LECTURE 2.3

Sticky Prices and the New Keynesian Phillips Curve

ECON42550 Macroeconomics

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Where We Are

1. Short-Run Fluctuations

1.1 The Keynesian Multiplier

1.2 Introducing IS-MP-PC

1.3 Analysing IS-MP-PC

1.4 The Zero Lower Bound

1.5 Banks, Runs, the Cycle

2. NK Building Blocks

2.1 Expectations, Investment

2.2 Consumption, Fiscal Policy

2.3 Sticky Prices and the NKPC

3. Long-Run Growth

3.1 Growth Facts, Solow

3.2 The Fundamental Causes

3.3 Endogenous Growth

3.4 Schumpeterian Growth

> **Today Closes Section 2**
> The short-run half of the module ends here.

Last Week's Lecture

Last week we derived consumption from a household choosing, and took the result to the data.

1. **The Two-Period Model.**
   Derive consumption from a household choosing, rather than from a rule of thumb.

2. **The General Case.**
   Take the two-period result to many periods and to uncertainty.

3. **Evidence and Policy.**
   Test the theory, then use it on fiscal policy.

Lecture Plan

1. **Why Prices Are Sticky.**
   Establish the fact the whole of Section 1 rested on, and the theories that explain it.

2. **The Calvo Model.**
   Derive a Phillips curve from firms that cannot reset their prices at will.

3. **The New Keynesian Phillips Curve.**
   Read the result, and confront it with the data.

> **Whelan, Chapter 8**
> Reading: Whelan (2023, ch. 8).

SECTION 1

Why Prices Are Sticky

The Assumption We Never Justified

Lecture 1.1 named the friction **nominal rigidity**: prices cannot adjust instantly. Every equation since has rested on it:

- With fully flexible prices, a demand shock is absorbed entirely by prices.
- Output would never leave trend, and monetary policy would be irrelevant.

> **The Claim Gets Checked, Then Modelled**
> Do prices actually sit still for months, and how would we know?

How Often Do Prices Actually Change?

Statistical agencies collect the individual price quotes behind the consumer price index. You can watch one product and count the months its price holds:

- In US micro data the typical price lasts about **four months** between changes.
- In euro-area micro data the typical price lasts about **ten to eleven months**.
- Both are **medians**, not means.

> **Prices Sit for Months**
> Prices are reset neither continuously nor annually. Months of stickiness is enough for a short run to exist.

The Average Hides the Interesting Part

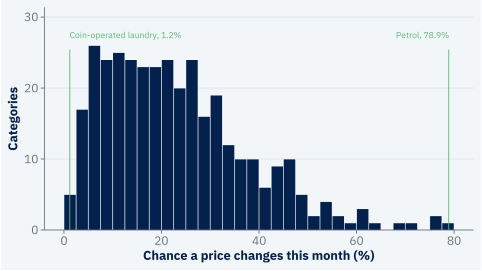

Figure 1: How often a price changes, across 350 CPI categories: the chance of a change in a given month.

> **Services Reprice Yearly, Petrol Weekly**
> Services, rents and restaurant meals reprice once a year. Petrol, fresh food and airfares reprice weekly, tracking commodity costs rather than demand.

Stickiness Is Not a Constant

The frequency of price changes is a **behaviour**. Firms reprice more often when inflation is high:

- Waller (2023) tests unanchored expectations against more frequent repricing after 2021.
- He finds for repricing. The monthly share changing roughly **doubled** by late 2021.

> **A Fixed Reset Probability Is a Modelling Choice**
> The next section holds the reset probability fixed. The 2021–2023 episode strained that assumption hardest.

Theories of Stickiness

Why would a firm not reprice when it could? Three answers, all complements:

- **Menu Costs:** A fixed cost of repricing makes a small change not worth making.
- **Contracts:** Many prices are fixed by agreement for a term, and wages dominate cost.
- **Coordination Failure:** A firm raising its price alone loses customers, so all wait.

> **Small Costs, Large Aggregate Effects**
> A single menu cost is trivially small — too small on its own. Combined with the coordination failure above, so a firm's desired price barely moves when nobody else's does, the price level adjusts slowly and a monetary shock has real effects for years.

