New Keynesian DSGE models

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Jonathan Benchimol

This presentation does not necessarily reflect the views of the Bank of Israel

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Layout

- Introduction
- A baseline model
- An augmented model
- Conclusion

Detailed layout (1)

- Introduction
  - What is a model ?
  - What is a DSGE model ?
  - Why DSGE modeling ?
  - Literature
- The baseline model
  - Households
  - Firms
  - Central bank
  - Equilibrium
  - The DSGE model

Detailed layout (2)

- The augmented model
  - Theory
  - Empirics
  - Practice
  - Results
- Conclusion
  - Interpretation
  - Critics
  - Answers

What is a model ?

A theoretical (hypothetical) construct that represents a process by a number of variables and a set of quantitative, or logical, relationships between them.

Jennifer Ann Francis (Physicist)

A simplistic theoretical and/or empirical method explaining complicated processes.

Peter James Richerson (Biologist)

The best way to simply (wrongly) describe **some** *workings of the economy.*

Unknown Economist

What are the objectives ?

- Provide an explanation (story) about a specific state.
- Determine what might happen in different scenarios.
- Determine what might happen at a future date.
- Prescribe new (economic) guidelines that will change future (economic) behaviors.
- Assist decision making processes: trading, investment, planning, resource allocations, economic policy etc.
- Provide logical defense to justify (economic) policies: national/political, organizational, household, etc.

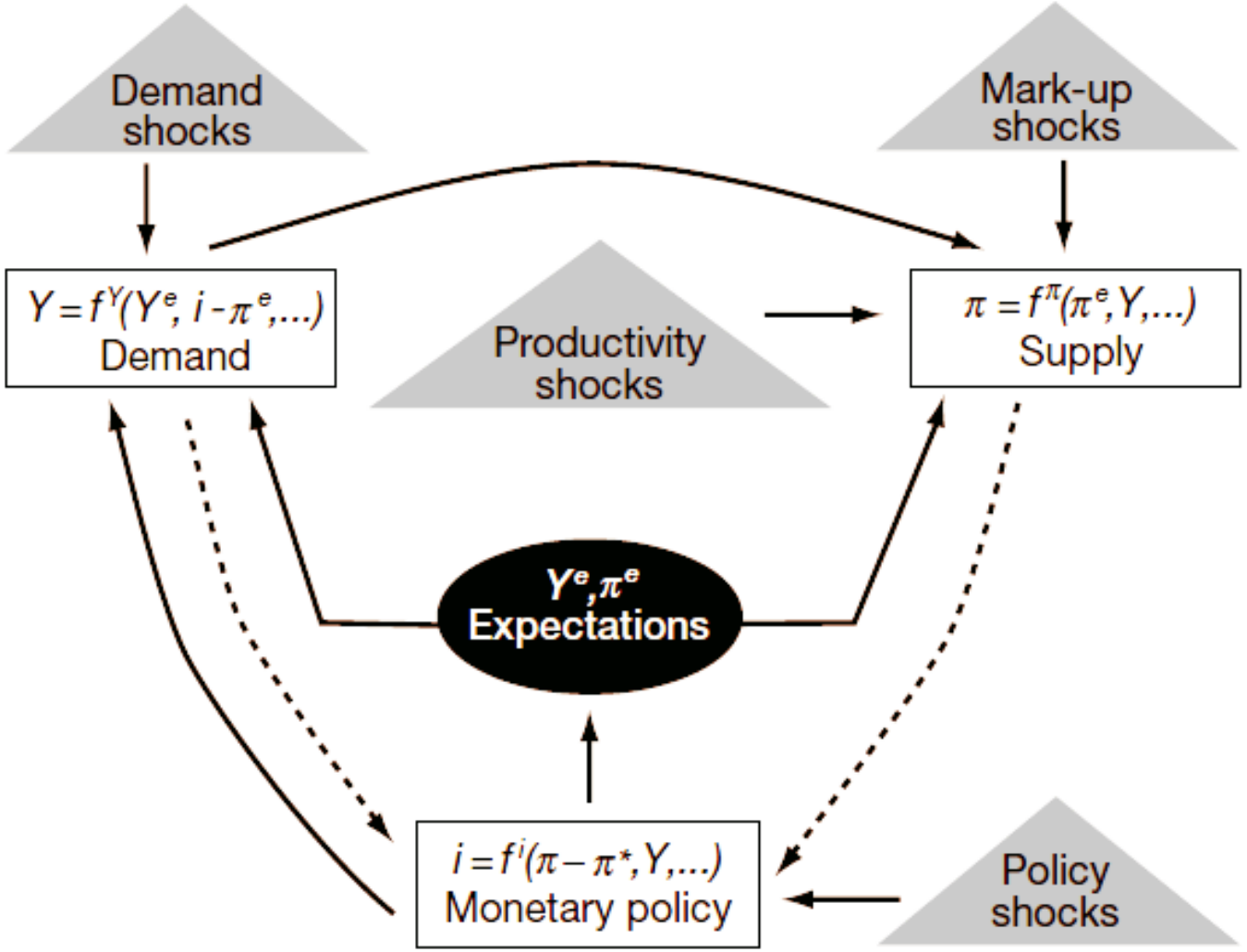
The birth

- Lucas (1973) on imperfect information, and subsequent research, provided fertile ground for examining the centrality of nominal rigidities in macroeconomics.
- The real business cycle (RBC) revolution, inspired by the neoclassical paradigm, finds an explanation in productivity dynamics (Kydland and Prescott, 1982).
- Integrating nominal rigidities in the RBC model gave birth to what we know as the New Keynesian Dynamic Stochastic General Equilibrium (NK DSGE) model.

What is a DSGE model ?

- DSGE models are dynamic, stochastic, and characterize the general equilibrium of the economy.
- They make three strategic modeling choices:
  1. The behavior of agents is formally derived from microfoundations (microfounded). Agents are assumed to behave **optimally** and **rationally**.
  2. The underlying economic environment is that of a competitive economy, but with a number of essential distortions added: nominal rigidities, monopoly power, information problems, etc.
  3. The model is thought and estimated as a system, rather than equation by equation.

The basic structure of a DSGE model



Why DSGE modeling ?

- A DSGE model is a VAR model with optimization-based constraints (economic foundations).
  - You like VAR ? You will like DSGE.
- Isolating micro-parameters in VAR modeling is quasi-impossible.
  - You should like DSGE.
- Structural **microfounded shocks** cannot be identified in VAR models.
  - Can you love DSGE ?

What is a VAR ?

- Basically, a VAR consists of a set of K endogenous variables $Y_t = (y_{1t}, \ldots, y_{kt}, \ldots, y_{Kt})$ for $k = 1, \ldots K$.
- A VAR model describes the evolution of a set of, let's say $K = 3$, endogenous variables over the same sample period as a linear function of only their *past* values.

$$\begin{bmatrix} 1 & A_1 & 0 \\ 0 & 1 & A_2 \\ A_3 & A_4 & 1 \end{bmatrix} \begin{bmatrix} \pi_t \\ y_t \\ i_t \end{bmatrix} = \begin{bmatrix} B_1 & 0 & 0 \\ B_2 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \mathbb{E}_t\left[\pi_{t+1}\right] \\ \mathbb{E}_t\left[y_{t+1}\right] \\ \mathbb{E}_t\left[i_{t+1}\right] \end{bmatrix}$$

$$+ \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & C_1 \end{bmatrix} \begin{bmatrix} \pi_{t-1} \\ y_{t-1} \\ i_{t-1} \end{bmatrix} + \begin{bmatrix} D_1 \\ D_2 \\ D_3 \end{bmatrix} + \begin{bmatrix} 1 & E_1 & 0 \\ 0 & 0 & 0 \\ 0 & E_2 & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_t^p \\ \varepsilon_t^a \\ \varepsilon_t^i \end{bmatrix}$$

Why comparing to VAR ?

- It is the closest modeling methodology.
- It is, and was, well accepted by the literature.
- Data science to single equation methodologies are too far from DSGE theoretical models.
- Yet, too much theory kills model's applications.

Why do we need DSGE ?

- The economy is thought as an interlinked system, excluding single equation methodologies (OLS, IV etc).
- Although it is possible to build an empirical methodology to estimate an economy thought as a system (VAR, SUR etc.), only DSGE modeling allows for a clear assessment and identification of structural shocks and structural parameters.
- DSGE models also allow to simulate calibrated microfounded models (calibration can be base on the literature or a previous estimation) without any available data.
- Policy assessment based on microeconomic behaviors and interlinkages, with or without data, is easier through DSGE models.
- To date, and to my limited knowledge, there is no simpler alternative.

Warning

Remember, dreams without goals are just dreams and they ultimately fuel disappointment.

Denzel Washington (Actor)

- In other words, never build a model without a **clear research question**. *Have dreams, but have goals...*
- Before the research question, you should:
  - have a clear intuition about the ingredients of your economy... ...Occam's razor.
  - think how ingredients should **interact**.
  - expect results (priors).
- DSGE models are not the only tool available to macroeconomists.

What is a simple DSGE ?

- Two very simple models will be presented:
  - A baseline DSGE model (**4** equations).
  - A simple extension (**6** equations).
- Two requirements:
  - Basic mathematical knowledge : optimization, derivation, linearization.
  - Savlanout !

Selected books

- Woodford, 2003. **Interest and Prices - Foundations of a Theory of Monetary Policy**, Princeton University Press.
- Galí, 2015. **Monetary policy, inflation and the business cycle: an introduction to the New Keynesian framework**, Princeton University Press. *Second Edition.*
- Walsh, 2017. **Monetary theory and policy**, MIT Press. *Fourth Edition.*

Selected papers

- Gertler, Gali, and Clarida, 1999. **The science of monetary policy: a New Keynesian perspective**, *Journal of Economic Literature*.
- Smets and Wouters, 2003. **An estimated Dynamic Stochastic General Equilibrium model for the Euro area**, *Journal of the European Economic Association*.
- Christiano, Eichenbaum, and Evans, 2005. **Nominal rigidities and the dynamic effects of a shock to monetary policy**, *Journal of Political Economy*.
- Smets and Wouters, 2007. **Shocks and frictions in US business cycles: a Bayesian DSGE approach**, *American Economic Review*.

Baseline framework

The model of Galí (2015) consists of economic agents of 3 types :

- **Households**
  Purchase goods for consumption, hold money and bonds, supply labor, and maximize the expected present value of utility.
- **Firms**
  Hire labor, produce and sell differentiated products in monopolistically competitive goods markets, and maximize profits.
- **Central bank**
  Controls the nominal rate of interest.

