Advanced Macroeconomics

Imperfect Competition and Staggered Price Adjustment

- In this chapter we will extend the RBC model with imperfect competition to account for nominal frictions (price rigidities)
- We derive the New-Keynesian Phillips Curve (NKPC) from firms' price-setting behavior
- We discuss the basic New-Keynesian Macroeconomic Model
- We introduce the Smets-Wouters Business Cycle Model

10. Price Rigidities and the New Keynesian Model

Calvo Pricing

- Assumption: firms cannot freely adjust prices in every period
- For any firm, the probability of adjusting prices in any period is $1-\gamma$
- A fraction of $1-\gamma$ of all firms adjusts its price in a given period, the remaining fraction γ adjusts prices at the steady state inflation rate π^*
- Firms set prices such that the expected present value of profits is maximized – given the probability of readjusting its price in any future period is $1-\gamma$, given the production function and given the demand function for its product
- Log-deviation from steady state price level

$$(1+\beta)\widehat{p}_t - \widehat{p}_{t-1} - \beta E_t \widehat{p}_{t+1} = \frac{(1-\gamma)(1-\beta\gamma)}{\gamma}\omega\left(\mu + \left(w_t + \frac{1}{1-\alpha}(\alpha y_t - a_t)\right)\right)$$

where $\beta = \frac{1}{1+\rho+\pi^*}$ and $\omega = \frac{1-\alpha}{1+\alpha(\epsilon-1)}$

The New-Keynesian Phillips Curve

- Firms satisfy aggregate demand at given prices such that actual output y_t may deviate from flexible-price output y_t^*
- Labor demand is derived from aggregate demand via the production function
- Calvo pricing implies the price adjustment equation (New-Keynesian Phillips Curve) which replaces the labor demand equation in the monopolistic competition model

$$\pi_t - \pi^* = \beta(E_t \pi_{t+1} - \pi^*) + \kappa(y_t - y_t^*)$$

where

$$\kappa = \frac{(1-\gamma)(1-\gamma\beta)}{\gamma} \frac{\theta(1-\alpha) + \varphi + \alpha}{1 - \alpha + \epsilon}$$

The New-Keynesian IS Equation

- New-Keynesian IS curve

$$y_t = E_t y_{t+1} - \frac{1}{\theta}(i_t - E_t \pi_{t+1} - \rho)$$

- From natural rate of interest

$$\psi E_t \Delta y^*_{t+1} = \frac{r^*_t - \rho}{\theta}$$

- Subtract flexible price output from IS equation

$$\begin{aligned}
y_t - y^*_t &= E_t y_{t+1} - y^*_t + E_t y^*_{t+1} - E_t y^*_{t+1} - \frac{1}{\theta}(i_t - E_t \pi_{t+1} - \rho) \\
&= E_t(y_{t+1} - y^*_{t+1}) + E_t \underbrace{\Delta y^*_{t+1}}_{\frac{1}{\theta}\Delta a_{t+1}} - \frac{1}{\theta}(i_t - E_t \pi_{t+1} - \rho) \\
&= E_t(y_{t+1} - y^*_{t+1}) - \frac{1}{\theta}(i_t - E_t \pi_{t+1} - r^*_t)
\end{aligned}$$

The Basic New Keynesian Model

(`nkmodel.mod`)

- New Keynesian IS equation ($\widehat{y}_t = y_t - y_t^*$)

$$\widehat{y}_t = E_t \widehat{y}_{t+1} - \frac{1}{\theta}(i_t - \pi^* - E_t \widehat{\pi}_{t+1} - r_t^*)$$

- New Keynesian Phillips curve ($\widehat{\pi}_t = \pi_t - \pi^*$)

$$\widehat{\pi}_t = \beta E_t \widehat{\pi}_{t+1} + \kappa \widehat{y}_t$$

- Monetary policy rule

$$i_t = \rho + \pi^* + \phi_\pi \widehat{\pi}_t + \phi_y \widehat{y}_t + \nu_t, \qquad \nu_t = \eta_i \nu_{t-1} + \varepsilon_t^i$$

- Natural rate of interest

$$r_t^* = \rho + \theta \psi E_t \Delta a_{t+1}$$

- Productivity

$$a_t = \eta_a a_{t-1} + \varepsilon_t^a, \qquad 0 \leq \eta_a < 1, \qquad \varepsilon_t^a \sim N(0, \sigma_a^2)$$

