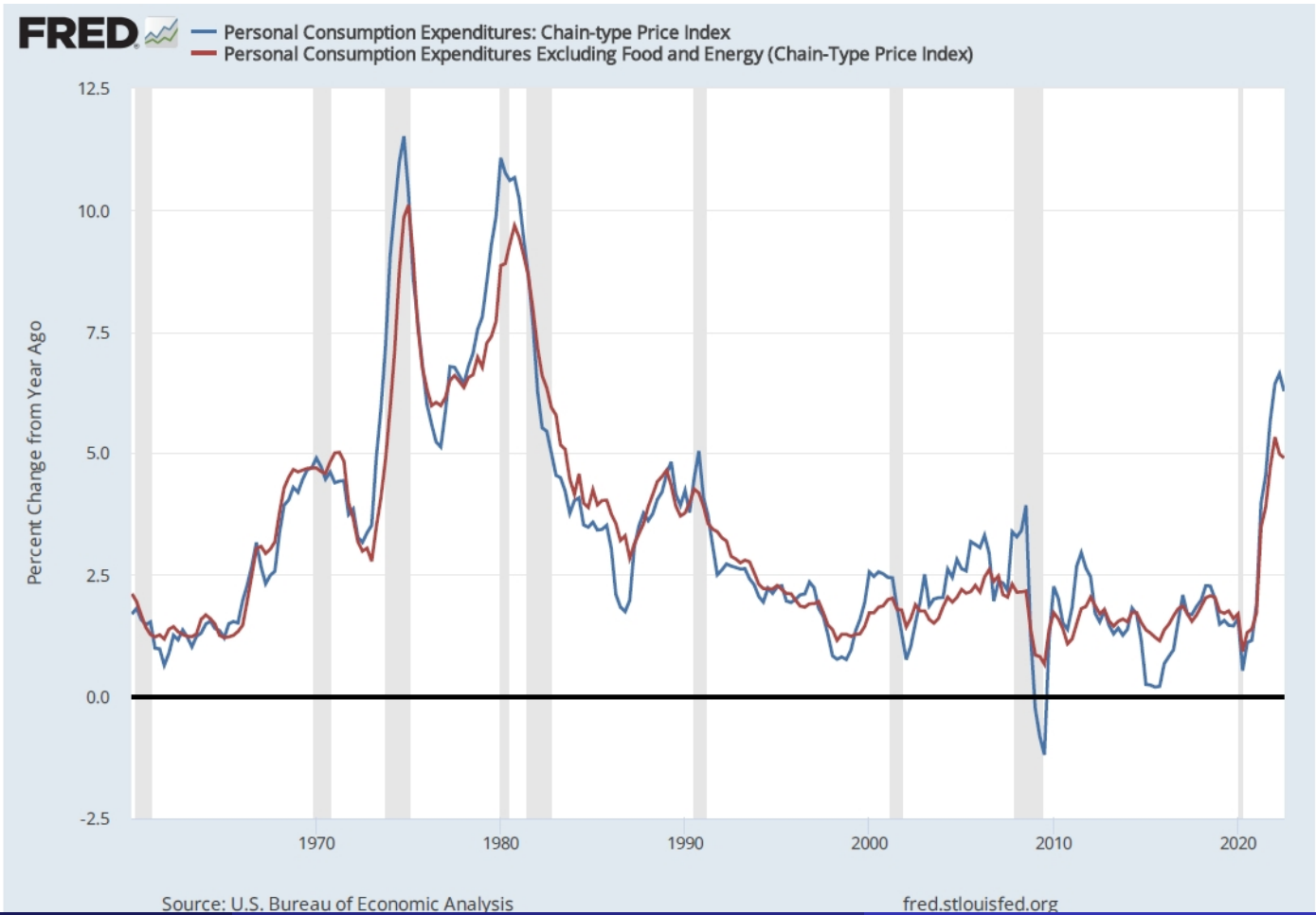

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A Simple 2-Sector NK Model: Overview

