# Chapter 18: Nominal Frictions and Business Cycles

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# Outline

# Introduction and Empirical Evidence on Price Rigidity

## Introduction

Two core ideas of Keynesian economics:

1. Productive factors may not be used at the optimal level
2. The level of nominal demand influences the level of production

This chapter:

- Reviews micro evidence that prices adjust infrequently
- Presents the **New Keynesian (NK) model**: microfounded sticky-price DSGE
- Explains why nominal rigidity gives monetary policy real effects
- Discusses optimal monetary policy

# Micro Evidence on Price Rigidity

BLS surveys: $\sim$85,000 individual items across 300 goods categories.

If a price changes with probability $1-\theta$ each month, expected duration $= \theta/(1-\theta)$.

# Micro Evidence: Estimates

**Estimates** (Klenow and Malin, 2010):

- Including sales: mean 6.2 months, median 3.4 months
- Excluding sales: mean 8.0 months, median 6.9 months
- Excluding sales and product substitutions: mean 10.1 months, median 8.3 months

Median absolute price change $\approx 11.5\%$ (Klenow and Kryvtsov, 2008): most price changes reflect sector-specific, not aggregate, conditions. Boivin, Giannoni, and Mihov (2009): disaggregated prices are sticky in response to macro shocks.

# The New Keynesian Model

# Environment

**Household**: preferences over consumption $C_t$ and labor $L_t$:

$$U_0 = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{L_t^{1+\psi}}{1+\psi} \right]$$

**Final good**: CES over intermediate varieties $j \in [0,1]$:

$$Y_t = \left( \int_0^1 y_{j,t}^{(\varepsilon-1)/\varepsilon} \, dj \right)^{\varepsilon/(\varepsilon-1)}, \qquad \varepsilon > 1$$

**Intermediate good** $j$: $y_{j,t} = A_t \ell_{j,t}$

**Demand for variety** $j$: $y_{j,t} = (P_{j,t}/P_t)^{-\varepsilon} Y_t$

**Price index**: $P_t = \left( \int_0^1 P_{j,t}^{1-\varepsilon} \, dj \right)^{1/(1-\varepsilon)}$

# Calvo Pricing

Each period, a firm can reset its price with probability $1 - \theta$ (i.i.d. across firms and time). Otherwise, the nominal price remains fixed.

- Monopolistic competition: firms set prices, stand ready to serve demand
- Output is **demand-determined** in the short run
- Cashless-limit argument (Chapter 17): money is the unit of account but not explicitly present
- Government sets nominal interest rate $i_t$ (Taylor rule)

# Household Optimality Conditions

**Euler equation**:

$$C_t^{-\sigma} = \beta \mathbb{E}_t \left[ \frac{1 + i_t}{1 + \pi_{t+1}} C_{t+1}^{-\sigma} \right]$$

**Intratemporal labor supply**:

$$C_t^{-\sigma} w_t = L_t^{\psi}$$

The Euler equation determines the intertemporal path of consumption via the **real interest rate** $(1 + i_t)/(1 + \pi_{t+1})$. Nominal rigidities affect these conditions only through equilibrium changes in $w_t$ and $r_t$.

# Firm's Price-Setting Problem

A firm resetting at $t$ chooses $P_t^R$ to maximize expected discounted profits over the (random) duration of the price. The optimal reset price satisfies:

$$p_t^R = \frac{p_t^N}{p_t^D}$$

where (with $p_t^R \equiv P_t^R / P_t$):

$$p_t^N = \frac{\varepsilon}{\varepsilon - 1} \frac{w_t}{A_t} u'(C_t) Y_t + \theta \beta \mathbb{E}_t [(1 + \pi_{t+1})^{1+\varepsilon} p_{t+1}^N]$$

$$p_t^D = u'(C_t) Y_t + \theta \beta \mathbb{E}_t [(1 + \pi_{t+1})^{\varepsilon} p_{t+1}^D]$$

With flexible prices ($\theta = 0$): $p_t^R = \mu \cdot w_t / A_t$ where $\mu = \varepsilon / (\varepsilon - 1)$ is the constant markup.

# Aggregation and Price Dispersion

**Price level evolution**:

$$P_t = \left[\theta P_{t-1}^{1-\varepsilon} + (1-\theta)(P_t^R)^{1-\varepsilon}\right]^{1/(1-\varepsilon)}$$

**Inflation and the reset price**:

$$1 + \pi_t = \left[\frac{1-(1-\theta)(p_t^R)^{1-\varepsilon}}{\theta}\right]^{1/(\varepsilon-1)}$$

**Price dispersion**: $D_t \equiv \int_0^1 (P_{j,t}/P_t)^{-\varepsilon} dj \geq 1$

$$D_t = (1-\theta)(p_t^R)^{-\varepsilon} + \theta(1+\pi_t)^{\varepsilon} D_{t-1}$$

Aggregate production: $Y_t = A_t L_t / D_t$. Price dispersion reduces effective productivity.

