Computational Economics

Lecture 8: New Keynesian Model

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Motivation: Limits of Neoclassical Models

In previous lectures, we studied frictionless neoclassical economies:

- Markets are perfectly competitive; prices are flexible and adjust instantaneously.
- Equilibria are (generically) efficient — the First Welfare Theorem applies.
- Money is neutral: changes in the nominal money supply have no real effects.

These properties make neoclassical models tractable and theoretically elegant, but they come at a cost: they struggle to match key features of the data.

Motivation: What the Data Tells Us

Neoclassicl models cannot match several well-documented empirical regularities:

- **Price stickiness**: Prices at the micro level adjust infrequently (Bils & Klenow 2004; Nakamura & Steinsson 2008).
- **Money non-neutrality**: Monetary policy shocks have significant, persistent effects on output and employment (Christiano, Eichenbaum & Evans 1999).
- **Slow quantity adjustment**: The dynamic responses of output and investment to macro shocks are hump-shaped.

Overview

New Keynesian (NK) models provide a framework that addresses these failures by introducing nominal and real rigidities into microfounded rational expectations model.

In this lecture, we proceed in two steps:

1. **Baseline NK model**: Monopolistic competition + Calvo price stickiness $\Rightarrow$ the *3-equation* NK model.
   (IS curve, NKPC, Taylor rule)

2. **Medium-scale NK model**: Add habit formation, sticky wages, and capital adjustment costs to generate realistic output and inflation persistence.

Main reference: Galì, *Monetary Policy, Inflation and the Business Cycle*.

The Baseline New Keynesian Economy

Firms

The primary departure from the neoclassical benchmark is twofold:

- **Monopolistic competition**: Firms sell differentiated goods. Optimal demand follows from a CES aggregator with price elasticity of substitution θ, so each firm faces a downward-sloping demand curve.
- **Calvo price frictions**: In each period only a random fraction $(1 - \zeta_p)$ of firms from a continuum $[0, 1]$ are able to reset their prices; the remaining fraction ζ_p keep their price unchanged.

Together, these features generate price stickiness: in response to a shock, only a fraction of firms can adjust, so the aggregate price level moves sluggishly.

Firms: Optimal Price-Setting

A firm $i \in [0,1]$ that can reset its price at time t solves:

$$\max_{\{P_t^*\}} \sum_{\tau=0}^{\infty} \zeta_p^\tau E_t \left\{ \beta^\tau \Lambda_{t,t+\tau} [P_{it} Y_{it+\tau|t} - \mathcal{C}(Y_{it+\tau|t})] \right\}$$

subject to

$$Y_{it+\tau|t} = \left(\frac{P_{it}}{P_{t+\tau}} \right)^{-\theta} Y_{t+\tau}$$

where $\Lambda_{t,t+\tau} = (U_{c,t+\tau}/U_{c,t}) \Pi_{t+\tau}^{-1}$ is a stochastic discount factor and $\mathcal{C}(\cdot)$ is the nominal cost function.

The firm discounts future profits by $\beta^\tau \zeta_p^\tau$ because it expects to be stuck with today's price with probability ζ_p^τ.

Note: We implicitly assume that a firm can always meet demand at its current price, which requires markups to be large enough and demand shifts due to shocks to not be too large.

Firms: Optimality Condition

Taking the derivative with respect to P_{it}, the firm's optimality condition is:

$$P_t^* = \frac{\theta}{\theta - 1} \frac{E_t \left[\sum_{\tau=0}^{\infty} (\beta \zeta_p)^\tau Y_{t+\tau} P_{t+\tau}^{\theta-1} MC_{t+\tau|t} \right]}{E_t \left[\sum_{\tau=0}^{\infty} (\beta \zeta_p)^\tau Y_{t+\tau} P_{t+\tau}^{\theta-1} \right]} \qquad (1)$$

where $MC_{t+\tau|t}$ is the nominal marginal cost of a firm that last reset its price in period t.

The firm sets its price as a weighted average of current and future marginal costs, since it may be unable to adjust in subsequent periods.

Flexible price benchmark

Without frictions ($\zeta_p = 0$), the firm sets a constant markup over current marginal cost: $P_t^* = \frac{\theta}{\theta-1} MC_t$.

Firms: Price Level Dynamics

The CES demand function implies an aggregate price index:

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

Given Calvo frictions (fraction ζ_p of firms cannot adjust), this can be written recursively as:

$$P_t^{1-\theta} = (1 - \zeta_p)(P_t^*)^{1-\theta} + \zeta_p P_{t-1}^{1-\theta}. \tag{2}$$

This is the law of motion for the price level: it is a weighted average of the newly set price P_t^* and the lagged price level P_{t-1}, with weights determined by the fraction of adjusting firms.

Note: Price dispersion across firms generates allocative inefficiencies in the economy.

The New Keynesian Phillips Curve

Taking a log-linear approximation around the non-stochastic steady state (nsss) of Equation (1) and Equation (2), combining and rearranging yields the New Keynesian Phillips Curve (NKPC):

$$\pi_t = \beta E_t[\pi_{t+1}] + \kappa_p s_t \tag{3}$$

where s_t is the (log-linearized) real marginal cost and $\kappa_p \equiv \frac{(1-\zeta_p)(1-\zeta_p\beta)}{\zeta_p}\Theta$ is the slope of the NKPC (decreasing in ζ_p).

Interpretation: Current inflation is driven by (i) expected future inflation and (ii) real marginal cost — a measure of real activity. As $\zeta_p \to 0$, prices become flexible and the NKPC steepens.