Households utility and budget constraint

- Preferences of the representative household are defined over a composite consumption good C_t, and leisure $1 - N_t$, where N_t is the time devoted to market employment.
- Standard (CRRA) utility function

$$U_t = \frac{1}{1-\sigma} C_t^{1-\sigma} - \frac{\chi N_t^{1+\eta}}{1+\eta} \tag{1}$$

- Budget constraint

$$P_t C_t + Q_t B_t + M_t \leq B_{t-1} + W_t N_t + M_{t-1} \tag{2}$$

Solving the model

- Budget constraint

$$C_t + Q_t \frac{B_t}{P_t} + \frac{M_t}{P_t} \leq \frac{B_{t-1}}{P_t} + \frac{W_t}{P_t} N_t + \frac{M_{t-1}}{P_t} \tag{3}$$

- Solvency condition

$$\forall t \lim_{n \longrightarrow \infty} \mathbb{E}_t \left[B_n \right] \geq 0 \tag{4}$$

- Households' Lagrangian

$$L_t = \sum_{k=0}^{\infty} \beta^k$$
$$\mathbb{E}_t \left[U_{t+k} - \delta_{t+k} \left(\begin{array}{c} C_{t+k} + \frac{M_{t+k}}{P_{t+k}} + Q_{t+k} \frac{B_{t+k}}{P_{t+k}} \\ - \frac{B_{t-1+k}}{P_{t+k}} - \frac{W_{t+k}}{P_{t+k}} N_{t+k} - \frac{M_{t-1+k}}{P_{t+k}} \end{array} \right) \right]$$

Optimization (1)

Consumption, labor supply, and bond holdings are chosen to maximize L_t subject to the budget constraint and the solvency condition:

$$\frac{\partial L_t}{\partial C_t} = 0 \qquad \Longrightarrow \qquad \delta_t = C_t^{-\sigma} \tag{5}$$

$$\frac{\partial L_t}{\partial B_t} = 0 \qquad \Longrightarrow \qquad Q_t = \beta \, \mathbb{E}_t \left[\frac{\delta_{t+1}}{\delta_t} \frac{P_t}{P_{t+1}} \right] \tag{6}$$

$$\frac{\partial L_t}{\partial N_t} = 0 \qquad \Longrightarrow \qquad \chi N_t^{\eta} = \delta_t \frac{W_t}{P_t} \tag{7}$$

Optimization (2)

- Assumption: existence of a continuum of goods represented, or indexed, by $i \in [0, 1]$.
- C_t is a consumption index given by

$$C_t = \left(\int_0^1 C_t(i)^{1-\frac{1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}} \tag{8}$$

  where $C_t(i)$ represents the quantity of good i consumed by the household in period t, and ε the elasticity of substitution between differentiated goods (of the same origin).
- The household must decide how to allocate its consumption expenditures among the different goods.
- This requires maximization of the consumption index, C_t, for any given level of expenditure, i.e.

$$\int_0^1 P_t(i) C_t(i) di = P_t C_t \tag{9}$$

Optimization (3)

The solution to that problem yields the set of demand equation

$$C_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} C_t \tag{10}$$

for all $i \in [0, 1]$, where

$$P_t = \left[\int_0^1 P_t(i)^{1-\varepsilon} di\right]^{\frac{1}{1-\varepsilon}} \tag{11}$$

is an aggregate price index.

Production

- Assumption: existence of a continuum of firms represented, or indexed, by $i \in [0, 1]$
- Each firm produces a differentiated good, but they all use an identical technology, represented by the production function

$$Y_t(i) = A_t N_t(i)^{1-\alpha} \tag{12}$$

  where $A_t = \exp(\varepsilon_t^a)$ represents the level of technology.
- Assumption: ε_t^a is the technology shock common to all firms, evolving exogenously over time.

Demand and prices

- All firms face
  - an identical isoelastic demand schedule (Eq. 10),
  - and take P_t (aggregate price level) and C_t (aggregate consumption index) as given.
- Following Calvo (1983), each firm may reset its price only with probability $1 - \theta$ in any given period, independent of the time elapsed since the last adjustment.
- For each period a measure $1 - \theta$ of producers reset their prices, while a fraction θ keep their prices unchanged.[1]
- In this context, θ becomes a natural index of price stickiness.

[1] The average duration of a price is given by $(1 - \theta)^{-1}$

Price dynamics (1)

- Let $S(t) \subset [0,1]$ represents the set of firms not reoptimizing their posted price in period t.
- Using the definition of the aggregate price level and the fact that all firms resetting prices will choose an identical price P_t^*,

$$\begin{aligned} P_t &= \left[\int_{S(t)} P_{t-1}(i)^{1-\varepsilon} di + (1-\theta)\left(P_t^*\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \\ &= \left[\theta P_{t-1}^{1-\varepsilon} + (1-\theta)\left(P_t^*\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \end{aligned} \tag{13}$$

where the second equality follows from the fact that the distribution of prices among firms not adjusting in period t corresponds to the distribution of effective prices in period $t-1$, though with total mass reduced to θ.

Price dynamics (2)

- Dividing both sides by P_{t-1},

$$\Pi_t^{1-\varepsilon} = \theta + (1-\theta)\left(\frac{P_t^*}{P_{t-1}}\right)^{1-\varepsilon} \tag{14}$$

where $\Pi_t = \frac{P_t}{P_{t-1}}$ is the gross inflation rate between $t-1$ and t.

- Log-linearization of the above equation around $\Pi_t = 1$ and $\frac{P_t^*}{P_{t-1}} = 1$ yields

$$\pi_t = (1-\theta)\left(p_t^* - p_{t-1}\right) \tag{15}$$

- Inflation results from the fact that firms reoptimizing in any given period choose a price that differs from the economy's average price in the previous period.

Price setting (1)

- A firm reoptimizing in period t will choose the price P_t^* that maximizes the current market value of the profits generated while that price remains effective, i.e.

$$\max_{P_t^*} \left\{ \sum_{k=0}^{\infty} \theta^k \, \mathbb{E}_t \left[Q_{t,t+k} \left(P_t^* Y_{t+k|t} - \Psi_{t+k} \left(Y_{t+k|t} \right) \right) \right] \right\} \tag{16}$$

subject to the sequence of demand constraints $Y_{t+k|t} = \left(\frac{P_t^*}{P_{t+k}} \right)^{-\varepsilon} C_{t+k}$ for $k = 0, 1, 2, \ldots$ where $Q_{t,t+k} = \beta^k \left(\frac{C_{t+k}}{C_t} \right)^{-\sigma} \frac{P_t^*}{P_{t+k}}$ is the stochastic discount factor for nominal payoffs, $\Psi(.)$ is the cost function, and $Y_{t+k|t}$ denotes output in period $t+k$ for a firm that last reset its price in period t.

Price setting (2)

- The first-order condition associated with the above problem takes the form

$$\sum_{k=0}^{\infty} \theta^k \ \mathbb{E}_t \left[Q_{t,t+k} Y_{t+k|t} \left(P_t^* - \frac{\varepsilon}{\varepsilon - 1} \Psi'_{t+k} \left(Y_{t+k|t} \right) \right) \right] = 0 \tag{17}$$

  where $\Psi'_{t+k} \left(Y_{t+k|t} \right)$ denotes the (nominal) marginal cost in period $t+k$ for a firm which last reset its price in period t.
- Note that in the limiting case of no price rigidities ($\theta = 0$), the previous condition collapses to the familiar optimal price-setting condition under flexible prices

$$P_t^* = \frac{\varepsilon}{\varepsilon - 1} \Psi'_{t+k} \left(Y_{t+k|t} \right) \tag{18}$$

  which allows us to interpret $\frac{\varepsilon}{\varepsilon-1}$ as the desired markup in the absence of constraints on the frequency of price adjustment.

Price setting (3)

- Next, the optimal price-setting condition (Eq. 17) is linearized around the zero inflation steady state.
- Rewriting Eq. 17 in terms of variables that have a well-defined value in that steady state[2] leads to

$$\sum_{k=0}^{\infty} \theta^k \, \mathbb{E}_t \left[Q_{t,t+k} Y_{t+k|t} \left(\frac{P_t^*}{P_{t-1}} - \frac{\varepsilon}{\varepsilon - 1} MC_{t+k|t} \Pi_{t-1,t+k} \right) \right] = 0 \tag{19}$$

  where $MC_{t+k|t} = \frac{\Psi'_{t+k}\left(Y_{t+k|t}\right)}{P_{t+k}}$ is the real marginal cost in period $t+k$ for a firm whose price was last set in period t.
- In the zero inflation steady state, $\frac{P_t^*}{P_{t-1}} = 1$ and $\Pi_{t-1,t+k} = 1$.

[2] Dividing by P_{t-1} and letting $\Pi_{t,t+k} = \frac{P_{t+k}}{P_t}$.

Price setting (4)

- Furthermore, $P_t^* = P_{t+k}$ in that steady state, from which it follows that $Y_{t+k|t} = Y$ and $MC_{t+k|t} = MC$, because all firms will be producing the same quantity of output.
- In addition, $Q_{t,t+k} = \beta^k$ must hold in that steady state, and $MC = \frac{\varepsilon-1}{\varepsilon}$.
- A first-order Taylor expansion of Eq. 19 around the zero inflation steady state yields to

$$p_t^* - p_{t-1} = (1-\beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k \ \mathbb{E}_t \left[\widehat{mc}_{t+k|t} + (p_{t+k} - p_{t-1}) \right] \tag{20}$$

where $\widehat{mc}_{t+k|t} = mc_{t+k|t} - mc$ denotes the log deviation of marginal cost from its steady state value $mc = -\mu$, and $\mu = \ln\left(\frac{\varepsilon}{\varepsilon-1}\right)$ is the log of the desired gross markup.

Goods market

- Market clearing in the goods market requires

$$Y_t(i) = C_t(i) \tag{21}$$

for all $i \in [0, 1]$ and all t.

- Letting aggregate output be defined as

$$Y_t = \left(\int_0^1 Y_t(i)^{1-\frac{1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}} \tag{22}$$

it follows that $Y_t = C_t$ must hold for all t.

- One can combine the above goods market clearing condition with the consumer's Euler equation (Eq. 6) to obtain the equilibrium condition

$$y_t = \mathbb{E}_t[y_{t+1}] - \sigma^{-1}(i_t - \mathbb{E}_t[\pi_{t+1}] - \rho) \tag{23}$$

Labor market

- Market clearing in the labor market requires

$$N_t = \int_0^1 N_t(i)\, di \tag{24}$$

- Using the production function (Eq. 12) leads to

$$\begin{aligned} N_t &= \int_0^1 \left(\frac{Y_t(i)}{A_t}\right)^{\frac{1}{1-\alpha}} di \\ &= \left(\frac{Y_t}{A_t}\right)^{\frac{1}{1-\alpha}} \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\frac{\varepsilon}{1-\alpha}} di \end{aligned} \tag{25}$$

where the second equality follows from the demand schedule (Eq. 10) and the goods market clearing condition.

Marginal cost (1)

- Taking logs,[3]

$$(1-\alpha)\, n_t = y_t - \varepsilon_t^a + d_t \tag{26}$$

- One can write the following approximate relation between aggregate output, employment, and technology as

$$y_t = \varepsilon_t^a + (1-\alpha)\, n_t \tag{27}$$

[3] d_t is equal to zero up to a first-order approximation.

Marginal cost (2)

An expression is derived for an individual firm's marginal cost in terms of the economy's average real marginal cost

$$
\begin{aligned}
mc_t &= (w_t - p_t) - mpn_t \\
&= (w_t - p_t) - (\varepsilon_t^a - \alpha n_t) - \ln(1-\alpha) && (28) \\
&= (w_t - p_t) - \frac{1}{1-\alpha}(\varepsilon_t^a - \alpha y_t) - \ln(1-\alpha) && (29)
\end{aligned}
$$

where Eq. 28 defines the economy's average marginal product of labor, mpn_t, in a way consistent with Eq. 27.