# Flexible-Price Equilibrium and Output Gap

With $\theta = 0$: all firms set $p^R = 1$, $D = 1$, $w^n/A = 1/\mu$. Natural output:

$$Y_t^n = \mu^{-1/(\sigma+\psi)} A_t^{(1+\psi)/(\sigma+\psi)}$$

Monopoly power ($\mu > 1$) reduces output below the efficient level $Y_t^* = A_t^{(1+\psi)/(\sigma+\psi)}$.

**Output gap**: $x_t \equiv \log Y_t - \log Y_t^n$

**Welfare-relevant gap**: $x_t^w \equiv \log Y_t - \log Y_t^* = x_t - \frac{1}{\sigma+\psi} \log \mu$

# The Three-Equation Model

Log-linearization around a zero-inflation steady state yields:

**IS curve** (demand):

$$x_t = \mathbb{E}_t x_{t+1} - \frac{1}{\sigma}(\hat{\imath}_t - \mathbb{E}_t \pi_{t+1} - r_t^n)$$

where $r_t^n = -\log\beta + \sigma\frac{1+\psi}{\sigma+\psi}(\mathbb{E}_t \hat{A}_{t+1} - \hat{A}_t)$ is the natural rate of interest.

**New Keynesian Phillips curve** (supply):

$$\pi_t = \kappa x_t + \beta \mathbb{E}_t[\pi_{t+1}]$$

where $\kappa \equiv (1-\theta)(1-\beta\theta)(\sigma+\psi)/\theta$.

# The Three-Equation Model: Policy Rule

**Interest rate rule** (Taylor rule):

$$\hat{\imath}_t = \phi_\pi(\pi_t - \pi^*) + \phi_x x_t + \omega_t$$

# Determinacy: The Taylor Principle

The three-equation model has a unique equilibrium if and only if:

$$(1-\beta)\phi_x + \kappa(\phi_\pi - 1) > 0$$

$\phi_\pi > 1$ is sufficient (and necessary if $\phi_x = 0$): the central bank must raise the nominal rate **more than one-for-one** with inflation to stabilize the economy.

**Intuition**: If $\phi_\pi < 1$, elevated inflation expectations $\Rightarrow$ lower real rate $\Rightarrow$ positive output gap $\Rightarrow$ higher inflation $\Rightarrow$ self-fulfilling. Multiple equilibria.

# The Classical Dichotomy Breaks Down

With flexible prices: $\pi_t$ depends only on expected future output gaps (zero if policy is right). Nominal variables have no real effects.

With sticky prices: a lower path for $i_t$ (expansionary monetary policy) does *not* produce an immediate offsetting fall in $\mathbb{E}_t[\pi_{t+1}]$. Instead:

- Real interest rate falls $\Rightarrow$ positive output gap (IS curve)
- Positive output gap $\Rightarrow$ rising inflation (NKPC)
- Rising inflation can reinforce the decline in real rates

$\Rightarrow$ Nominal demand affects real output. The monetary policy rule matters.

# Monetary Policy Strategies

# Policy Objectives

The planner's efficient output: $Y_t^* = A_t^{(1+\psi)/(\sigma+\psi)}$

Two sources of inefficiency:

1. Aggregate output $\neq$ efficient level (monopoly distortion + sticky-price markup variation)
2. Price dispersion ($D_t > 1$): misallocation of labor across varieties

# Policy Objectives: Welfare Loss

**Welfare loss** (second-order approximation around zero-inflation steady state with subsidy correcting monopoly distortion):

$$U \approx -\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\pi_t^2 + \frac{\kappa}{\varepsilon} x_t^2\right]$$

$\Rightarrow$ Minimize squared inflation (price dispersion) and squared output gap.

# The Divine Coincidence

From the NKPC: if $x_t = 0$ for all $t$, then $\pi_t = 0$ for all $t$.

$\Rightarrow$ No trade-off between output gap stabilization and inflation stabilization in the baseline model.