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  1. **Flexible-price sector** (agriculture, food, gasoline), denoted by F
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  2. **Stick price sector** (standard goods/services subject to nominal rigidities), denoted by S
     $\Longrightarrow$ probability of not being able to change price is $\theta^S > 0$
     REMARK: we could generalize it to a model with stickiness in all sectors, $0 < \theta^F < \theta^S < 1$

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  2. disutility from working will come from supplying labor to both sectors: $H_{F,t}$ and $H_{S,t}$

- More specifically:

$$U_t = \frac{\left(C_{F,t}^{\alpha} C_{S,t}^{1-\alpha}\right)^{1-\sigma}}{1-\sigma} - \underbrace{\left[\psi_F \frac{H_{F,t}^{1+\chi}}{1+\chi} + \psi_S \frac{H_{S,t}^{1+\chi}}{1+\chi}\right]}_{\text{imperfect labor substitutability}} \tag{4}$$

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- Both $C_{F,t}$ and $C_{S,t}$ are final consumption goods, with prices $P_{F,t}$ and $P_{S,t}$
  $\Longrightarrow$ Consumer Price Index (CPI)

$$P_t = P_{F,t}^{\alpha} P_{S,t}^{1-\alpha} \quad \underset{\text{usual steps}}{\Longrightarrow} \quad \hat{p}_t = \alpha \hat{p}_{F,t} + (1-\alpha)\, \hat{p}_{S,t} \tag{5}$$

II. Heterogeneous Nominal Rigidities

Households

- More specifically:

$$U_t = \frac{\left(C_{F,t}^{\alpha} C_{S,t}^{1-\alpha}\right)^{1-\sigma}}{1-\sigma} - \underbrace{\left[\psi_F \frac{H_{F,t}^{1+\chi}}{1+\chi} + \psi_S \frac{H_{S,t}^{1+\chi}}{1+\chi}\right]}_{\text{imperfect labor substitutability}} \tag{4}$$

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- CPI inflation is then

$$\hat{\pi}_t = \hat{p}_t - \hat{p}_{t-1} = \alpha \hat{\pi}_{F,t} + (1-\alpha)\, \hat{\pi}_{S,t} \tag{6}$$

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  - for $\alpha = 0$ ($C_t = C_{S,t}$ in utility) $\Longrightarrow$ baseline NK model with monetary non-neutrality

II. Heterogeneous Nominal Rigidities

Central Bank

- Fed adopts a Taylor rule for monetary policy:

$$\hat{r}_t = \phi_\pi \hat{\pi}_t^T + \hat{v}_t$$

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  2. Fed is free to choose what measure of inflation is most appropriate to conduct monetary policy. Namely:

$$\hat{\pi}_t^T = \gamma \hat{\pi}_{F,t} + (1-\gamma)\,\hat{\pi}_{S,t} \tag{9}$$

with γ being a Fed's choice

$$\begin{aligned} \gamma &= \alpha \quad \Longrightarrow \quad \text{Fed targets CPI/headline inflation} \\ \gamma &= 0 \quad \Longrightarrow \quad \text{Fed targets Core inflation} \\ & \qquad\qquad\quad \text{(no food and energy)} \end{aligned}$$

II. Heterogeneous Nominal Rigidities

Equilibrium System

- Without loss of generality, assume $\hat{z}_t^S = 0$ (no TFP shock in S-sector)

$$\textbf{Euler Eq.} \quad : \quad \hat{c}_t^S = E_t \hat{c}_{t+1}^S - \sigma^{-1} \left(\hat{r}_t - E_t \hat{\pi}_{t+1}^S \right) \tag{10}$$

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$$\hat{c}_t^F = \hat{y}_t^F = \frac{1+\chi}{\sigma+\chi} \hat{z}_t^F \tag{12}$$

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  - no response to $\hat{z}_t^F$

- Very different results if the Fed responds to headline inflation

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Equilibrium System

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- Define the relative price $Q_t \equiv \frac{P_t^F}{P_t^S}$, one can show that

$$\underbrace{\hat{y}_t^F - \hat{y}_t^S}_{\text{change in relative demand}} = - \underbrace{\hat{q}_t}_{\hat{p}_t^F - \hat{p}_t^S} \quad \underset{\hat{y}_t^F = \hat{z}_t^F}{\Longrightarrow} \quad \hat{q}_t = \hat{y}_t^S - \hat{z}_t^F \quad (14)$$