Marginal cost (3)

Using the fact that

$$\begin{aligned} mc_{t+k|t} &= (w_{t+k} - p_{t+k}) - mpn_{t+k|t} \\ &= (w_{t+k} - p_{t+k}) - \frac{1}{1-\alpha}\left(\varepsilon^a_{t+k} - \alpha y_{t+k|t}\right) - \ln(1-\alpha) \end{aligned}$$

then

$$\begin{aligned} mc_{t+k|t} &= mc_{t+k} + \frac{\alpha}{1-\alpha}\left(y_{t+k|t} - y_{t+k}\right) \\ &= mc_{t+k} - \frac{\alpha\varepsilon}{1-\alpha}\left(p^*_t - p_{t+k}\right) \end{aligned} \tag{30}$$

where the second equality follows from the demand schedule (Eq. 10) combined with the market clearing condition ($c_t = y_t$).

Phillips curve (1)

Substituting Eq. 30 into Eq. 20 and rearranging terms yields

$$\begin{aligned} p_t^* - p_{t-1} &= (1-\beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^k \ \mathbb{E}_t\left[\Theta\widehat{mc}_{t+k} + (p_{t+k} - p_{t-1})\right] \\ &= (1-\beta\theta)\,\Theta\sum_{k=0}^{\infty}(\beta\theta)^k \ \mathbb{E}_t\left[\widehat{mc}_{t+k}\right] + \sum_{k=0}^{\infty}(\beta\theta)^k \ \mathbb{E}_t\left[\pi_{t+k}\right] \end{aligned}$$

where $\Theta = \frac{1-\alpha}{1-\alpha+\alpha\varepsilon} \leq 1$.

- Notice that the above discounted sum can be rewritten more compactly as the difference equation

$$p_t^* - p_{t-1} = \beta\theta\ \mathbb{E}_t\left[p_{t+1}^* - p_t\right] + (1-\beta\theta)\,\Theta\widehat{mc}_t + \pi_t \quad (31)$$

Phillips curve (2)

- Finally, combining Eq. 15 and Eq. 31 yields to the inflation equation

$$\pi_t = \beta \, \mathbb{E}_t \left[\pi_{t+1} \right] + \lambda \widehat{mc}_t \tag{32}$$

where $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta} \Theta$ is strictly decreasing[4] in

  - the index of price stickiness θ,
  - the measure of decreasing returns α,
  - and in the demand elasticity ε.

[4] Note tha $\theta < 1$, $\beta < 1$, $\alpha < 1$, and $\varepsilon > 1$.

Phillips curve (3)

- A relation is derived between the economy's real marginal cost and a measure of aggregate economic activity

$$
\begin{aligned}
mc_t &= (w_t - p_t) - mpn_t \\
&= (\sigma y_t + \varphi n_t) - (y_t - n_t) - \ln(1-\alpha) && (33) \\
&= \left(\sigma + \frac{\varphi + \alpha}{1-\alpha}\right) y_t - \frac{1+\varphi}{1-\alpha}\varepsilon_t^a - \ln(1-\alpha) && (34)
\end{aligned}
$$

where derivation of Eq. 33 and Eq. 34 make use of:

- the household's optimality condition (Eq. 7),
- and the (approximate) aggregate production relation (Eq. 27).

Phillips curve (4)

- Under flexible prices the real marginal cost is constant and given by $mc = -\mu$.
- Defining the natural level of output, denoted by y_t^f, as the equilibrium level of output under flexible prices

$$mc = \left(\sigma + \frac{\varphi + \alpha}{1 - \alpha}\right) y_t^f - \frac{1 + \varphi}{1 - \alpha} \varepsilon_t^a - \ln(1 - \alpha) \tag{35}$$

implies

$$y_t^f = \psi^f \varepsilon_t^a + v^f \tag{36}$$

where $v^f = -\frac{(1-\alpha)(\mu - \ln(1-\alpha))}{\sigma(1-\alpha)+\varphi+\alpha} > 0$ and $\psi^f = \frac{1+\varphi}{\sigma(1-\alpha)+\varphi+\alpha}$.

- Notice that when $\mu = 0$ (perfect competition), the natural level of output corresponds to the equilibrium level of output in the classical economy.

Phillips curve (5)

- Subtracting Eq. 35 from Eq. 34 leads to

$$\widehat{mc}_t = mc_t - mc = \left(\sigma + \frac{\varphi + \alpha}{1 - \alpha}\right)\left(y_t - y_t^f\right) \tag{37}$$

- By combining Eq. 37 with Eq. 32 one can obtain an equation relating inflation to its one period ahead forecast and the output gap

$$\pi_t = \beta\, \mathbb{E}_t\left[\pi_{t+1}\right] + \kappa\left(y_t - y_t^f\right) \tag{38}$$

  where $\kappa = \lambda\left(\sigma + \frac{\varphi+\alpha}{1-\alpha}\right)$.
- Eq. 38 is often referred to as the New Keynesian Phillips curve and constitutes one of the key building blocks of the basic New Keynesian model.
- The second key equation describing the equilibrium of the New Keynesian model is the Euler equation (Eq. 23).

Closing the model

- We add an ad-hoc monetary policy rule to close the model (Taylor-type rule).
- We can add a demand shock or a cost-push shock, but not both: 3 shocks because 3 historical variables.
- Structural shocks are assumed to follow a first-order autoregressive process with an *i.i.d.*-normal error term such as $\varepsilon_t^k = \rho_k \varepsilon_{t-1}^k + \omega_{k,t}$ where $\varepsilon_{k,t} \sim N(0; \sigma_k)$ for $k = \{p, i, a\}$

Not fully microfounded

$$\pi_t = \beta \, \mathbb{E}_t \left[\pi_{t+1}\right] + \kappa \left(y_t - y_t^f\right) + \varepsilon_t^p \tag{39}$$

$$y_t = \mathbb{E}_t \left[y_{t+1}\right] - \sigma^{-1} \left(i_t - \mathbb{E}_t \left[\pi_{t+1}\right] - \rho\right) \tag{40}$$

$$y_t^f = \psi^f \varepsilon_t^a + v^f \tag{41}$$

$$i_t = (1 - \lambda_i) \left(\lambda_\pi \pi_t + \lambda_x \left(y_t - y_t^f\right)\right) + \lambda_i i_{t-1} + \varepsilon_t^i \tag{42}$$

- Here, three shocks, two are ad-hoc and one is microfounded: a monetary policy shock (ε_t^i), a technology shock (ε_t^a) and a cost-push shock (ε_t^p).

Remember VAR models

$$\begin{bmatrix} 1 & -\kappa & 0 \\ 0 & 1 & 1/\sigma \\ -\lambda_\pi (1-\lambda_i) & -\lambda_x/\sigma & 1 \end{bmatrix} \begin{bmatrix} \pi_t \\ y_t \\ i_t \end{bmatrix} =$$

$$\begin{bmatrix} \beta & 0 & 0 \\ -1/\sigma & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \mathbb{E}_t[\pi_{t+1}] \\ \mathbb{E}_t[y_{t+1}] \\ \mathbb{E}_t[i_{t+1}] \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & \lambda_i \end{bmatrix} \begin{bmatrix} \pi_{t-1} \\ y_{t-1} \\ i_{t-1} \end{bmatrix}$$

$$+ \begin{bmatrix} -\kappa v^n \\ -\sigma^{-1}\rho \\ -\lambda_x \sigma^{-1} v^n \end{bmatrix} + \begin{bmatrix} 1 & -\kappa\psi^n & 0 \\ 0 & 0 & 0 \\ 0 & -\lambda_x\sigma^{-1}\psi^n & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_t^p \\ \varepsilon_t^a \\ \varepsilon_t^i \end{bmatrix}$$

Intuition

- Existing literature **almost** forgot the link between consumption and money.
- Yet, risk aversion impacts the trade-off between holding money and consuming in real life.
- If you take this link into account, should the central bank react with respect to **a** monetary aggregate ?

Specific literature

- Benchimol and Fourçans, 2012. **Money and risk in a DSGE framework: A Bayesian application to the Eurozone**, *Journal of Macroeconomics*.
- Benchimol and Fourçans, 2017. **Money and monetary policy in the Eurozone: an empirical analysis during crises**, *Macroeconomic Dynamics*.

Households utility and budget constraint

- Preferences of the representative household are defined over a composite consumption good C_t, real money balances $\frac{M_t}{P_t}$, and leisure $1 - N_t$.
- CES MIU utility function

$$U_t = \frac{1}{1-\sigma}\left((1-b)\,C_t^{1-\nu} + be^{\varepsilon_t^m}\left(\frac{M_t}{P_t}\right)^{1-\nu}\right)^{\frac{1-\sigma}{1-\nu}} - \frac{\chi N_t^{1+\eta}}{1+\eta} \tag{43}$$

- The budget constraint (Eq. 3) and the solvency condition (Eq. 4) are identical.
- First order conditions will be very different from Eq. 5, Eq. 6 and Eq. 7.

First order conditions (1)

- The FOC corresponding to the demand for contingent bonds implies that

$$\begin{aligned}\hat{c}_t &= \mathbb{E}_t\left[\hat{c}_{t+1}\right] - \left(\hat{\imath}_t - \mathbb{E}_t\left[\hat{\pi}_{t+1}\right]\right) / \left(\nu - a_1\left(\nu - \sigma\right)\right) \\ &\quad - \frac{\left(1 - a_1\right)\left(\nu - \sigma\right)}{\nu - a_1\left(\nu - \sigma\right)} \mathbb{E}_t\left[\Delta\hat{m}_{t+1} - \hat{\pi}_{t+1}\right] + \xi_{t,c} \quad (44)\end{aligned}$$

where $\xi_{t,c} = -\frac{(1-a_1)(\nu-\sigma)}{(1-\nu)(\nu-a_1(\nu-\sigma))} \mathbb{E}_t\left[\Delta\varepsilon^m_{t+1}\right]$ and by using the steady state of the first order conditions $a_1^{-1} = 1 + \left(\frac{b}{1-b}\right)^{\frac{1}{\nu}} (1-\beta)^{\frac{\nu-1}{\nu}}$.

- The lowercase (ˆ) denotes the log-linearized (around the steady state) form of the original aggregated variables.

First order conditions (2)

- The FOC corresponding to the optimal demand for cash is given by

$$-\nu\left(\hat{m}_t-\hat{p}_t\right)+\nu\hat{c}_t+\varepsilon_t^m=a_2\hat{\imath}_t \tag{45}$$

with $a_2=\frac{1}{\exp(1/\beta)-1}$ and where real cash holdings depend positively on consumption with an elasticity equal to unity and negatively on the nominal interest rate.

- The FOC corresponding to the optimal consumption-leisure arbitrage implies that

$$\begin{aligned}\hat{w}_t-\hat{p}_t &= \eta\hat{n}_t+\left(\nu-a_1\left(\nu-\sigma\right)\right)\hat{c}_t \\ &\quad -\left(\nu-\sigma\right)\left(1-a_1\right)\left(\hat{m}_t-\hat{p}_t\right)+\xi_{t,m}\end{aligned} \tag{46}$$

where $\xi_{t,m}=-\frac{(\nu-\sigma)(1-a_1)}{1-\nu}\varepsilon_t^m$.

First order conditions (3)

- Finally, these equations represent:
  - the Euler condition for the optimal intratemporal allocation of consumption (Eq. 44),
  - the intertemporal optimality condition setting the marginal rate of substitution between money and consumption equal to the opportunity cost of holding money (Eq. 45),
  - and the intratemporal optimality condition setting the marginal rate of substitution between leisure and consumption equal to the real wage (Eq. 46).