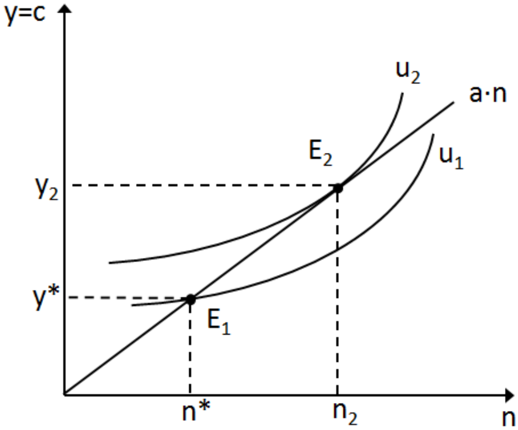
10. Price Rigidities and the New Keynesian Model

The Divine Coincidence

- Optimal monetary policy: $\pi_t = \pi^*$
- Monetary policy can stabilize output gap and inflation at the same time by setting the real interest rate equal to the natural rate of interest ($r_t = r_t^*$)
- In practice, the natural rate of interest is unknown
- The interest rate rule is a proxy for the optimal monetary policy rule

Short-term and Long-term Economic Policy

(Holtemöller 2008, Abb. 5.19)



- Pareto optimum: y_2
- Optimal output with imperfect competition: y^*
- Short-term policy: Stabilization of output around y^*
- Long-term policy: Increase y_t^*
  - Anti-trust policy: decrease mark-up
  - Education, research and innovation: increase a

10. Price Rigidities and the New Keynesian Model

The Smets-Wouters Model: Background

- The Smets–Wouters (2003, Journal of the European Economic Association) model develops and estimates a medium-scale New Keynesian DSGE model for the Euro area
- The 2003 paper was among the first to show that a richly specified DSGE model with nominal rigidities and multiple structural shocks can be successfully estimated using Bayesian methods and provide a coherent empirical description of macroeconomic dynamics
- The model was later extended and refined in Smets & Wouters (2007, American Economic Review), where it is applied to the U.S. economy and becomes a benchmark model in modern macroeconomics
- Together, these contributions helped establish DSGE models as a practical tool for policy analysis, bridging the gap between theoretical New Keynesian models and empirical macroeconomics

The Smets-Wouters Model: Key Features

- Nominal rigidities: sticky prices and wages
- Real frictions: habit formation, investment adjustment costs, variable capacity utilization
- Multiple structural shocks: technology, monetary policy, demand, wage/price markups, investment-specific shocks
- Forward-looking agents and rational expectations

The Smets-Wouters Model: What is it Useful for?

- Analyzing monetary policy transmission and interest-rate rules
- Understanding the sources of business-cycle fluctuations
- Decomposing output, inflation, and hours into structural shocks
- Producing model-based forecasts and counterfactual policy experiments
- Studying inflation-output trade-offs in a fully structural framework

The Smets-Wouters (2007) Model: Main Ingredients

- Starting point: The core structure extends the three-equation New-Keynesian model
  - Dynamic IS curve (intertemporal consumption choice)
  - New-Keynesian Phillips curve (price setting under nominal rigidity)
  - Monetary policy rule (Taylor rule)
  - Agents are forward-looking
- Why do the extensions matter? Compared to the basic NK model, these ingredients allow the model to ...
  - Support empirical estimation and policy analysis
  - Fit observed macroeconomic dynamics more closely
  - Match persistence in inflation and output

The Smets-Wouters (2007) Model: Households

- Infinitely lived households maximize expected utility
- Habit formation in consumption: current utility depends on consumption relative to past consumption
- Households supply differentiated labor, allowing for wage stickiness
- Capital accumulation with:
  - Investment adjustment costs
  - Variable capacity utilization

The Smets-Wouters (2007) Model: Firms

- Final-goods firms operate under monopolistic competition
- Calvo price stickiness with partial indexation to past inflation
- Intermediate firms use capital and labor to produce output
- Price markups fluctuate due to price markup shocks

The Smets-Wouters (2007) Model: Labor Market

- Households set wages in a monopolistically competitive labor market
- Sticky nominal wages (Calvo mechanism) with indexation
- Wage markup shocks capture labor market frictions

The Smets-Wouters (2007) Model: Monetary Policy

- Central bank follows a systematic interest-rate rule:
  - Responds to inflation and the output gap
  - Includes interest-rate smoothing
  - Monetary policy shocks capture unexpected deviations from the rule

The Smets-Wouters (2007) Model: Shocks

- Multiple structural shocks drive fluctuations:
  - Technology shocks (neutral and investment-specific)
  - Preference (demand) shocks
  - Price and wage markup shocks
  - Monetary policy shocks