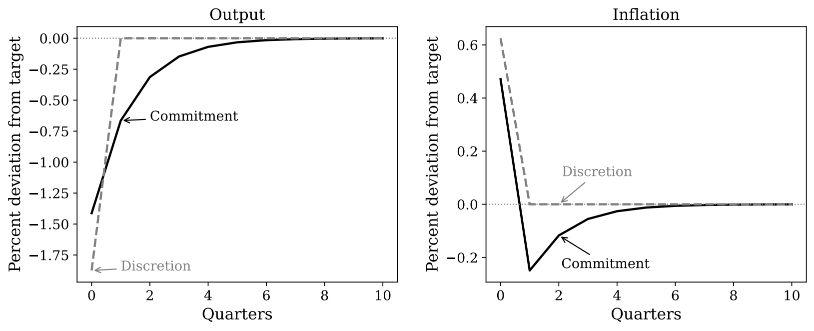
**Breaking the divine coincidence**: need a time-varying wedge between $Y_t^n$ and $Y_t^*$. Example: **cost-push shocks** $\eta_t$ (from time-varying elasticity of substitution):

$$\pi_t = \kappa x_t + \beta \mathbb{E}_t[\pi_{t+1}] + \eta_t$$

Now $x_t = 0$ does not imply $\pi_t = 0 \Rightarrow$ meaningful policy trade-off.

# Commitment vs. Discretion

Response of output and inflation to a transitory cost-push shock




Parameters: $\beta = 0.99$, $\kappa = 0.2$, $\varepsilon = 3$.

# Commitment vs. Discretion: Policy Paths

**Discretion**: Raise $i$ at $t = 0$, return to steady state at $t = 1$. $\pi_0 > 0$, then $\pi_t = 0$.

**Commitment**: Raise $i$ less at $t = 0$, keep rates high for several periods. $\pi_0$ lower; $\pi_t < 0$ for $t \geq 1$ (price level returns to target).

Commitment dominates at $t = 0$ but is time-inconsistent: at $t = 1$, the central bank wants to switch to discretion.

## Inflation Targeting vs. Price-Level Targeting

**Flexible inflation targeting**: minimize
$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t [(\pi_t - \pi^*)^2 + \lambda x_t^2]$

**Price-level targeting**: $i_t = \bar{\imath} + \phi_P (P_t - P_t^*) + \phi_x x_t$

- Returns the price level to a target path after shocks
- Provides greater certainty about long-run price level (good for long-term nominal contracts)
- Automatically commits to undoing unwanted price-level changes

# Aggregate Evidence

# Identifying Monetary Policy Shocks

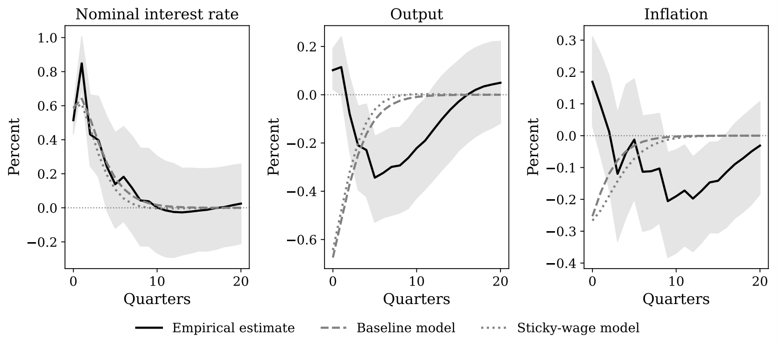
**Challenge**: Monetary policy responds endogenously to the economy. Need exogenous variation.

**High-frequency identification** (Kuttner, 2001; Gürkaynak, Sack, Swanson, 2005): Changes in financial market rates in a narrow window around policy announcements. Forecast = systematic component; surprise = shock.

**Narrative approach** (Romer and Romer, 2004): Regress interest rate changes on central bank forecasts. Residual = shock (deviation from systematic response to the outlook).

# Responses to a Monetary Policy Shock

Empirical and simulated responses to a monetary policy shock




Left: nominal interest rate. Center: output. Right: inflation. Empirical (Romer–Romer), baseline NK model, and sticky-wage model.

# Monetary Policy Shock: Model vs. Data

**Qualitatively**: Model matches data—higher $i \Rightarrow$ higher $r \Rightarrow$ lower output $\Rightarrow$ lower inflation.

**Quantitatively**: Baseline model predicts immediate responses; data shows delayed, hump-shaped responses. Sticky-wage model improves the fit.

# Estimating the Phillips Curve

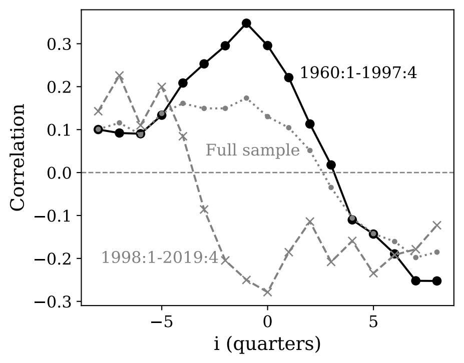
Galí and Gertler (1999): Real marginal cost $\approx$ labor share $s_t^L = w_t L_t / Y_t$.

$$\pi_t = \kappa \hat{s}_t^L + \beta \pi_{t+1} + \zeta_t$$

Estimate via GMM with lagged instruments (valid if $\mathbb{E}_{t-1}[\eta_t] = 0$). Implied average price duration: 3–6 quarters (longer than micro evidence suggests).