Production function and prices

- Let's use the same production function (Eq. 12)
- Here, we consider a microfounded cost-push shock, called price-markup shock, such as

$$C_t = \left(\int_0^1 C_t\left(i\right)^{1-\frac{1}{\Lambda_t}} di \right)^{\frac{\Lambda_t}{\Lambda_t - 1}} \tag{47}$$

  where $\Lambda_t = 1 + \frac{1}{\frac{1}{\varepsilon - 1} + \varepsilon_t^p}$ is the elasticity of substitution between consumption goods in period t.
- $\frac{\Lambda_t}{\Lambda_t - 1}$ is the (time varying) markup of prices over marginal costs.
- We will see how and why this feature can be considered as a price markup shock.

Price-markup shock

- Instead of Eq. 32, we obtain a time varying Θ, that is now $\Theta_t = \frac{1-\alpha}{1-\alpha+\alpha\Lambda_t} \leq 1$, which take into account the price-markup shock.
- The inflation equation becomes

$$\pi_t = \beta \, \mathbb{E}_t \left[\pi_{t+1}\right] + \lambda_{mc_t} \widehat{mc}_t \tag{48}$$

where $\lambda_{mc_t} = \frac{(1-\theta)(1-\beta\theta)}{\theta}\Theta_t$.

Solving the model (1)

- In addition to the previous Phillips curve (Eq. 48), we used Lagrangian method to optimize the utility function with respect to the budget constraint, and obtained the three first-order optimal conditions.
- We log-linearize around the steady state these conditions (Eq. 44, Eq. 45, and Eq. 46).
- We add an ad-hoc Taylor type rule equation to close our model.

Solving the model (2)

- Finally, we have 6 equations of 6 unknown variables for our economy:
  - the output gap ($\hat{y}_t$) and its flexible-price counterpart ($\hat{y}_t^f$),
  - the real money balances ($\widehat{mp}_t$) and its flexible-price counterpart ($\widehat{mp}_t^f$),
  - the inflation rate ($\hat{\pi}_t$),
  - and the nominal interest rate ($\hat{\imath}_t$).
- Structural shocks are also assumed to follow a first-order autoregressive process with an *i.i.d.*-normal error term such as $\varepsilon_t^k = \rho_k \varepsilon_{t-1}^k + \omega_{k,t}$ where $\varepsilon_{k,t} \sim N(0; \sigma_k)$ for $k = \{p, m, i, a\}$.

The DSGE model

$$\hat{y}_t^f = v_a^y \varepsilon_t^a + v_m^y \widehat{mp}_t^f - v_c^y + v_{sm}^y \varepsilon_t^m \tag{49}$$

$$\widehat{mp}_t^f = v_{y+1}^m \, \mathbb{E}_t \left[\hat{y}_{t+1}^f \right] + v_y^m \hat{y}_t^f + \frac{1}{\nu} \varepsilon_t^m \tag{50}$$

$$\hat{\pi}_t = \beta \, \mathbb{E}_t \left[\hat{\pi}_{t+1} \right] + \kappa_{x,t} \left(\hat{y}_t - \hat{y}_t^f \right) + \kappa_{m,t} \left(\widehat{mp}_t - \widehat{mp}_t^f \right) \tag{51}$$

$$\begin{aligned} \hat{y}_t \quad = \quad & \mathbb{E}_t \left[\hat{y}_{t+1} \right] - \kappa_r \left(\hat{\imath}_t - \mathbb{E}_t \left[\hat{\pi}_{t+1} \right] \right) \\ & + \kappa_{mp} \, \mathbb{E}_t \left[\Delta \widehat{mp}_{t+1} \right] + \kappa_{sm} \, \mathbb{E}_t \left[\Delta \varepsilon_{t+1}^m \right] \end{aligned} \tag{52}$$

$$\widehat{mp}_t = \hat{y}_t - \kappa_i \hat{\imath}_t + \frac{1}{\nu} \varepsilon_t^m \tag{53}$$

$$\hat{\imath}_t \quad = \quad (1 - \lambda_i) \left(\lambda_\pi \left(\hat{\pi}_t - \pi_c \right) + \lambda_x \left(\hat{y}_t - \hat{y}_t^f \right) + \lambda_m \tilde{M}_{t,k} \right)$$

Microfounded model

$$\upsilon_a^y = \frac{1+\eta}{(\nu-(\nu-\sigma)a_1)(1-\alpha)+\eta+\alpha} \qquad \kappa_r = \frac{1}{\nu-a_1(\nu-\sigma)}$$

$$\upsilon_m^y = \frac{(1-\alpha)(\nu-\sigma)(1-a_1)}{(\nu-(\nu-\sigma)a_1)(1-\alpha)+\eta+\alpha} \qquad \kappa_{mp} = \frac{(\sigma-\nu)(1-a_1)}{\nu-a_1(\nu-\sigma)}$$

$$\upsilon_c^y = \frac{(1-\alpha)}{(\nu-(\nu-\sigma)a_1)(1-\alpha)+\eta+\alpha} \ln\left(\frac{\varepsilon}{\varepsilon-1}\right) \qquad \kappa_i = a_2/\nu$$

$$\upsilon_{sm}^y = \frac{(\nu-\sigma)(1-a_1)(1-\alpha)}{((\nu-(\nu-\sigma)a_1)(1-\alpha)+\eta+\alpha)(1-\nu)} \qquad \kappa_{sm} = -\frac{(1-a_1)(\nu-\sigma)}{(\nu-a_1(\nu-\sigma))(1-\nu)}$$

$$\upsilon_{y+1}^m = -\frac{a_2}{\nu}\left(\nu-(\nu-\sigma)\,a_1\right) \qquad a_1 = \frac{1}{1+(b/(1-b))^{1/\nu}(1-\beta)^{(\nu-1)/\nu}}$$

$$\upsilon_y^m = 1+\frac{a_2}{\nu}\left(\nu-(\nu-\sigma)\,a_1\right) \qquad a_2 = \frac{1}{\exp(1/\beta)-1}$$

$$\kappa_{m,t} = (\sigma-\nu)\,(1-a_1)\,\frac{(1-\alpha)\left(\frac{1}{\theta}-\beta\right)(1-\theta)(1+(\varepsilon-1)\varepsilon_t^p)}{1+(\alpha+\varepsilon_t^p)(\varepsilon-1)}$$

$$\kappa_{x,t} = \left(\nu-(\nu-\sigma)\,a_1+\frac{\eta+\alpha}{1-\alpha}\right)\frac{(1-\alpha)\left(\frac{1}{\theta}-\beta\right)(1-\theta)(1+(\varepsilon-1)\varepsilon_t^p)}{1+(\alpha+\varepsilon_t^p)(\varepsilon-1)}$$

Money in the Taylor rule

- To evaluate further the role of money we analyze different specifications of the Taylor rule ($\tilde{M}_{t,k}$ for $k = \{0, 1, 2, 3\}$).
- We test four types of Taylor rules:
  - without money ($\tilde{M}_{t,0} = 0$).
  - with a real money gap ($\tilde{M}_{t,1} = \widehat{mp}_t - \widehat{mp}_t^f$).
  - with a nominal money growth ($\tilde{M}_{t,2} = \widehat{m}_t - \widehat{m}_{t-1}$).
  - with a real money growth ($\tilde{M}_{t,3} = \widehat{mp}_t - \widehat{mp}_{t-1}$).

Why not least squares or simple FIML ?

- Impossible to capture inter-equations dynamics.
- Large sample size is needed.
- Unable to estimate micro-parameters.
- Unable to capture microfounded shocks role.

Why not GMM, doubles least squares or other IV estimators ?

- How to select optimally IV ?
- Large sample size is needed.
- Unable to estimate micro-parameters.
- Unable to capture microfounded shocks role.

Why not maximum likelihood ?

- An and Schorfheide (2007).
- Identification issues for misspecified parameters.
- Large sample size are needed.

Why not VAR / BVAR ?

- An and Schorfheide (2007).
- Unable to capture microfounded shocks role.
- Fernandez-Villaverde and Rubio-Ramirez (2004).

Why Bayesian estimation of DSGE models ?

- Likelihood of the model (in terms of interlinked equation and interlinked macro-parameters).
- Able to study all micro-parameters and microfounded shocks.
- Less historical data are needed (but more reliance on priors).

Empirical methodology

- As in Smets and Wouters (2003) and An and Schorfheide (2007), we apply **Bayesian techniques** to estimate our DSGE model.
- We use **Eurozone data** like Andrès et *al.* (2006) and Barthélemy, Clerc and Marx (2011) from the Euro Area Wide Model (AWM) database (Fagan, Henry and Mestre, 2001).
- We use the $M3$ monetary aggregate from the Eurostat database, which is the broadest monetary aggregate.
- To make output and real money balances stationary, we use first detrended data, as in Ireland (2004), Andrés, López-Salido and Vallés (2006), and Barthélemy, Clerc and Marx (2011).

Data

- $\hat{\pi}_t$ is the log-linearized detrended **inflation** rate measured as the yearly log difference of detrended GDP Deflator from one quarter to the same quarter of the previous year;
- $\hat{y}_t$ is the log-linearized detrended **output** per capita measured as the difference between the log of the real GDP per capita and its trend;
- $\hat{\imath}_t$ is the 3-month detrended **nominal interest rate**.
- $\widehat{mp}_t$ is the log-linearized detrended **real money balances** per capita measured as the difference between the real money per capita (log difference between the money stock per capita and the GDP Deflator) and its trend.
- $\hat{y}_t^f$, the **flexible-price output**, and $\widehat{mp}_t^f$, the **flexible-price real money balances**, are completely determined by structural shocks.

Calibration

- Following standard conventions, we calibrate **beta** distributions for parameters that fall between zero and one, **inverted gamma** distributions for parameters that need to be constrained to be greater than zero, and **normal** distributions in other cases.
- The calibration of σ is inspired by Rabanal and Rubio-Ramírez (2007) and Casares (2007), respectively of 2.5 and 1.5.
- $\sigma = 2$ corresponds to a standard risk aversion.
- $\sigma = 4$, represents a high level of risk aversion.[5]
- As our goal is to analyze two different configurations of risk, we adopt the same priors in the two models with different risk aversion calibrations.

[5] Twice the standard value. $\sigma = 4$ is also around twice the estimated value in normal periods.

Estimation characteristics

- Sample: 117 observations from 1980Q4 to 2009Q4 in order to avoid high volatility periods before 1980.
- Algorithm: Metropolis-Hastings of 10 distinct chains, each of 100000 draws (Smets and Wouters, 2007; Adolfson et *al.*, 2007).
- Average acceptation rate per chain for the benchmark model (σ estimated) are included in the interval $[0.2601; 0.2661]$ and for ($\sigma = 4$) in the interval $[0.2587; 0.2658]$.