Households

Households can save in nominal bonds paying gross nominal return R_t. The first-order condition yields the Euler equation:

$$U_{c,t} = \beta E_t \left[U_{c,t+1} \left(\frac{R_t}{\Pi_{t+1}} \right) \right] \tag{4}$$

where $U_{c,t}$ is the marginal utility of consumption and $\Pi_{t+1} = P_{t+1}/P_t$ is gross inflation. Log-linearizing around the nsss:

$$u_{c,t} = E_t \left[u_{c,t+1} \right] + E_t \left[r_t - \pi_{t+1} \right] \tag{5}$$

This is the dynamic IS equation: household consumption is a function of the real interest rate $r_t - E_t[\pi_{t+1}]$ path.

Central Bank

The nominal interest rate is set by the central bank according to a Taylor rule:

$$r_t = \rho_r r_{t-1} + (1 - \rho_r)\phi\pi_t \tag{6}$$

- $\rho_r \in [0, 1)$ is the interest rate smoothing parameter.
- $\phi > 1$ determines the central bank's response to inflation.

A condition, referred to as the Taylor principle, on ϕ must be met for determinacy (i.e., ϕ must be large enough).

Note: The Taylor rule can be augmented to respond to other variables such as the output gap, output growth, etc.

The 3-Equation NK Model

Assuming labor is the only input to production, Equation (3) and Equation (5) can be expressed as functions of the output gap $\tilde{y}_t \equiv y_t - y_t^n$ (actual vs. natural output). Together with the Taylor rule Equation (6), the model closes as:

$$\begin{aligned} \tilde{y}_t &= E_t[\tilde{y}_{t+1}] - \sigma^{-1}(r_t - E_t[\pi_{t+1}] - r_t^n) \\ \pi_t &= \beta E_t[\pi_{t+1}] + \kappa \tilde{y}_t \\ r_t &= \rho_r r_{t-1} + (1 - \rho_r)\phi \pi_t \end{aligned}$$

This "3-equation" model is the workhorse for studying monetary policy transmission and the effects of nominal rigidities. (See Galì Ch. 3.)

Medium Scale New Keynesian Economy

Limitations of the Baseline Model

While tractable, the baseline 3-equation NK model struggles on several dimensions:

- **Lack of intrinsic persistence**: Inflation and output respond on impact but revert quickly — the model does not generate the *hump-shaped* impulse responses seen in the data.
- **No real rigidities**: Real marginal cost is too sensitive to output, making the NKPC slope κ implausibly large to match observed inflation dynamics.
- **No investment dynamics**: The baseline model has no capital, so it misses a key amplification and propagation channel.

$\Rightarrow$ Additional "patches" in the form of real and nominal rigidities are needed. This is the medium-scale NK model (Christiano, Eichenbaum & Evans 2005; Smets & Wouters 2007).

Habit Formation

Motivation: Consumption exhibits excess smoothness and a hump-shaped response to shocks that the standard Euler equation cannot explain.

Households utility depend on current and previous period consumption:

$$U(C_t, C_{t-1}, N_t) = \frac{(C_t - hC_{t-1})^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi}$$

where $h \in [0, 1)$ is the habit persistence parameter.

This specification makes households sensitive to the growth rate of consumption, introducing persistence in their response.

Sticky Wages

Motivation: Wages are at least as sticky as prices in the data.

Analogously to price setting, we introduce Calvo wage frictions: in each period only a fraction $(1 - \zeta_w)$ of households (who supply differentiated labor) can re-optimize their nominal wage.

This delivers a New Keynesian Wage Phillips Curve:

$$\pi_t^w = \beta E_t[\pi_{t+1}^w] + \kappa_w \mu_t^w$$

where π_t^w is wage inflation, μ_t^w is the (log-deviation of the) wage markup, and $\kappa_w \equiv \frac{(1-\zeta_w)(1-\zeta_w\beta)}{\zeta_w(1+\varphi\theta_w)}$.

Wage stickiness dampens the response of real marginal cost to output fluctuations, flattening the price NKPC.

Capital Adjustment Costs

Motivation: Investment is *much* more volatile than consumption in the data, yet also it also responds sluggishly to shocks.

We introduce convex capital adjustment costs: installed capital evolves as

$$K_{t+1} = \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] I_t + (1-\delta)K_t$$

where $S(\cdot)$ satisfies $S(1) = S'(1) = 0$ and $S''(1) \equiv \xi > 0$.

These costs penalize *rapid changes* in investment, generating a hump-shaped investment response: firms smooth capital accumulation over time rather than adjusting on impact.

Other Extensions

Sticky prices and wages, habit formation, and investment adjustment costs help bridge the gap between the model and the data. Medium-scale models are typically further enriched with:

- **Variable capital utilization**: Firms can vary the intensity of capital use, adding a margin of adjustment that amplifies output responses.
- **Wage and price indexation**: Non-optimizing firms and households index their prices and wages to lagged inflation, generating *intrinsic* inflation persistence even without re-optimization.
- **Multiple shocks**: Technology, preference, government spending, monetary policy, cost-push shocks, and more.

Beyond these, the framework can be extended to incorporate other aspects of the economy such as a financial sector.

My Own Views

A few observations on the NK framework:

- Some of the adjustment frictions arguably lack solid microfoundations (i.e., the Calvo mechanism assumes a constant, history-independent probability of price adjustment).

- The medium-scale model fits the data well by design: with enough shocks and frictions, matching moments is not hard. Identification of structural parameters is challenging.

That said, the NK framework remains the dominant paradigm in central banking and policy analysis, and understanding its mechanics is worthwhile.