New Classical Versus New Keynesian

Thirty years of macroeconomic disagreement turn on whether prices clear markets.

New Classical

Prices and wages clear markets. Money is neutral. Output deviates from trend only when agents are **surprised** — and rational agents are not surprised systematically.

New Keynesian

Optimising agents and rational expectations, **plus** nominal rigidity. Money is not neutral in the short run, because prices cannot all move at once.

One Friction Puts Policy to Work

Both sides accept optimisation and rational expectations. The New Keynesian model adds one friction, and that friction is what monetary policy works on.

Which Evidence Would You Put in a Model?

You now have micro durations, a wide distribution, and three theories of waiting.

> **Question**
> What is the strongest single piece of evidence that prices are sticky, and the strongest objection to building a model on it?

Two minutes on your own, then compare with the person beside you.

SECTION 2

The Calvo Model

Sticky Prices Need a Price Firms Are Sticking To

A model of stickiness needs two prices, not one. The gap between them is where the economics sits:

- The **frictionless price** is what an unconstrained firm would choose today.
- The **actual price** is what it chose when it was last allowed to reset.
- Inflation is the actual price chasing the frictionless price.

> **Logs Make the Mark-Up Additive**
> Everything in this section is in logs, so differences read as percentages and the mark-up is additive rather than multiplicative.

The Price a Firm Would Like to Charge

A firm free to reset would charge its log mark-up (μ) over marginal cost:

$$p_t^* = \mu + mc_t \tag{1}$$

- p_t^*: the frictionless price, in logs
- mc_t: log nominal marginal cost

> **This Star Is a Choice, Not a Resting Point**
> In Section 1 a star marked a resting point (r^*, y_t^*). Here p_t^* solves an **optimisation problem** — the exception, not a new rule.

The Calvo Assumption

A firm may reset each period, with a fixed probability independent of its wait. Here θ is the chance it **cannot** reset, not Section 1's damping factor:

$$\Pr(\text{firm resets at } t) = 1 - \theta, \qquad 0 < \theta < 1 \tag{2}$$

> **Not Realistic, but Tractable**
> Firms do not toss a coin. Resetters are then a **random sample**, so the price level is an average.

How Long Does a Price Last?

Duration evidence pins θ down directly:

$$E[\text{duration}] = \frac{1}{1-\theta} \tag{3}$$

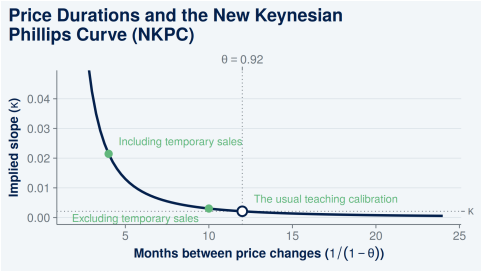

Figure 2: The implied NKPC slope κ against the months a price lasts, falling steeply, with three durations marked: about four months, the US median; about ten and a half, the euro-area median; and twelve at the teaching calibration $\theta = 0.92$.

The Loss Function

A resetting firm minimises squared pricing errors over the price's whole life:

$$L(z_t) = \sum_{k=0}^{\infty} (\theta\beta)^k E_t \underbrace{(z_t - p^*_{t+k})^2}_{\text{the squared pricing error}} \tag{4}$$

- z_t: the price chosen today by a firm that is allowed to reset

> **Why the Weight Is $(\theta\beta)^k$ and Not β^k**
> β is the discount factor; θ^k is the chance the price still holds. Stickier prices make the firm look further ahead.

The Optimal Reset Price

Differentiate with respect to z_t, zero the derivative, and sum the weights:

$$\sum_{k=0}^{\infty} (\theta\beta)^k E_t \left(z_t - p^*_{t+k} \right) = 0 \tag{5}$$

$$z_t = (1 - \theta\beta) \sum_{k=0}^{\infty} (\theta\beta)^k E_t \, p^*_{t+k} \tag{6}$$

Not Pricing for Today Alone
The reset price is a **weighted average of expected future frictionless prices**.