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- From the same definition

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- Combining (14)-(15):

$$\hat{\pi}_t^F = \hat{\pi}_t^S + \hat{y}_t^S - \hat{y}_{t-1}^S - \left(\hat{z}_t^F - \hat{z}_{t-1}^F\right) \quad (16)$$

- Let's look at it more closely:

$$\underbrace{\hat{\pi}_t^F}_{\text{flex inflation}} = \underbrace{\hat{\pi}_t^S}_{\text{sticky inflation}} + \underbrace{\hat{y}_t^S - \hat{y}_{t-1}^S}_{\text{change in sticky demand}} - \underbrace{\left(\hat{z}_t^F - \hat{z}_{t-1}^F\right)}_{\text{change in flex TFP}} \tag{17}$$

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- Because of factors driving $\hat{\pi}_t^F$, responding to headline inflation,

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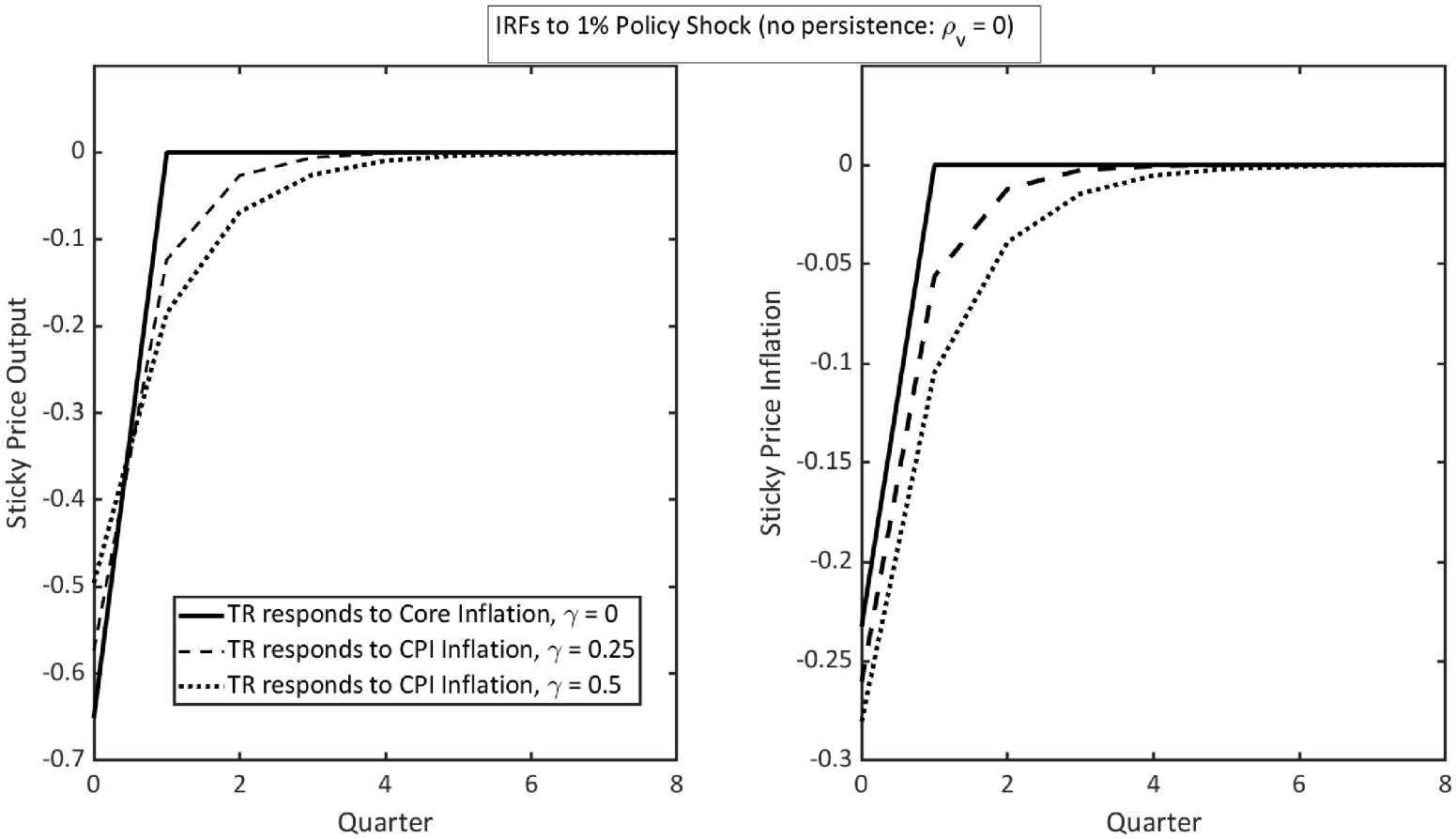
Impulse Responses to 1% Policy Shock



