New Keynesian Macroeconomics:
a framework for policy evaluation

Recent vintage of "new-keynesian" macroeconomic models incorporating:

- **imperfect competition** on goods (and labor) markets
- **nominal rigidities** in price (and wage) setting
- **forward-looking**, **intertemporally optimizing** agents

in a ***general equilibrium*** framework, with an explicitly modelled ***dynamic*** dimension and with various ***stochastic*** disturbances

⇒ **D**ynamic **S**tochastic **G**eneral **E**quilibrium macro models (**DSGE**)

used for:

- understanding the main channels of transmission of the effects of shocks across markets and over time
- simulating the effects of different policy actions

Basic structure of NK-DSGE models

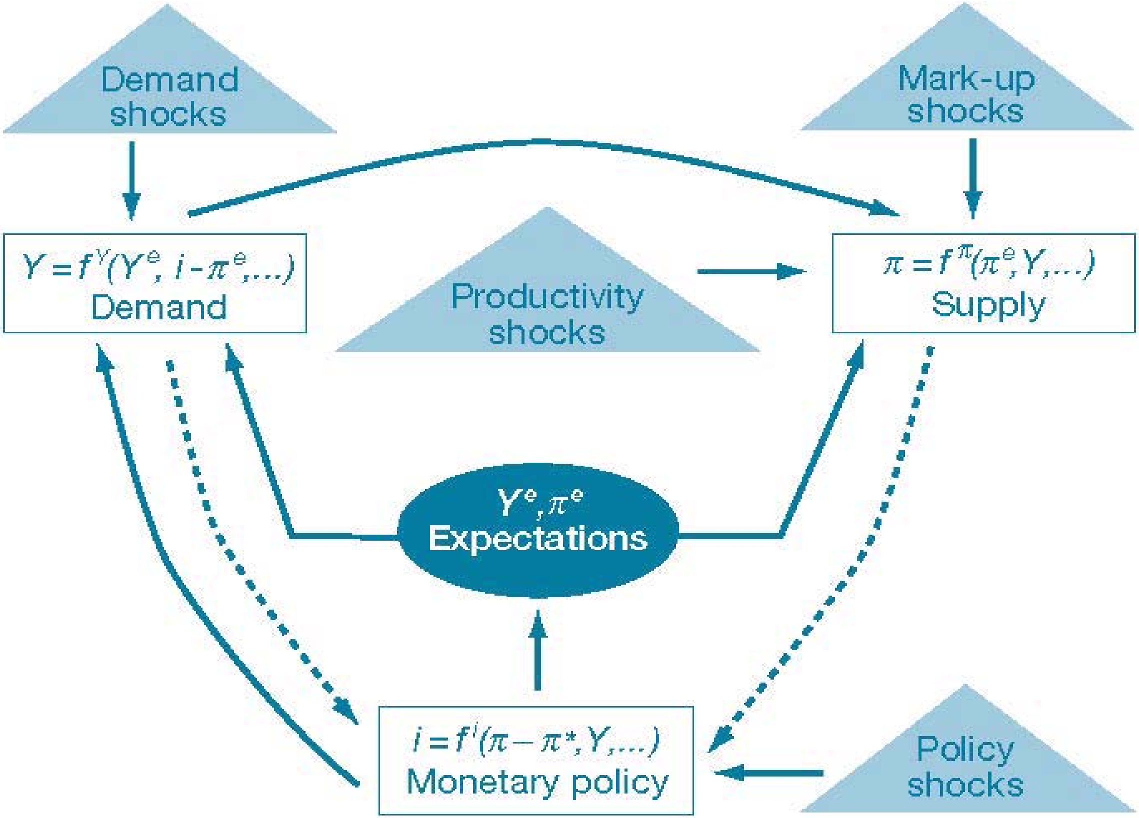
Main features:

- *methodological approach of RBC models*: equilibrium conditions for macro variables derived from optimizing behavior of agents with rational expectations and simultaneous clearing in all markets
- firms are *monopolistic competitors* and *intertemporal* profit-maximizing *price-setters*
- *nominal rigidities* are present and determine real effects of monetary policy
- the central bank reacts to developments in the economy following a *monetary policy rule*