Dynare (1)

```
var y, pi, r, mp, yf, mpf, ep, ei, em, at;
varexo up, ui, um, ua;
parameters alpha beta teta vega sigma neta epsilon b a1 a2 li1 li2 li3 li4 rhoa rhop
rhoi rhom pb yb mpb rb;
alpha = 0.33;
beta = 0.99;
teta = 0.66;
vega = 1.25;
sigma = 2.0;
b = 0.25;
a1 = 1/(1+((b/(1-b))^(1-vega))*((1/(1-exp(-1/beta)))^((1-vega)/vega)));
a2 = 1/(exp(1/beta)-1);
neta = 1.0;
epsilon = 6.0;
```

Dynare (2)

```
li1 = 0.5;
li2 = 3.0;
li3 = 1.5;
li4 = 1.5;

rhoa = 0.75;
rhop = 0.75;
rhoi = 0.25;
rhom = 0.75;
pb = 2;
```

Dynare (3)

```
model(linear);
```

Write your log linearized DSGE model's equations here

Example:

```
r = (1-li1)*(li2*(pi-pb) + li3*(y-yf)) + li1*r(-1) + ei;
at = rhoa * at(-1) + ua;
ep = rhop * ep(-1) + up;
ei = rhoi * ei(-1) + ui;
em = rhom * em(-1) + um;
end;
steady;
check;
```

Dynare (4)

```
shocks;
var ua = 0.05;
var ui = 0.05;
var up = 0.05;
var um = 0.05;
end;
estimated_params;
  alpha,    beta_pdf,     0.33,    0.05;
  teta,     beta_pdf,     0.66,    0.05;
  vega,     normal_pdf,   1.25,    0.05;
  sigma,    normal_pdf,   2.0,     0.5;
  b,        beta_pdf,     0.25,    0.1;
```

Dynare (5)

```
pb,        normal_pdf,   2.0,   0.1;
neta,      normal_pdf,   1.0,   0.1;
epsilon,   normal_pdf,   6.0,   0.1;
li1,       beta_pdf,     0.5,   0.1;
li2,       normal_pdf,   3.0,   0.5;
li3,       normal_pdf,   1.5,   0.5;
li4,       normal_pdf,   1.5,   0.5;

rhoa,      beta_pdf,     0.75,  0.1;
rhop,      beta_pdf,     0.75,  0.1;
rhoi,      beta_pdf,     0.25,  0.1;
rhom,      beta_pdf,     0.75,  0.1;
```

Dynare (6)

```
  stderr ua,    inv_gamma_pdf,    0.05,    2;
  stderr ui,    inv_gamma_pdf,    0.05,    2;
  stderr up,    inv_gamma_pdf,    0.05,    2;
  stderr um,    inv_gamma_pdf,    0.05,    2;
end;
varobs pi y mp r;
estimation(nograph,order=1,datafile=databdet117m3pc,mode_compute=4,
forecast=12,mh_jscale=0.5,mh_replic=50000,mh_nblocks=10) pi y mp r yf mpf;
shock_decomposition;
stoch_simul(nograph,order=2,irf=40,conditional_variance_decomposition=[1:60]);
```

Bayesian estimation of structural parameters (1)

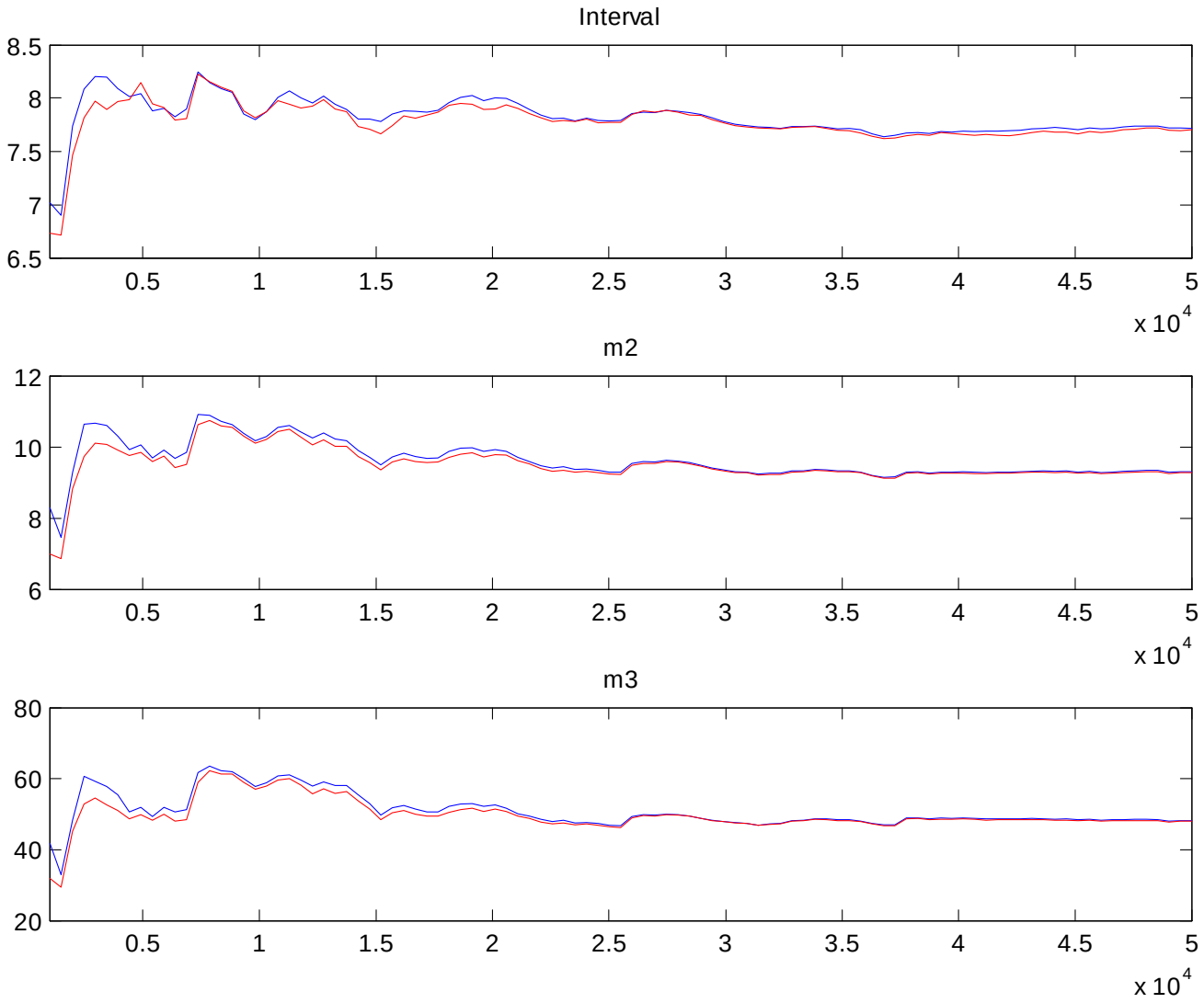
	Priors			Posteriors	
				σ estimated	$\sigma = 4$
	Law	Mean	Std.	Mean	Mean
α	beta	0.33	0.05	0.378	0.484
θ	beta	0.66	0.05	0.710	0.726
v	normal	1.25	0.05	1.447	1.528
σ	normal	2.00	0.50	2.157	
b	beta	0.25	0.10	0.252	0.246
η	normal	1.00	0.10	1.053	1.120
ε	normal	6.00	0.10	5.978	5.979
λ_i	beta	0.50	0.10	0.573	0.614
λ_π	normal	3.00	0.50	3.494	3.491
λ_x	normal	1.50	0.50	1.872	1.923
λ_m	normal	1.50	0.50	1.011	0.964
π_c	normal	2.00	0.10	1.903	1.908

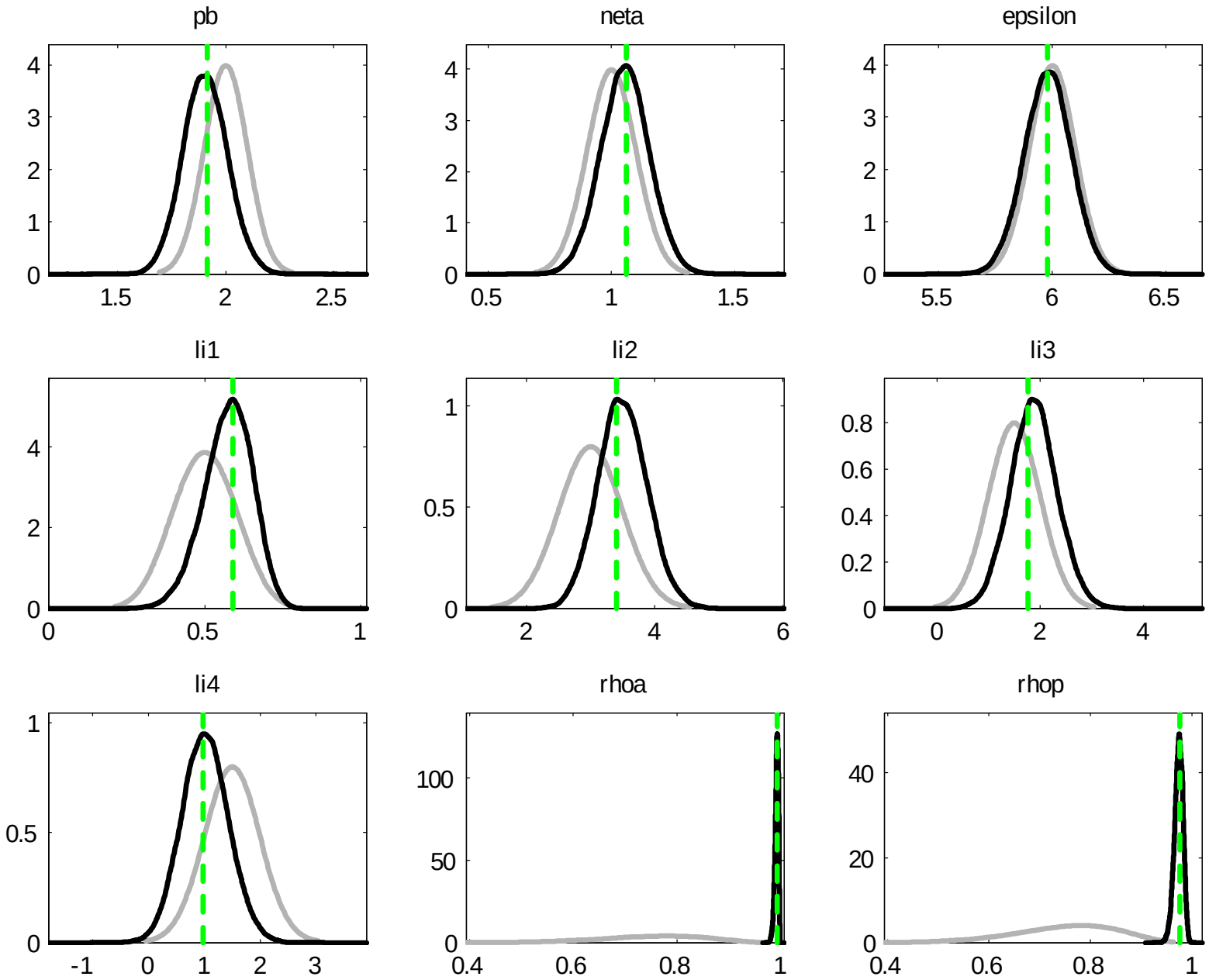
Bayesian estimation of structural parameters (2)

	Priors			Posteriors	
				σ estimated	$\sigma = 4$
ρ_a	beta	0.75	0.10	0.992	0.994
ρ_p	beta	0.75	0.10	0.973	0.972
ρ_i	beta	0.50	0.10	0.460	0.560
ρ_m	beta	0.75	0.10	0.971	0.984
σ_a	invgamma	0.02	2.00	0.013	0.019
σ_i	invgamma	0.02	2.00	0.018	0.012
σ_p	invgamma	0.02	2.00	0.004	0.004
σ_m	invgamma	0.02	2.00	0.026	0.027

Validation tools

- Distribution of the estimated shocks: stochastically around zero.
- Stable convergence of the within variance to the between and within variance, over the three first moments, of the multivariate Metropolis–Hastings convergence diagnosis.
- Simple look at the informativeness of the data by comparing prior and posterior distributions.
- Sensitivity analysis.
- Economic-relevant simulations: impulse response functions and variance decompositions.