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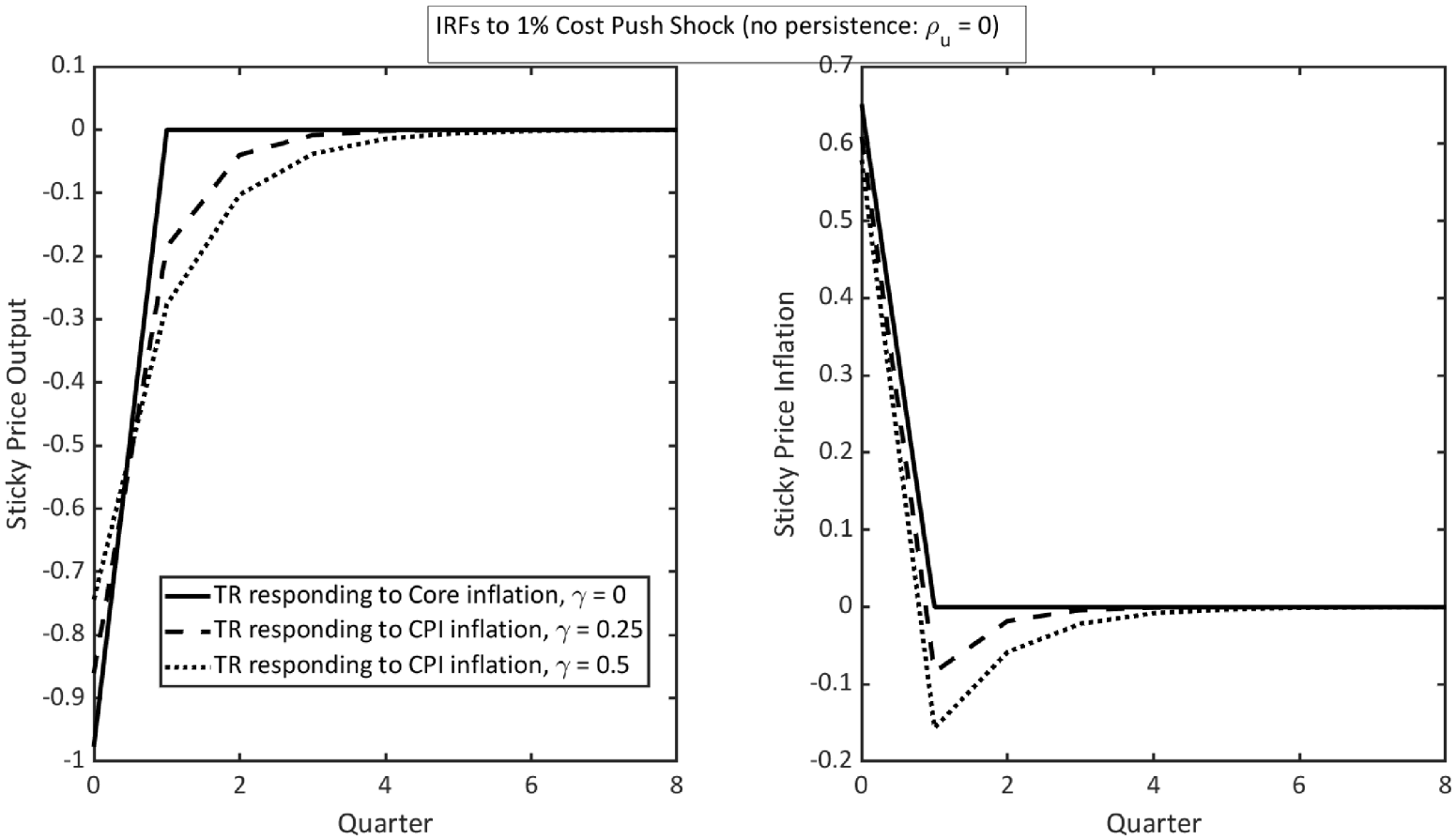