The Same Thing, Written Recursively

Split the $k = 0$ term off the sum, and what remains is $\theta\beta E_t z_{t+1}$:

$$z_t = \theta\beta\, E_t z_{t+1} + (1 - \theta\beta)\,(\mu + mc_t) \tag{7}$$

All the Forward-Looking Behaviour Enters Here

Today's reset price is a weighted average of **tomorrow's expected reset price** and **today's frictionless price**. This one line makes the curve forward-looking.

From Reset Prices to the Price Level

A fraction $1 - \theta$ charge the reset price; the rest keep last period's. Non-resetters are a random sample, so their average is the old log price level (p_{t-1}):

$$p_t = \theta p_{t-1} + (1 - \theta)\, z_t \tag{8}$$

The reset-price recursion carries the same z_t:

$$z_t = \theta\beta\, E_t z_{t+1} + (1 - \theta\beta)\,(\mu + mc_t) \tag{9}$$

The Price Level Cannot Jump

The price level is a weighted average of its own past and the reset price.

Two Equations, One Unknown Price Level

Rearranged, the price-level equation reads $z_t = (p_t - \theta p_{t-1})/(1-\theta)$. That block goes in wherever the reset price appears in the recursion:

$$\frac{p_t - \theta p_{t-1}}{1-\theta} = \theta\beta\, E_t \frac{p_{t+1} - \theta p_t}{1-\theta} + (1-\theta\beta)(\mu + mc_t) \tag{10}$$

Multiply through by $(1-\theta)$ and collect the p_t terms:

$$p_t\left(1 + \theta^2\beta\right) - \theta p_{t-1} - \theta\beta\, E_t p_{t+1} = (1-\theta)(1-\theta\beta)(\mu + mc_t) \tag{11}$$

> **Dividing by θ Reaches Inflation**
> The coefficient on p_t is $1/\theta + \theta\beta$, and the slope that survives is $(1-\theta)(1-\theta\beta)/\theta$.

Inflation Obeys a Forward-Looking Equation

Divide by θ, write $\pi_t \equiv p_t - p_{t-1}$, and the price levels resolve into inflation:

$$\pi_t = \beta E_t \pi_{t+1} + \frac{(1-\theta)(1-\theta\beta)}{\theta} \underbrace{(\mu + mc_t - p_t)}_{\text{desired price minus actual price}} \tag{12}$$

No π_{t-1} Anywhere in It
Inflation today depends on expected inflation tomorrow and on today's pricing gap.

What Is a Resetting Firm Minimising?

The derivation so far: a loss function, a reset price, and the price level.

> **Question**
> What does a firm resetting its price today try to minimise, and over what horizon?

Two minutes from memory, then fix whichever of you is wrong.

SECTION 3

The New Keynesian Phillips Curve

Marginal Cost Is the Output Gap in Disguise

Nobody observes marginal cost. Above potential, labour is scarce and wages are bid up. Real marginal cost then rises by λ per point of output gap:

$$\mu + mc_t - p_t = \lambda \tilde{y}_t \tag{13}$$

A Tilde Means a Gap

$\tilde{y}_t$ is shorthand for the output gap ($y_t - y_t^*$), measured from potential as in Part 1 — Galí measures it from flexible-price output. Both spellings appear in the past papers, so both appear here.

The New Keynesian Phillips Curve

Every firm optimises, only a fraction can act, and inflation obeys:

$$\pi_t = \beta\, E_t\pi_{t+1} + \gamma\, \tilde{y}_t, \qquad \gamma = \frac{\lambda(1-\theta)(1-\theta\beta)}{\theta} \tag{14}$$

This is Section 1's Phillips curve, derived rather than assumed. The expectation is of **next period's** inflation, and γ is now a formula.

> **Check What the Slope Letter Multiplies**
> SQ2 Q6 and 2023 Q3 put γ on the **elasticity**, writing $p_t^* = p_t + \gamma y_t + \varepsilon_t$, and leave the composite unnamed.

What the NKPC Leaves Out

- **No π_{t-1}:** Inflation has no inertia, which is what makes disinflation costless.
- **No ε_t^{π}:** No cost-push shock here; adding one is a line of algebra.
- **No Unemployment:** Reaching unemployment from the output gap needs Okun's law.
- **No Unit Coefficient:** Expected inflation carries $\beta < 1$, not one.