Interval
8.5
8
7.5
7
6.5
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
x 10^4
m2
12
10
8
6
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
x 10^4
m3
80
60
40
20
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
x 10^4


pb
neta
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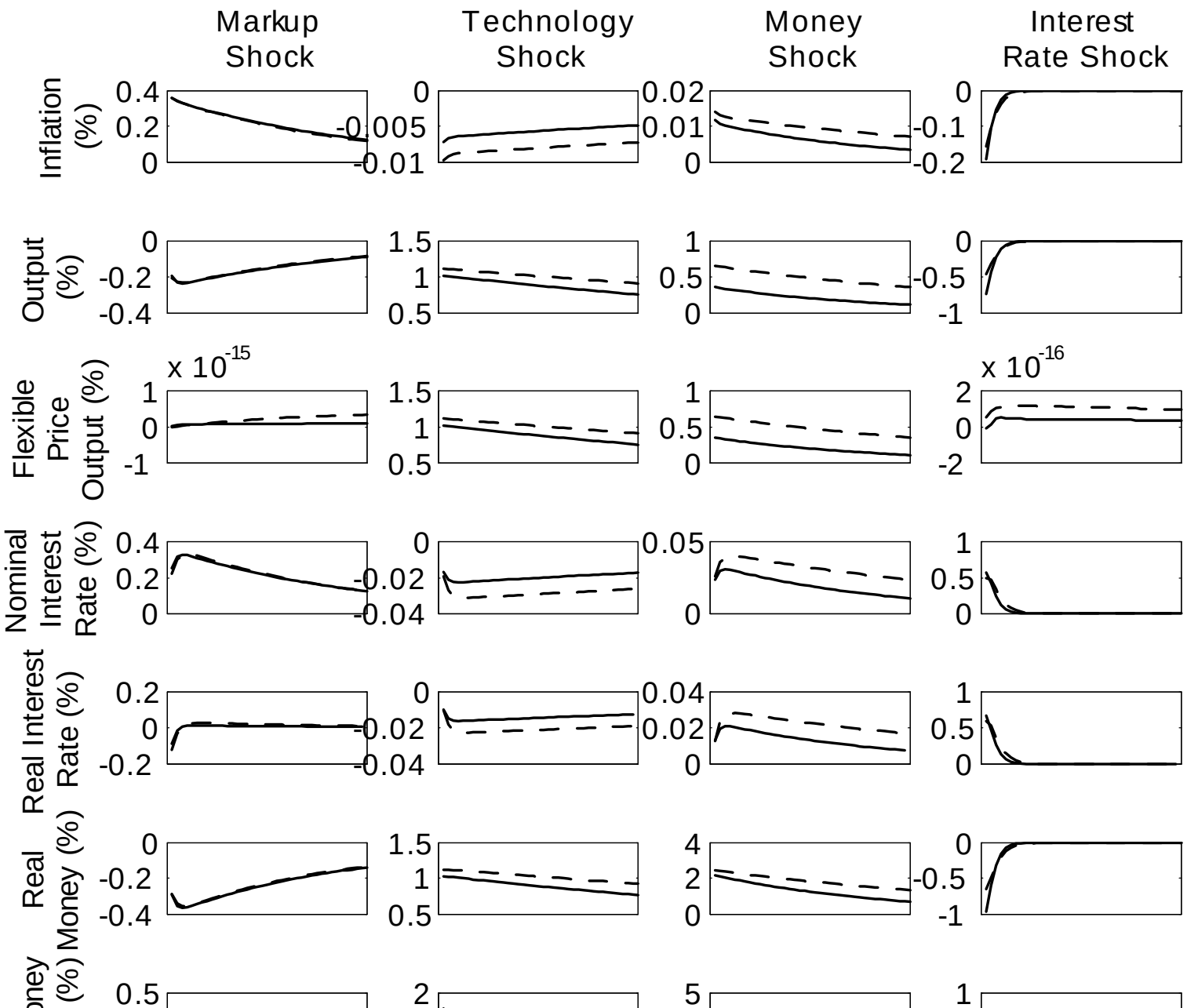

Markup Shock
Technology Shock
Money Shock
Interest Rate Shock
Inflation (%)
Output (%)
Flexible Price Output (%)
Nominal Interest Rate (%)
Real Interest Rate (%)
Real Money (%)
x 10^-15
x 10^-16

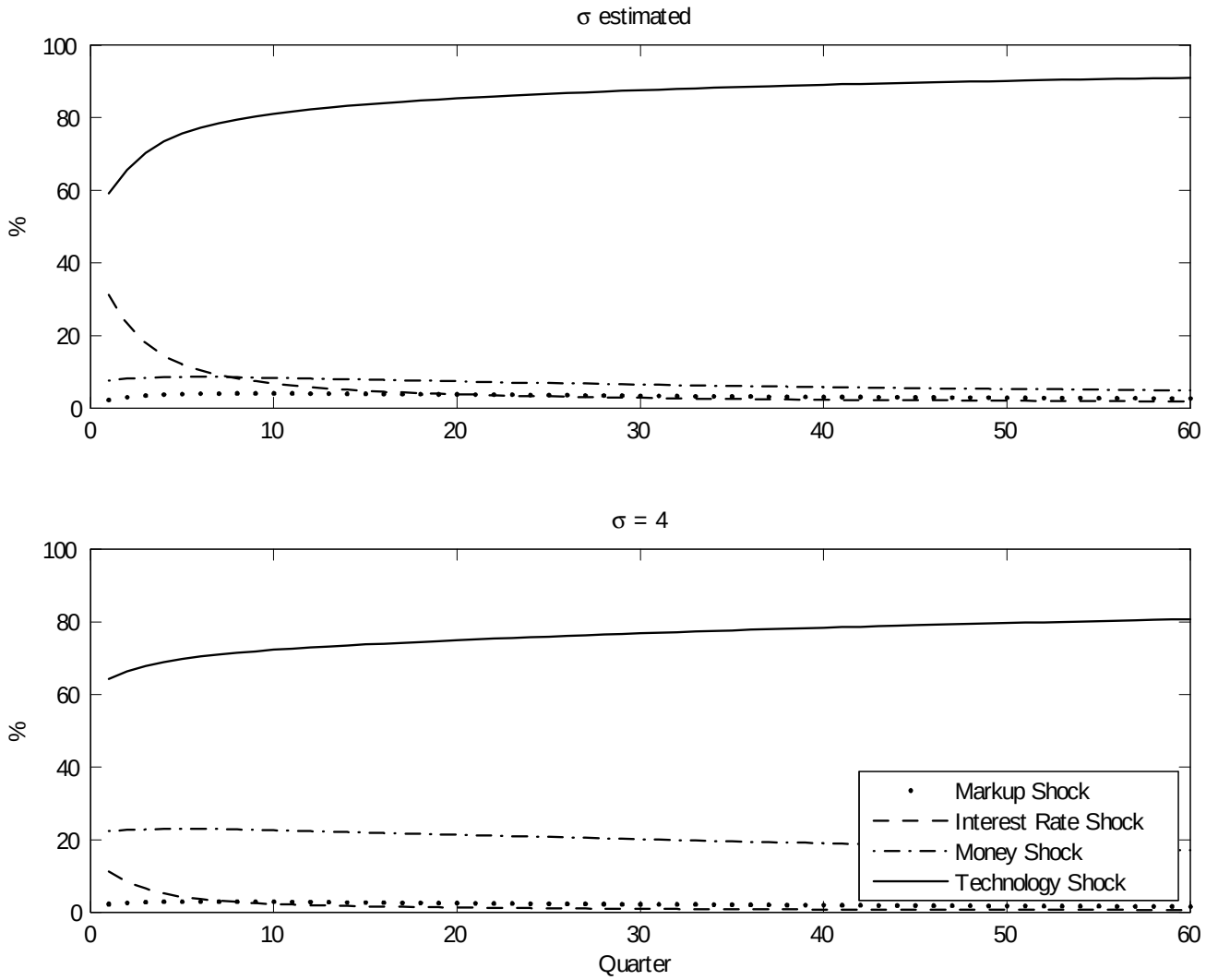
First period variance decomposition (percent)

	estimated σ				$\sigma = 4$			
	ε_t^p	ε_t^i	ε_t^m	ε_t^a	ε_t^p	ε_t^i	ε_t^m	ε_t^a
$\hat{y}_t$	2.16	31.17	**7.50**	59.16	2.23	11.19	**22.38**	64.20
$\hat{\pi}_t$	77.72	22.16	0.08	0.03	83.73	16.08	0.13	0.06
$\hat{\imath}_t$	16.35	83.44	0.14	0.07	16.66	82.99	0.23	0.13
$\widehat{mp}_t$	1.28	13.76	69.46	15.49	1.09	5.46	77.25	16.20
$\hat{y}_t^f$	0.00	0.00	**10.56**	89.44	0.00	0.00	**24.89**	75.11
$\widehat{mp}_t^f$	0.00	0.00	81.72	18.28	0.00	0.00	82.62	17.38

Unconditional variance decomposition (percent)

	estimated σ				$\sigma = 4$			
	ε_t^p	ε_t^i	ε_t^m	ε_t^a	ε_t^p	ε_t^i	ε_t^m	ε_t^a
$\hat{y}_t$	1.65	1.09	**3.07**	94.18	0.83	0.28	**10.38**	88.51
$\hat{\pi}_t$	97.66	2.14	0.09	0.12	97.64	1.79	0.24	0.33
$\hat{\imath}_t$	78.53	19.64	0.64	1.19	74.41	20.67	1.86	3.07
$\widehat{mp}_t$	1.85	0.91	52.49	44.75	0.83	0.26	60.87	38.04
$\hat{y}_t^f$	0.00	0.00	**3.06**	96.94	0.00	0.00	**10.23**	89.77
$\widehat{mp}_t^f$	0.00	0.00	54.42	45.58	0.00	0.00	62.04	37.96

Conditional variance decomposition of output



Alternative Taylor rules (1)

	estimated σ			
	$\tilde{M}_{t,0}$	$\tilde{M}_{t,1}$	$\tilde{M}_{t,2}$	$\tilde{M}_{t,3}$
λ_i	0.527	0.573	0.561	0.547
$(1-\lambda_i)\,\lambda_\pi$	1.594	1.491	1.463	1.537
$(1-\lambda_i)\,\lambda_x$	1.066	0.799	1.018	1.042
$(1-\lambda_i)\,\lambda_m$		0.431	0.136*	0.084*
ST_m^y (%)	7.05	7.50	2.23	3.66
LT_m^y (%)	2.75	3.07	2.24	2.36
LMD	-629.8	**-618.2**	-634.9	-635.3