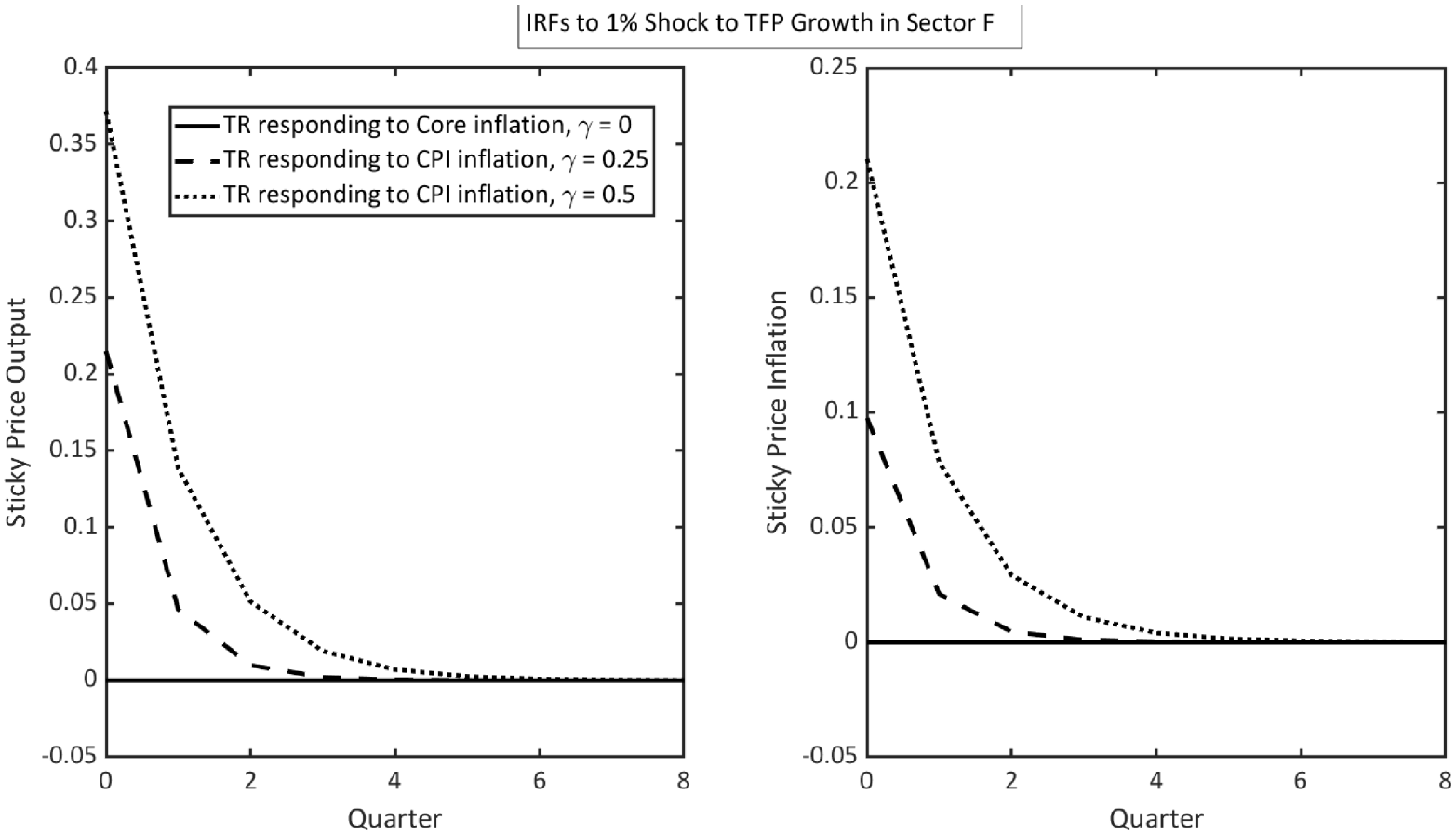
Impulse Responses to 1% Cost Push Shock