> **The Long-Run Curve Here Is Not Vertical**
> Setting $\pi_t = E_t\pi_{t+1} = \pi$ gives $\pi = \gamma\tilde{y}/(1-\beta)$.

Inflation as an Asset Price

$$\pi_t = \gamma \underbrace{\sum_{k=0}^{\infty} \beta^k E_t \tilde{y}_{t+k}}_{\text{the present value of future gaps}} \tag{15}$$

The Past Does Not Enter, Only the Expected Future
A credible promise about policy three years out cuts inflation today.

The Backward-Looking Contrast

The relationship estimated from the 1970s onwards, still the forecasting workhorse:

$$\pi_t = \pi_{t-1} + \alpha - \beta u_t \tag{16}$$

> **These Two Letters Are Borrowed**
> α and β here label an intercept and a slope on unemployment (u_t). They are **not** the capital share and **not** the discount factor.

One Unemployment Rate Holds Inflation Still

Set $\pi_t = \pi_{t-1}$ and solve for the unemployment rate at which inflation is stable:

$$u^* = \frac{\alpha}{\beta} \tag{17}$$

- u^*: the non-accelerating-inflation rate of unemployment

> **Inflation's Change, Not Its Level**
> Friedman (1968) as a regression: the trade-off is with the **change** in inflation, not its level. The star marks a resting point, unlike p_t^*.

The Two Curves Describe Different Worlds

One name, two equations, and they disagree about whether inflation has a memory.

1. **The backward-looking curve.**
   Inflation carries its own momentum. Unemployment below u^* makes inflation rise without limit; disinflation needs unemployment above u^*.

2. **The New Keynesian curve.**
   Inflation has no momentum. Only the whole expected path of the output gap matters.

> **Which Curve Is Right Decides a Disinflation's Cost**
> See Blanchard (2018) on whether the natural rate hypothesis survives the evidence.

Costless Disinflation?

The central bank announces a disinflation, is believed, and promises zero output gaps at every horizon: $E_t\,\tilde{y}_{t+k} = 0$ for every k. It lands where every expected gap was, in the present value of future gaps:

$$\pi_t = \gamma \sum_{k=0}^{\infty} \beta^k \, 0 \; = \; 0 \tag{18}$$

- Inflation falls the instant the announcement is believed: it is a jump variable.
- The output gap stays at zero; credibility substitutes for the recession.
- A gradual glide down needs a **boom**, so the sacrifice ratio turns negative.

> **The NKPC Predicts a Sacrifice Ratio of Zero or Below**
> The sacrifice ratio is cumulative output lost, as a percentage of trend. The divisor is the percentage-point fall in trend inflation.

The Disinflation, Drawn

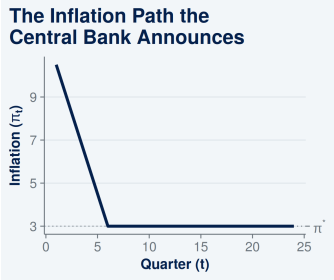

Figure 3: Inflation falling to its new target under a credible disinflation.

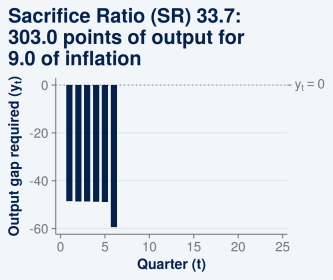

Figure 4: The output gap over the same run.

> **Gradual Disinflation Needs a Boom**
> The two panels are one run: the inflation path on the left, the output gap it costs on the right. **Fast:** the gap stays at zero. **Gradual:** the gap must be positive throughout.

What the Sacrifice Ratio Actually Is

The model says zero or negative. Estimated ratios are positive almost everywhere:

- **Twenty-Eight Episodes, Nine Countries:** ratios run **0.0 to 3.6**, 27 positive.
- **Country Averages:** Germany 2.9, the United States 2.4, France 0.8, the UK 0.8.
- **Volcker, 1979–82:** with rates near 20%, the ratio is **1.8 to 1.9**.

> **Disinflation Costs Output After All**
> Disinflation costs output, and the forward-looking model says it should not.