Three main blocks:

- *demand* block: determines current output (Y) as a function of the real expected interest rate ($i - \pi^e$), and expected future real activity (Y^e)
- *supply* block: describes how firms set prices and, in the aggregate, how the inflation rate evolves over time. Current inflation (π) is determined by current output and expected inflation
- *monetary policy* is conducted by setting the nominal interest rate as a function of output and of deviation of the inflation rate from a target level (π^*): the nominal rate is raised when output is relatively high and when inflation exceeds its target.

The Basic Structure of DSGE Models



A simple New-Keynesian macro model

Three-equation model specifying:

- *aggregate demand*
- *aggregate supply* (inflation dynamics)
- *monetary policy*

Aggregate demand

Derived from the solution of an *intertemporal utility maximization* problem by a representative consumer (as in standard RBC models)

$\Rightarrow$ first-order condition for optimal allocation between consumption and saving (*Euler equation*):

$$\underbrace{u'(C_t)}_{\substack{\text{marginal utility} \\ \text{of } C \text{ at } t}} = \underbrace{\frac{1}{1+\rho} E_t \left\{ [1 + (i_t - \pi_{t+1})] \, u'(C_{t+1}) \right\}}_{\substack{\text{marginal utility of saving at } t \\ \text{and consuming at } t+1}}$$

Basic RBC model

Solution:

system of first-order conditions for c_t, l_t, n_t and k_{t+1} with constraints (*) and (**)

$$u_c(c_t, l_t) = \lambda_t$$

$$u_l(c_t, l_t) = \omega_t$$

$$\lambda_t z_t f_n(k_t, n_t) = \omega_t$$

$$\beta E_t(\lambda_{t+1} [z_{t+1} f_k(k_{t+1}, n_{t+1}) + 1 - \delta]) = \lambda_t$$

marg. utility at t+1

marg. utility at t

Assuming a **C**onstant **R**elative **R**isk **A**version (CRRA) utility function:

$$u(C_t) = \frac{C_t^{1-\sigma} - 1}{1-\sigma} \qquad \sigma > 0$$

where σ measures the degree of consumers' *risk aversion*:

$$u'(C_t) = C_t^{-\sigma} \quad \text{and} \quad u'(C_{t+1}) = C_{t+1}^{-\sigma}$$

and taking logs ($c \equiv \log(C)$) the Euler equation can be rewritten:

$$E_t c_{t+1} - c_t = \frac{1}{\sigma}\left[(i_t - E_t \pi_{t+1}) - \rho\right]$$

$\frac{1}{\sigma}$ measures the *intertemporal elasticity of substitution*

In our simplified economy consumption is equal to output:

$$c_t = y_t$$

and rearranging the Euler equation we get:

$$y_t = -\frac{1}{\sigma}\left[(i_t - E_t \pi_{t+1}) - \rho\right] + E_t y_{t+1}$$

Output at t has two main determinants:

- expected real interest rate $i_t - E_t \pi_{t+1}$ (a typical "*IS*" feature)
- expected output $E_t y_{t+1}$ (an explicitly *dynamic* element)

$\Rightarrow$ ***dynamic IS equation***

Aggregate supply

Centered on the specification of i*nflation dynamics* in a production environment with:

- *monopolistic competition*: large number of firms supplying differentiated products
- *nominal rigidities:* price setting process by firms is *staggered* (in each period only a fraction of firms adjust their prices, whereas the others keep prices fixed)

Price setting with nominal rigidities ("Calvo-pricing")

Basic assumptions:

- in each period a firm has a fixed probability $1 - \theta$ of **adjusting** its price (choosing the optimal level p^*) and a probability θ of **not** being able to **adjust**
- the probabilities are independent of the individual firm's own history of price changes (i.e. they are independent of how long a firm has kept its price fixed)
  - $\Rightarrow$ for each firm, price adjustments occur at irregularly spaced intervals of time

Implication for the evolution over time of the (log of the) *aggregate price level* p_t:

$$p_t = (1-\theta)p_t^* + \theta p_{t-1}$$

price chosen optimally by firms that adjust (p_t^*)

average price of firms that do not adjust (p_{t-1})

$\Rightarrow \theta$ governs the degree of nominal price rigidity

How do adjusting firms choose optimal price p^*?