Solving the Smets-Wouters (2007) Model: General Approach

- The Smets–Wouters model is a nonlinear, forward-looking DSGE model
- In Dynare, it is solved by:
  - Computing the deterministic steady state
  - Log-linearizing the model around that steady state
  - Solving the resulting linear rational expectations system
- Step 1: Flexible-price equilibrium
- Step 2: Sticky-price equilibrium
- Link between the two equilibria:
  - The gap between sticky-price output and flexible-price output defines the output gap
  - Monetary policy stabilizes inflation and the output gap relative to the flexible-price benchmark

Solving the Smets-Wouters (2007) Model: Flexible-price Equilibrium

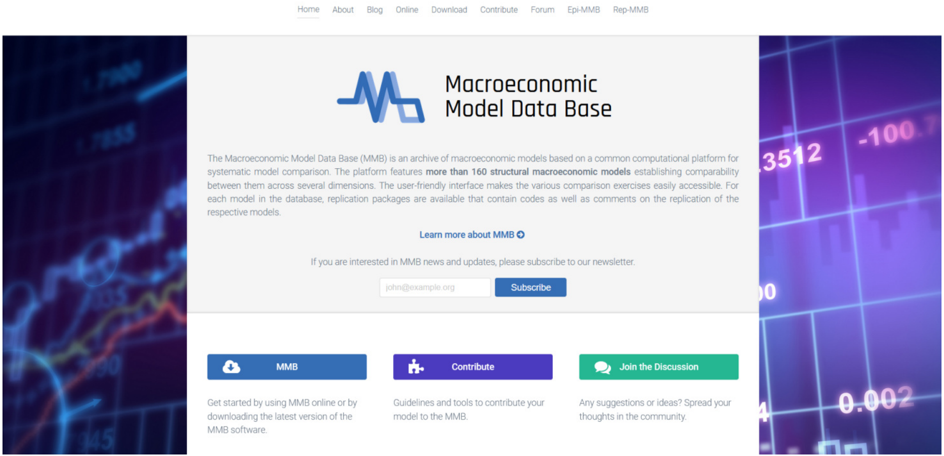
- A version of the model is solved under flexible prices and wages:
  - No nominal rigidities
  - Markups are constant
- This equilibrium corresponds to the efficient allocation (up to distortionary taxes)
- It provides:
  - The model's notion of potential output
  - The natural real interest rate

Solving the Smets-Wouters (2007) Model: Sticky-price Equilibrium

- The Smets–Wouters model introduces:
  - Sticky prices and wages (Calvo contracts)
  - Indexation to past inflation
- These frictions generate:
  - Inflation persistence
  - Real effects of monetary policy
- Dynare solves this version around its steady state and computes:
  - Impulse response functions
  - Variance decompositions
  - Model-based forecasts

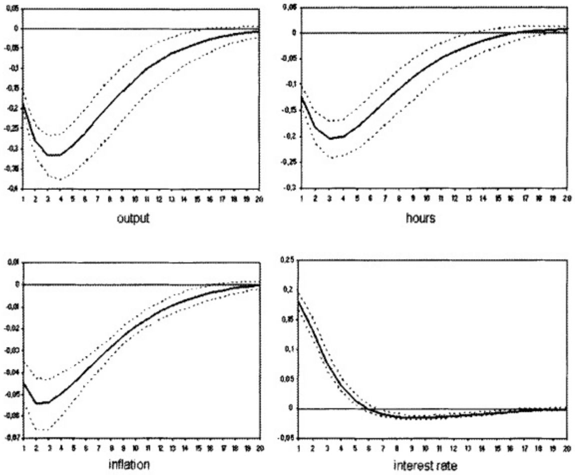
Macroeconomic Model Database

(https://www.macromodelbase.com/)



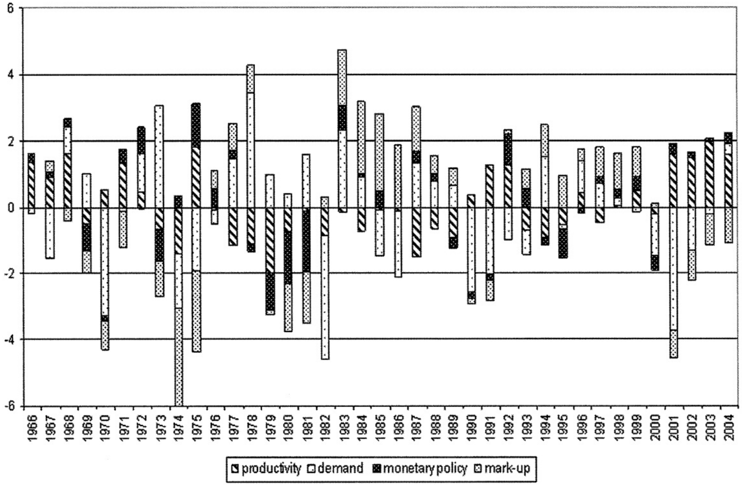
Impulse Responses to a Monetary Policy Shock