*estimations are not significant in terms of student tests (t<1.645)

Alternative Taylor rules (2)

	$\sigma = 4$			
	$\tilde{M}_{t,0}$	$\tilde{M}_{t,1}$	$\tilde{M}_{t,2}$	$\tilde{M}_{t,3}$
λ_i	0.545	0.614	0.546	0.547
$(1-\lambda_i)\,\lambda_\pi$	1.579	1.345	1.585	1.575
$(1-\lambda_i)\,\lambda_x$	1.034	0.741	1.038	1.039
$(1-\lambda_i)\,\lambda_m$		0.371	-0.012*	-0.018*
ST_m^y (%)	22.61	22.38	23.20	23.28
LT_m^y (%)	9.56	10.38	9.29	9.15
LMD	-639.8	**-626.5**	-646.1	-646.1

*estimations are not significant in terms of student tests (t<1.645)

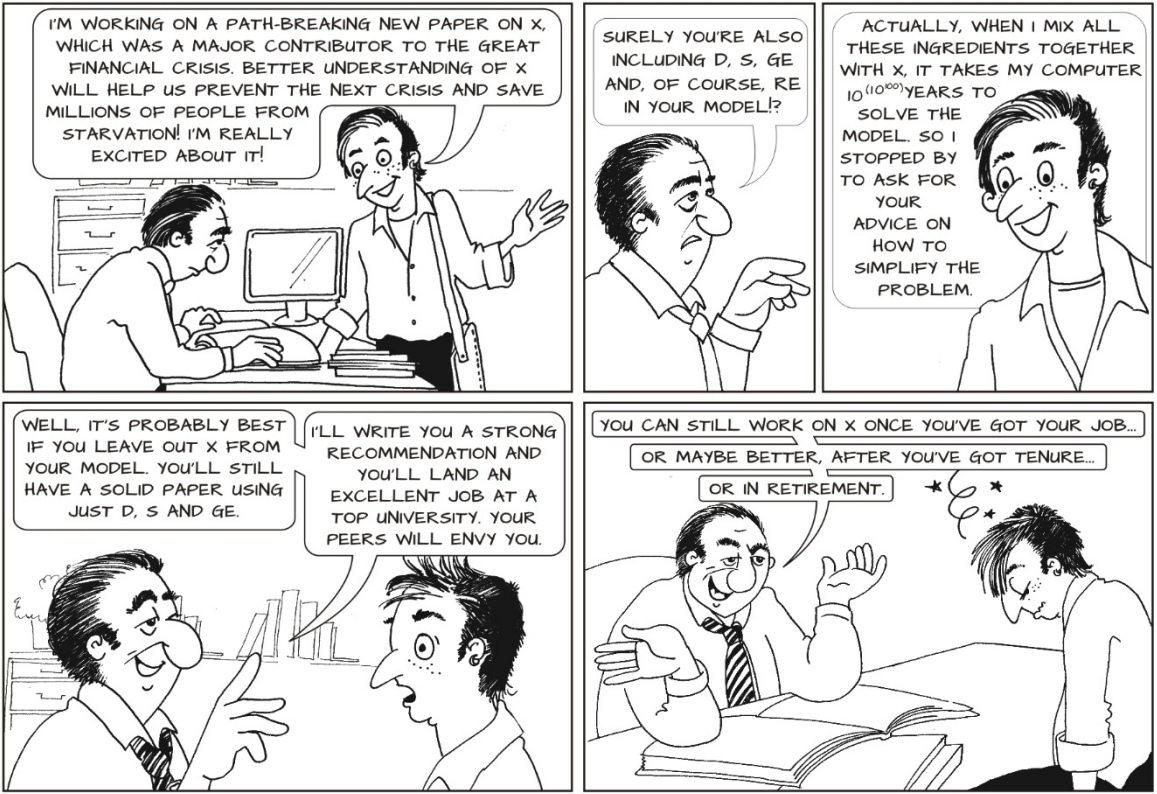
Role of Money

- Whatever the formulation of the Taylor rule, the estimated parameters of the whole model are quite similar.
- The impact of a money shock on output are also rather similar whatever the Taylor rule
- The weight of the money shock on output dynamics, κ_{sm}, and on flexible-price output, v^y_{sm}, increases with risk aversion.
- **The higher the risk aversion, the higher the role of money on output.**
- The explicit money variable does not appear to have a notable direct role in explaining inflation variability.
- One may infer that by **changing economic agents' perception of risks**, the last financial crisis may have increased the **role of money** in the transmission mechanisms and in output changes.

Monetary Policy

- The central bank strives for financial stability in crisis periods. The smoothing parameter in the Taylor rule equation, λ_i, increases with risk aversion.
- **The higher the risk aversion, the stronger the smoothing of the interest rate.** This reflects probably the central bankers' objective not to agitate markets.
- The introduction, or not, of a money variable in the ECB monetary policy reaction function does not really appear to change significantly the impact of money on output and inflation dynamics.
- Our results suggest that a nominal or real money growth variable does not improve the estimated ECB monetary policy rule. Yet, a **real money gap** variable significantly improves the estimated Taylor rule.

PROGRESS AND INCENTIVES IN MACROECONOMICS



The foundations

- **Intertemporal optimization**. In deciding how much to consume, consumers think not only about current income but also about future income; that in deciding how much to invest, firms think not only about current but also future profitability; and so on.
- **Nominal rigidities**. Macroeconomics would be easier and more elegant without nominal rigidities. Unfortunately, they do exist. The price level is a sum of very many individual prices, each of them set for some period of time; this fact drastically changes price-level dynamics.
- **Imperfect competition**. That goods, labor, and credit markets are not perfectly competitive is nearly self-evident. That these imperfections are central to macroeconomic is more controversial, but not much.

Some answers in Oxford Review of Economic Policy

Volume 34, Issue 1-2, 2018.

- Blanchard : **On the future of macroeconomic models**.
- Lindé : **DSGE models: still useful in policy analysis ?**
- Reis : **Is something really wrong with macroeconomics?**
- Ghironi : **Macro needs micro**.

Some paths in macroeconomics

- Behavioral
  - Bounded rationality (myopia), time inconsistency (present bias), etc.
- Expectation formation
  - Learning : adaptative learning, etc.
- Heterogenous agents
  - HANK, incomplete markets etc.
- Financial frictions
  - LTV constraints, asset pricing, etc.
- Additional sectors
  - Banking, housing, fiscal authority, etc.
- Additional economies
  - Open economy, SOE, etc.

Thank you for your attention

- Email : **jonathan@benchimol.name**
- Website: **JonathanBenchimol.com**

Miscellaneous

- Does risk aversion impacted output and real money balance dynamics differently ?
- Baseline model (presented above) + risk aversion shock.
- Benchimol, 2014. **Risk Aversion in the Eurozone**, *Research in Economics*.
- Periods:
  - **P1**: from **1971** Q1 to **1991** Q1.
  - **P2**: from **1976** Q1 to **1996** Q1.
  - **P3**: from **1981** Q1 to **2001** Q1.
  - **P4**: from **1986** Q1 to **2006** Q1.
  - **P5**: from **1991** Q1 to **2011** Q1.