The Evidence, Drawn

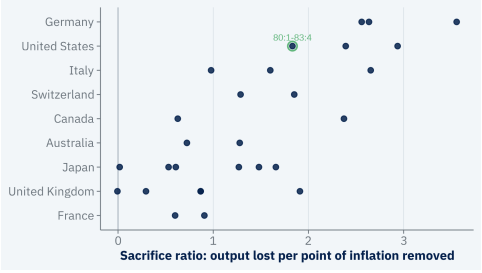

Figure 5: Output lost per point of inflation removed, 28 disinflations in 9 countries.

> **Almost Every Point Sits Above Zero**
> The line at zero is the NKPC's prediction. The spread runs from near zero to over three, and whatever sets that cost, the model does not contain it.

The Lucas Critique Again

The estimated backward-looking curve fitted the data for years. Fitting is not enough:

- An estimated curve's coefficients are the **reduced form** of expected policy.
- Change the regime, expectations change, the coefficients change, the forecast fails.
- The 1960s trade-off broke because policy exploited it and expectations adjusted.

> **Even θ May Not Be Structural**
> θ, β and λ are meant to be structural. The doubling of price-change frequency after 2021 says θ is not.

The Curve That Started It

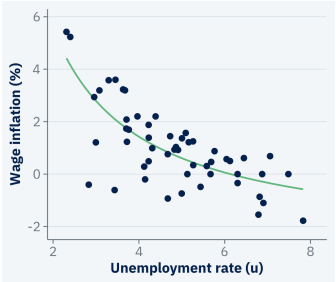

Figure 6: UK wage inflation and unemployment over Phillips's own fitted period, 1861–1913.

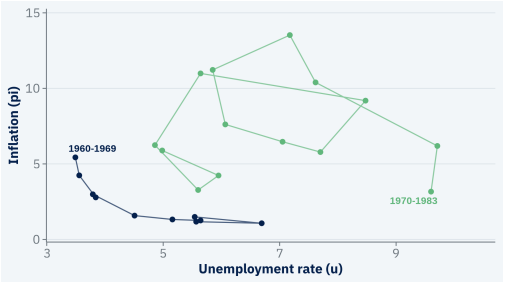

Figure 7: US inflation and unemployment: the scatter that was stable, then was not.

> **Friedman Predicted the Menu Would Break**
> Phillips (1958) fitted UK data back to 1861; Samuelson & Solow (1960) made it a policy menu.

The Third Equation, Derived

1 Why prices are sticky.
Micro data show prices lasting months, and menu costs, contracts and coordination failure explain the waiting.

2 The Calvo model.
A firm resetting at random prices for the whole expected life of its price, so the price level cannot jump.

3 The New Keynesian Phillips curve.
Inflation is discounted expected inflation plus the output gap. Credible disinflation is then costless, which the sacrifice-ratio evidence denies.

> **A Promise from Lecture One Kept**
> Lecture 1.1 wrote $\pi_t = \pi_t^e + \gamma(y_t - y_t^*) + \varepsilon_t^\pi$ and promised the derivation.

Before Lecture 3.1

1. **Play:** the Calvo app. Run a disinflation fast, then gradually, and watch the sacrifice ratio change sign.
2. **Apply:** Problem set 5, due before Lecture 3.1. It covers 2.2 and 2.3.
3. **Review:** Whelan chapters 10 and 11, on growth accounting and Solow.

> **Three Things Here Are on the Sample List**
> The Calvo loss function through to the NKPC is a problem: SQ2 Q5 and Q6. The stickiness evidence and the NKPC against econometric curves are discussions.

Next Week

Section 3 opens on the long run, where prices are flexible again:

- **Lecture 3.1:** Growth accounting, and the Solow model.

> **Whelan, Chapters 10 and 11**
> Reading: Whelan (2023, ch. 10-11).

Thank you

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BACKUP

Appendix

Notes and Tools

- **Whelan's lecture notes** — the notes for this module. Chapter 8 goes with today.
- **The toy models** — the Calvo app runs today's derivation for any θ and β, in your browser, nothing to install.
- **Waller, "The unstable Phillips curve"** — the price-change frequency evidence, in fifteen readable pages.

> **Only Whelan Is Required**
> Whelan is the only required reading.

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