(Smets/Wouters 2007, Figure 6)



Historical Decomposition of GDP Growth

(Smets/Wouters 2007, Figure 4)



10. Price Rigidities and the New Keynesian Model

Summary

- The basic New Keynesian model extends the RBC model by including monopolistic competition and staggered price setting
- The New Keynesian model can explain aggregate fluctuations caused by monetary shocks through staggered price setting
- There is still no unemployment in the basic New Keynesian model
- There is no trade-off between the stabilization of output and inflation in the model (divine coincidence)
- Some of these weaknesses can be addressed by adding labor market frictions and markup shocks to the model

Literature

- Alogoskoufis, George (2019): Dynamic Macroeconomics, MIT Press, Chapter 16
- Gali, J. (2015): Monetary Policy, Inflation, and the Business Cycle, Second Edition, Princeton University Press, Chapers 2 and 3
- Smets, F.; Wouters, R (2003): An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area, Journal of the European Economic Association 1(5), 1123-1175
- Smets, F.; Wouters, R (2007): Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach, American Economic Review 97(3), 586-606

TAYLOR-Approximation

- TAYLOR-Approximation of order n with one variable

$$f(x) \approx f(x_0) + f'(x_0)(x - x_0) + \frac{1}{2} f''(x_0)(x - x_0)^2 + \ldots + \frac{1}{n!} f^{(n)}(x_0)(x - x_0)^n$$

- Example: $f(x) = \ln(1 + x)$, $x_0 = 0$ and $n = 1$

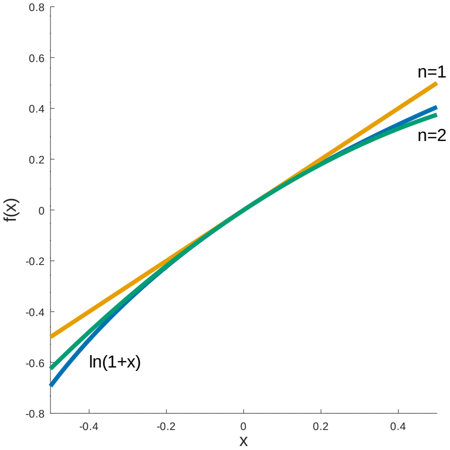
$$f(x) \approx \ln(1 + x_0) + \frac{1}{1 + x_0}(x - x_0) = \ln 1 + 1 \cdot x = x$$

- Example: $f(x) = \ln(1 + x)$, $x_0 = 0$ and $n = 2$

$$f(x) \approx \ln(1 + x_0) + \frac{1}{1 + x_0}(x - x_0) - \frac{(x - x_0)^2}{2} \frac{1}{1 + x_0^2} = x - \frac{x^2}{2}$$

TAYLOR-Approximation: Example $f(x) = \ln(1 + x)$

(Example_2_2.m)



Example: Growth Rate of a Product ($x_0 = 0, y_0 = 0$)

- Taylor-approximation

$$f(x,y) \approx f(x_0,y_0) + f_x(x_0,y_0)(x-x_0) + f_y(x_0,y_0)(y-y_0)$$

- Growth rate of product of AB

$$A(1+x)B(1+y) = AB(1+z)$$

- Approximation

$$(1+x)(1+y) \approx (1+x_0)(1+y_0) + (1+y_0)(x-x_0) + (1+x_0)(y-y_0) = 1+x+y$$

- The growth rate of a product is approximately equal to the sum of the growth rates of the two factors

$$z \approx x+y$$

Example: Growth Rate of a Ratio ($x_0 = 0, y_0 = 0$)

- Taylor-approximation

$$f(x,y) \approx f(x_0,y_0) + f_x(x_0,y_0)(x-x_0) + f_y(x_0,y_0)(y-y_0)$$

- Growth rate of a ratio

$$(A(1+x))/(B(1+y)) = (A/B)(1+z), \qquad z \approx x - y$$

- Approximation

$$\frac{1+x}{1+y} \approx \frac{1+x_0}{1+y_0} + \frac{1}{1+y_0}(x-x_0) - \frac{1+x_0}{(1+y_0)^2}(y-y_0) = 1 + x - y$$