Insight:

monopolistically competitive firms choose the optimal price p_t^* over marginal costs ***taking into account the constraint on the frequency of price adjustment*** (the possibility that the chosen price will be fixed for several periods)

Consider two cases:

(a) Under perfect price flexibility (all firms adjust prices in any period, $\theta = 0$):

firms set prices at time t as a constant mark-up over ***current*** nominal marginal costs:

$$P_t^* = \underbrace{\left(\frac{\varepsilon}{\varepsilon - 1}\right)}_{\text{markup}} MC_t$$

where ε is the elasticity of demand (assumed time-invariant). In logs

$$p_t^* = mc_t + \mu$$

(b) With nominal rigidities ($\theta > 0$):

firms rationally consider *future* market conditions and set p_t^* as a mark-up on a weighted average of ***current*** and ***expected future*** marginal costs

The *weight* on the marginal costs in any future period $t + k$ depends on the discounted probability that the firm will still have its price fixed at level p_t^* at that time.

To derive the weights, consider that

$$(\beta\theta)^k = \begin{array}{c}\text{discounted prob. that } p_t^* \\ \text{will still be in force at } t+k\end{array}$$

where $\beta = \frac{1}{1+\rho}$ is the time discount factor and $0 < \beta\theta < 1$.

$$1 + \beta\theta + (\beta\theta)^2 + (\beta\theta)^3 + \ldots = \sum_{k=0}^{\infty}(\beta\theta)^k = \frac{1}{1-\beta\theta}$$

is the sum of all discounted probabilities. Then the weights attached to expected marginal costs for any future period $t+k$ are

$$\frac{(\beta\theta)^k}{\left(\frac{1}{1-\beta\theta}\right)} = (1-\beta\theta)(\beta\theta)^k$$

Applying the appropriate weights to each future expected nominal marginal cost mc_{t+k} we obtain the optimal price p_t^*:

$$p_t^* = \mu + (1 - \beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k E_t \, mc_{t+k}$$

This expression can be equivalently written as:

$$p_t^* = \beta\theta E_t p_{t+1}^* + (1 - \beta\theta)(mc_t + \mu)$$

where $E_t p_{t+1}^*$ captures the effect of future expected marginal costs on the current optimal price.

- firms' optimal price setting behaviour is ***forward-looking***, taking into account the future expected dynamics of marginal costs

Inflation dynamics

Combining the equations for:

- the current price level p_t
- the optimal price chosen by adjusting firms p_t^*

we can derive the dynamics of the inflation rate π_t (details in the Appendix) defined as

$$\pi_t \equiv p_t - p_{t-1}$$

Defining the expected inflation rate $E_t\pi_{t+1}$ as

$$E_t\pi_{t+1} \equiv E_t p_{t+1} - p_t$$

and the firm's ***real*** marginal costs mcr_t as

$$mcr_t \equiv mc_t - p_t$$

the *inflation rate* in period t is obtained as

$$\pi_t = \beta E_t\pi_{t+1} + \frac{(1-\theta)(1-\beta\theta)}{\theta}(mcr_t + \mu)$$

To interpret the term $mcr_t + \mu$, recall that *in the case of "perfect price flexibility"* firms set optimal prices at the level

$$p_t^* = mc_t + \mu$$

and the corresponding *real* marginal cost $\overline{mcr}_t$ is then

$$\begin{aligned}\overline{mcr}_t &= mc_t - p_t^* = mc_t - (mc_t + \mu) \\ &= -\mu\end{aligned}$$

We can now define $\widehat{mcr}_t$ as the deviation of current real marginal cost from $\overline{mcr}_t$:

$$\begin{aligned}\widehat{mcr}_t &\equiv mcr_t - \overline{mcr}_t = mcr_t - (-\mu) \\ &= mcr_t + \mu\end{aligned}$$