# Labor Share and Inflation

Correlation between the labor share at $t$ and inflation at $t+i$




Dynamic correlation between the labor share and lags and leads of inflation; data are HP-filtered. Positive in the early sample (1960:1–1997:4); weaker or negative post-1998.

## Labor Share and Inflation: Implication

The weakening labor share–inflation correlation poses a challenge for the NKPC.

# Extensions

# Sticky Wages

Wages set by monopolistically competitive unions, Calvo-style ($1-\theta_w$ update probability). With both sticky prices and sticky wages, three equations replace the single NKPC:

$$\pi_t = \beta \mathbb{E}_t[\pi_{t+1}] + \xi_p(\hat{w}_t - \hat{A}_t)$$

$$\pi_t^w = \beta \mathbb{E}_t[\pi_{t+1}^w] - \xi_w(\hat{w}_t - \hat{A}_t) + \kappa_w x_t$$

$$\hat{w}_t = \hat{w}_{t-1} + \pi_t^w - \pi_t$$

# Sticky Wages: Dynamics

Price inflation depends on real wages relative to productivity; wage inflation depends on MRS relative to wages. The real wage is an endogenous state variable $\Rightarrow$ richer dynamics.

Figure 18.2 shows that layering wage and price rigidities generates more persistent, hump-shaped responses, improving the fit to data.

# Habit Formation

Replace standard preferences with:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{(C_t - \gamma C_{t-1})^{1-\sigma}}{1-\sigma} - \frac{L_t^{1+\psi}}{1+\psi} \right], \qquad \gamma \in [0,1)$$

Households smooth both the *level* and the *growth rate* of consumption $\Rightarrow$ gradual, hump-shaped adjustment to shocks.

# Capital, Investment, and Adjustment Costs

Add Cobb-Douglas production: $y_{j,t} = A_t k_{j,t}^{\alpha} \ell_{j,t}^{1-\alpha}$

Capital accumulation with adjustment costs:

$$K_{t+1} = (1-\delta)K_t + \xi(I_t/K_t)K_t$$

$\xi$ increasing and concave $\Rightarrow$ costly to vary the investment rate $\Rightarrow$ gradual investment adjustment.

# Capital: Why Adjustment Costs Matter

Without adjustment costs: small changes in $i_t$ produce extreme investment volatility (small $\delta$ means $I \ll K$, so small $\%\Delta K \Rightarrow$ large $\%\Delta I$).

Variable capacity utilization ($u_t K_t$ as effective capital) provides an additional margin, helping reconcile the slope of the NKPC with micro evidence.

# Summary

# Key Takeaways (I)

1. **Micro evidence**: Prices adjust every 6–11 months on average (US CPI data); considerable heterogeneity across goods; most price changes reflect sector-specific conditions.
2. **NK model**: CES production with Calvo pricing. Household Euler + labor supply; firm's optimal reset price balances current and expected future marginal costs weighted by $(\beta\theta)^{\tau-t}$.
3. **Three-equation model**: IS curve ($x_t$ forward-looking, decreasing in real rate), NKPC ($\pi_t = \kappa x_t + \beta \mathbb{E}_t[\pi_{t+1}]$, $\kappa = (1-\theta)(1-\beta\theta)(\sigma+\psi)/\theta$), Taylor rule.
4. **Taylor principle**: Unique equilibrium iff $(1-\beta)\phi_x + \kappa(\phi_\pi - 1) > 0$. Nominal rate must respond more than one-for-one to inflation.

# Key Takeaways (II)

5. **Welfare**: Loss $\propto \mathbb{E}[\pi_t^2 + (\kappa/\varepsilon)x_t^2]$. Two inefficiencies: markup variation (wrong output level) and price dispersion (misallocation).
6. **Divine coincidence**: $x_t = 0 \Rightarrow \pi_t = 0$ in baseline. Broken by cost-push shocks $\eta_t \Rightarrow$ meaningful inflation-output trade-off.
7. **Commitment vs. discretion**: Commitment to future tight policy reduces $\pi_0$ with less output cost. Time-inconsistent: central bank wants to renege at $t = 1$.

# Key Takeaways (III)

8. **Aggregate evidence**: Contractionary monetary shocks raise real rates, lower output and inflation. Baseline NK matches qualitatively; sticky wages + habits + adjustment costs needed for hump-shaped dynamics.
9. **Phillips curve estimation**: Labor share as marginal cost proxy. Positive correlation with inflation weakens post-1998.