II. Heterogeneous Nominal Rigidities

Impulse Responses to 1% Shock to TFP Growth in Sector F



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- **Question**: what measure of inflation should the Fed try to stabilize?
  $\Longrightarrow$ what inflation measure should enter into the Fed's objective/loss function?

- It can be shown that, in this model, with a sticky price sector S and a (fully) flexible price sector F, the optimal monetary policy problem is

$$\max E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t^F, C_t^S, H_t\right) \approx \min \frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t \left[\left(\hat{\pi}_t^S\right)^2 + \alpha_x \left(\hat{x}_t^S\right)^2\right]$$

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- Namely: the Fed should not be concerned at all about inflation fluctuations in the flexible price sector
  NOTE: there is no output gap in sector F: $\hat{x}_t^F = 0$

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Interesting Extensions to Open Economies

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- The centralized monetary authority (the ECB) sets one area-wide interest rate to stabilize the economy against shocks to fundamentals
- What is the most appropriate area-wide measure of inflation the ECB should try to stabilize around target?

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- Is the expenditure weighted HICP optimal?

- Allowing for heterogeneous degree of competition and price stickiness in a 2-country currency union (let's denote countries by F and S for simplicity), Benigno shows that the ECB's loss function *should* take the following form

$$\min L_t = \frac{1}{2}\left[\alpha_x \hat{x}_t^2 + \alpha_F \left(\hat{\pi}_t^F\right)^2 + \alpha_S \left(\hat{\pi}_t^S\right)^2\right]$$

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- Hence, HICP is the optimal measure to target *if and only if* countries display same extent of price stickiness (which is not the case in the data)

III. Heterogeneous Agents

Limited Asset Market Participation

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- Expanding literature about full-blown heterogeneous agents models (HANK). See works by G. Violante at Princeton University

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  - they supply labor to firms to earn labor income

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$$\max E_0 \sum_{t=0}^{\infty} \beta^t U_t \qquad \text{for} \qquad U_t = \underbrace{\gamma U_t^R}_{\text{restricted}} + \underbrace{(1-\gamma)\, U_t^U}_{\text{unrestricted}}$$

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- Without loss of generality, assume $\sigma = 1$. One can show that

$$\max E_0 \sum_{t=0}^{\infty} \beta^t U_t \approx \min \frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t \left[\hat{\pi}_t^2 + \alpha_x \hat{x}_t^2\right]$$

$$\alpha_x = \frac{\kappa_x}{(1-\gamma)\,\epsilon}, \qquad \kappa_x = \text{ slope of NKPC}$$

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1. if $\gamma = 0 \quad \Longrightarrow \quad \alpha_x = \frac{\kappa_x}{\epsilon}$ (as in baseline, see notes)
2. α_x is strictly increasing in share parameter γ
   $\Longrightarrow$ the larger the share of consumers without access to asset markets, the more the Fed should care about stabilizing output relative to stabilizing inflation

- It turns out that with LAMP, under discretion, the optimal targeting rule remains

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  - ORV is strictly increasing in the degree of limited participation
  - inflation is no longer necessarily less volatile than the output gap (as we found for baseline)

III. Heterogeneous Agents

Impulse Responses to 1% Cost Push Shock