The equation for the current inflation rate can then be written as

$$\pi_t = \beta E_t \pi_{t+1} + \frac{(1-\theta)(1-\beta\theta)}{\theta} \widehat{mcr}_t$$

Current inflation is determined by two factors:

- $E_t \pi_{t+1}$: *expected* inflation, capturing the expected future dynamics of real marginal costs

- $\widehat{mcr}_t$: current deviation of real marginal costs from its level with fully flexible prices

The "New-Keynesian" Phillips curve

Inflation dynamics can be expressed in a form linking π_t to a measure of aggregate economic activity, as in the traditional Phillips curve.

To this aim, we exploit a positive relation between $\widehat{mcr}_t$ and deviations of aggregate output (y_t) from the level prevailing with perfect price flexibility ($\bar{y}_t$):

$$\widehat{mcr}_t = \varphi (y_t - \bar{y}_t) \qquad \varphi > 0$$

Inflation dynamics can then be written in the form of the

New Keynesian Phillips curve ($NKPC$)

$$\pi_t = \beta E_t \pi_{t+1} + \frac{(1-\theta)(1-\beta\theta)}{\theta}\varphi(y_t - \bar{y}_t)$$
$$= \beta E_t \pi_{t+1} + \kappa(y_t - \bar{y}_t)$$

$$\pi_t = \beta E_t \pi_{t+1} + \kappa (y_t - \bar{y}_t)$$

Specific features of the New Keynesian Phillips curve:

- explicitly derived from a fully-specified microeconomic price-setting problem faced by firms with market power, with constraints on the frequency of price adjustments

  $\Rightarrow$ the inflation rate becomes a ***forward-looking*** variable: firms will take into account the expected evolution of their marginal costs in setting optimal current prices, as captured by the term $E_t \pi_{t+1}$

Note: in the traditional "expectations-augmented" Phillips curve the expectation term is usually $E_{t-1} \pi_t$

- the reaction of inflation to current output developments $(y_t - \bar{y}_t)$, captured by κ, depends on some basic parameters in the model:

$$\kappa = \frac{(1-\theta)(1-\beta\theta)}{\theta}\varphi$$

  - positively affected by φ (elasticity of real marginal costs to output): if costs react more to output movements, also prices will be affected in the same direction

  - negatively affected by θ (degree of nominal rigidity): if θ increases, opportunities of adjusting prices occur less frequently and firms will weight current marginal costs less in setting prices; therefore inflation will be less sensitive to current output fluctuations

- the measure of activity that enters inflation dynamics, the ***output gap*** $y_t - \bar{y}_t$ is the deviation of current output from its equilibrium level in the absence of nominal rigidities. That level, $\bar{y}_t$, can change over time as a result of real shocks (e.g. technology) but is invariant to monetary policy

Monetary policy

Simple rule that the central bank follows in setting the *short-term nominal interest rate* i_t

The rule specifies the response of the interest rate to economic conditions, captured by the level of the inflation rate and the output gap:

$$i_t = \rho + \phi_\pi \pi_t + \phi_y (y_t - \bar{y}_t)$$

$$i_t = \rho + \phi_\pi \pi_t + \phi_y (y_t - \bar{y}_t)$$

- ρ (the rate of households' time preference) is interpreted as the **real** interest rate prevailing in a steady state (no growth) equilibrium

- policy parameters capture the reactions of the central bank:
  - to the inflation rate: $\phi_\pi > 1$ (when inflation increases, the positive response of the policy nominal rate implies an increase of the *real* short-term interest rate)
  - to the output gap: $\phi_y > 0$

Dynamic properties of the model: monetary policy shocks

Simple three-equation version of the new-Keynesian macro model:

dynamic IS $$y_t = -\frac{1}{\sigma}\left[(i_t - E_t\pi_{t+1}) - \rho\right] + E_t y_{t+1}$$

new-keynesian PC $$\pi_t = \beta E_t \pi_{t+1} + \kappa(y_t - \bar{y}_t)$$

monetary policy rule $$i_t = \rho + \phi_\pi \pi_t + \phi_y(y_t - \bar{y}_t) + v_t$$

v_t : stochastic element added to the interest rate setting rule to capture contractionary ($v_t > 0$) or expansionary ($v_t < 0$) *monetary policy shocks*

Contractionary monetary policy shock: $v_t > 0$

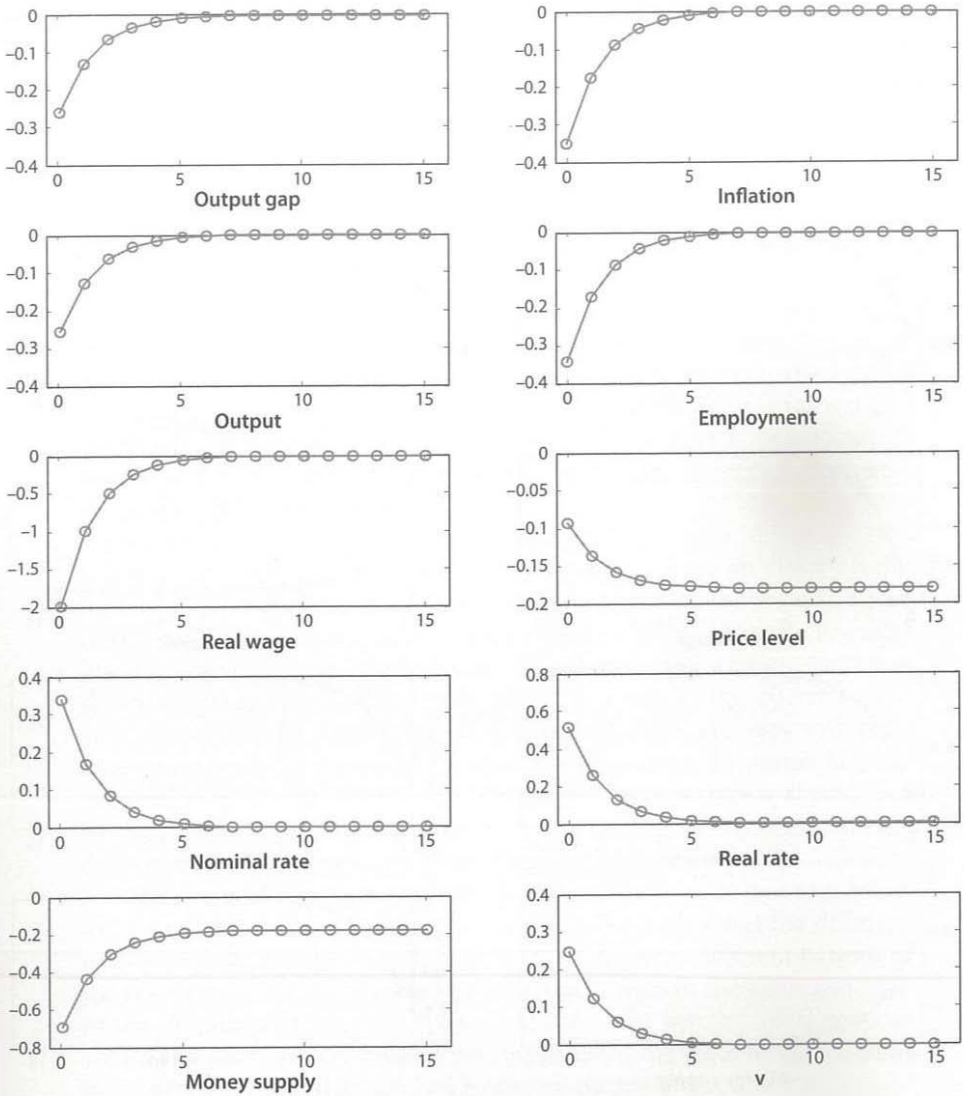
Main channel of transmission:

→ change in the ***real interest rate***: ↑ in i_t and ↓ in $E_t\pi_{t+1}$

→ affecting ***consumers' intertemporal choice***: y_t ↓ more than $E_t y_{t+1}$

→ determining ***current inflation rate***: π_t ↓ due to y_t ↓ and $E_t\pi_{t+1}$ ↓ (because of $E_t mcr_{t+k}$ ↓)

→ feedback on ***monetary policy***: over time i_{t+k} responds to inflation and output levels



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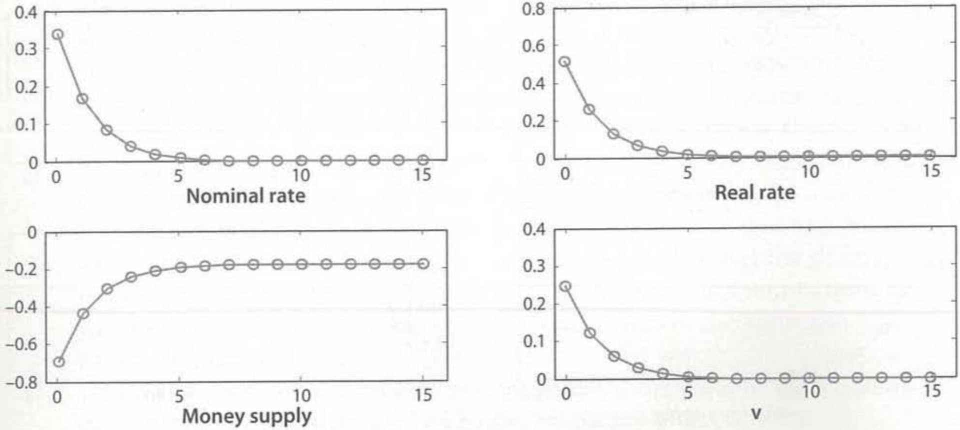

Nominal rate
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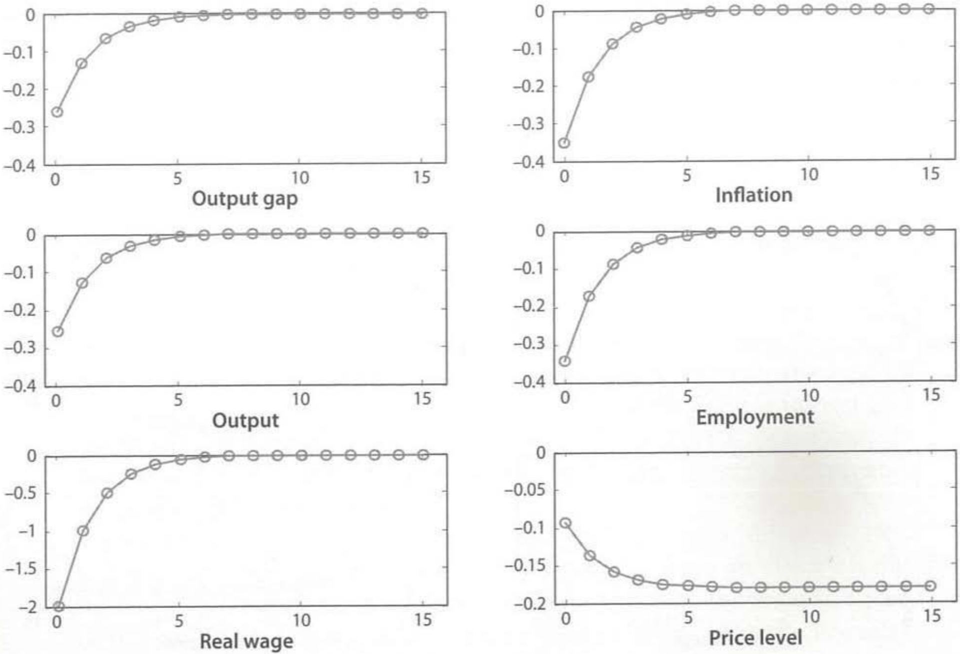
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Price level