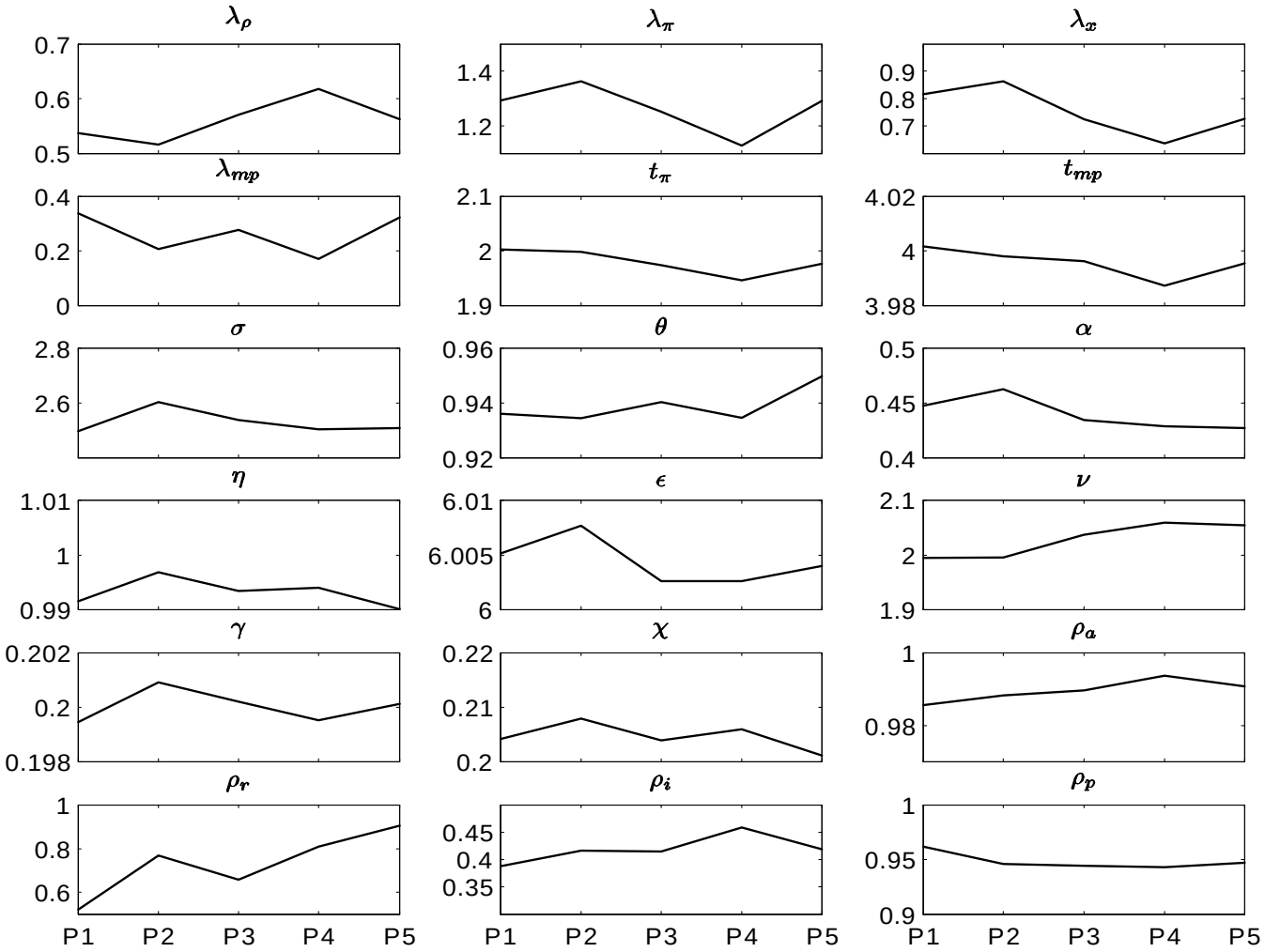


Figure: Bayesian estimation of parameters over the selected periods

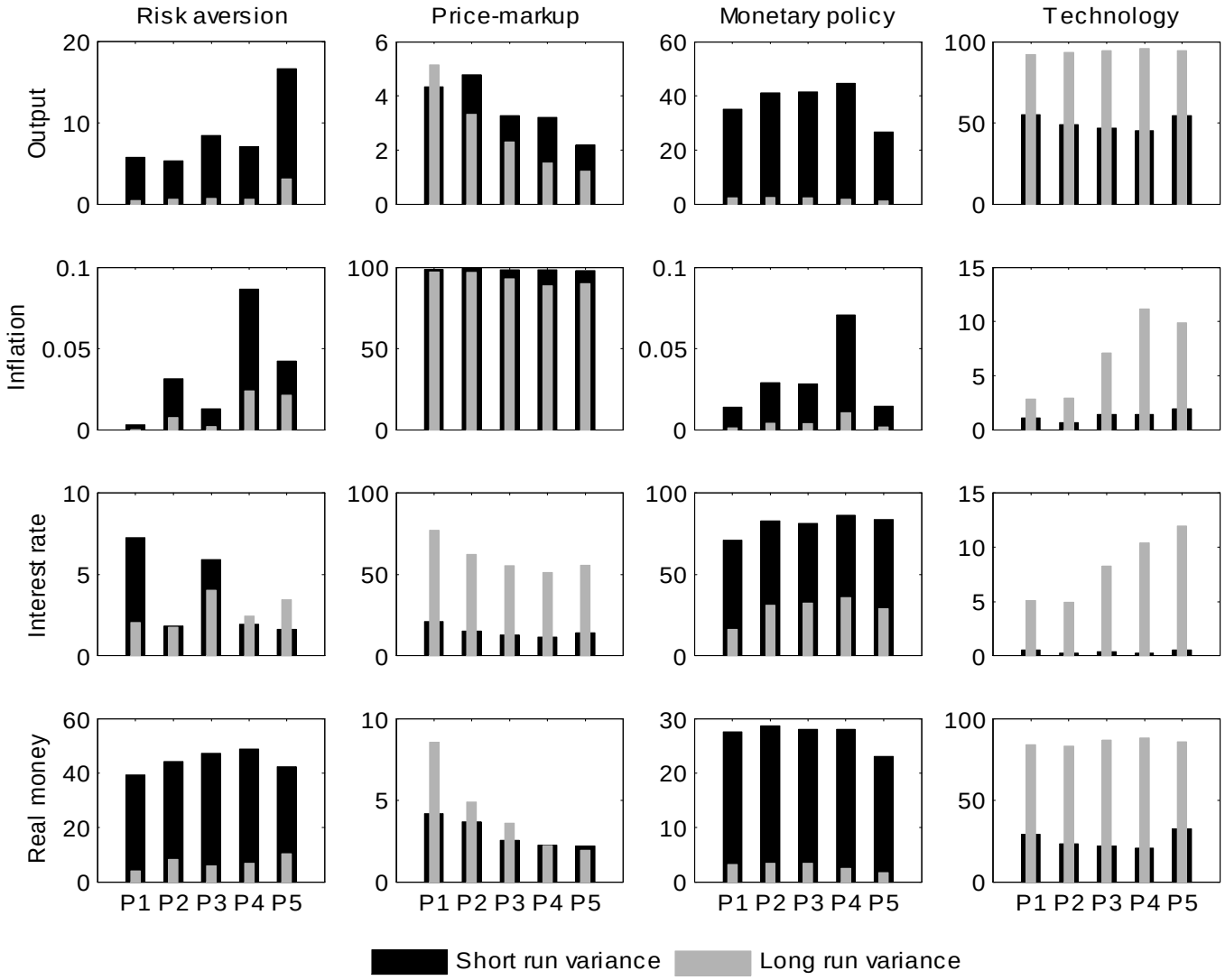


Figure: Variance decomposition over the selected periods

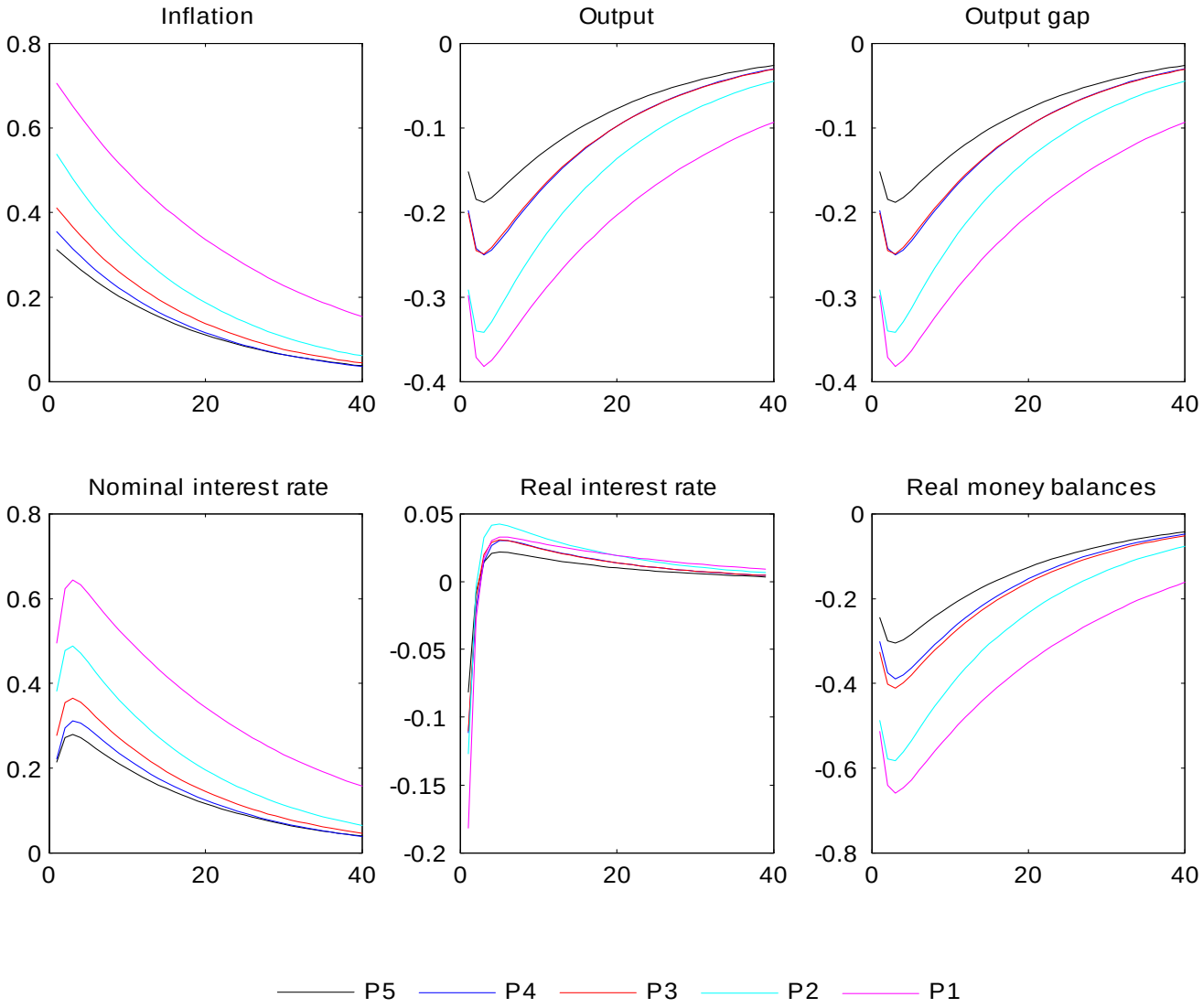


Figure: Impulse response function with respect to a price-markup shock

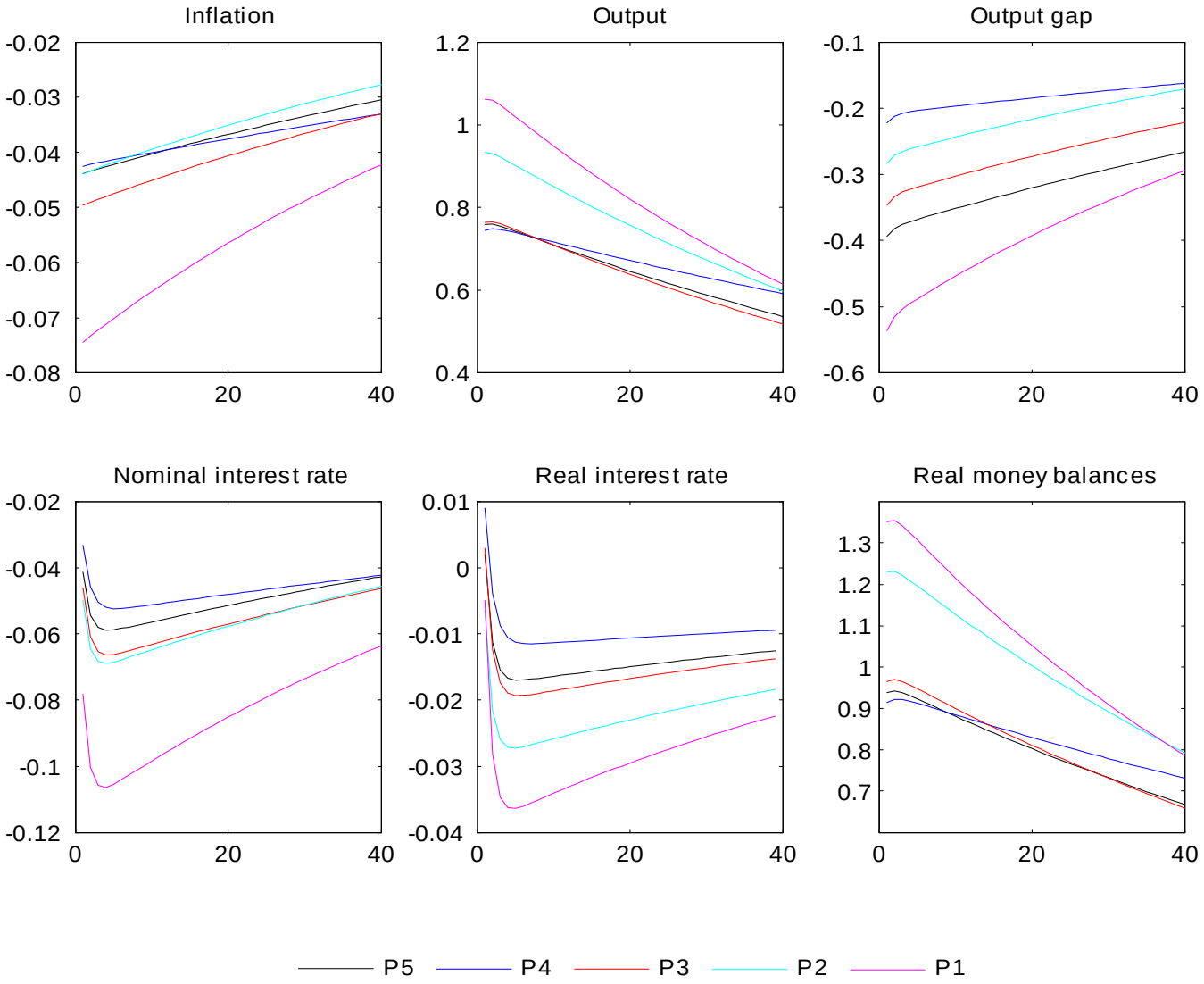


Figure: Impulse response function with respect to a technology shock

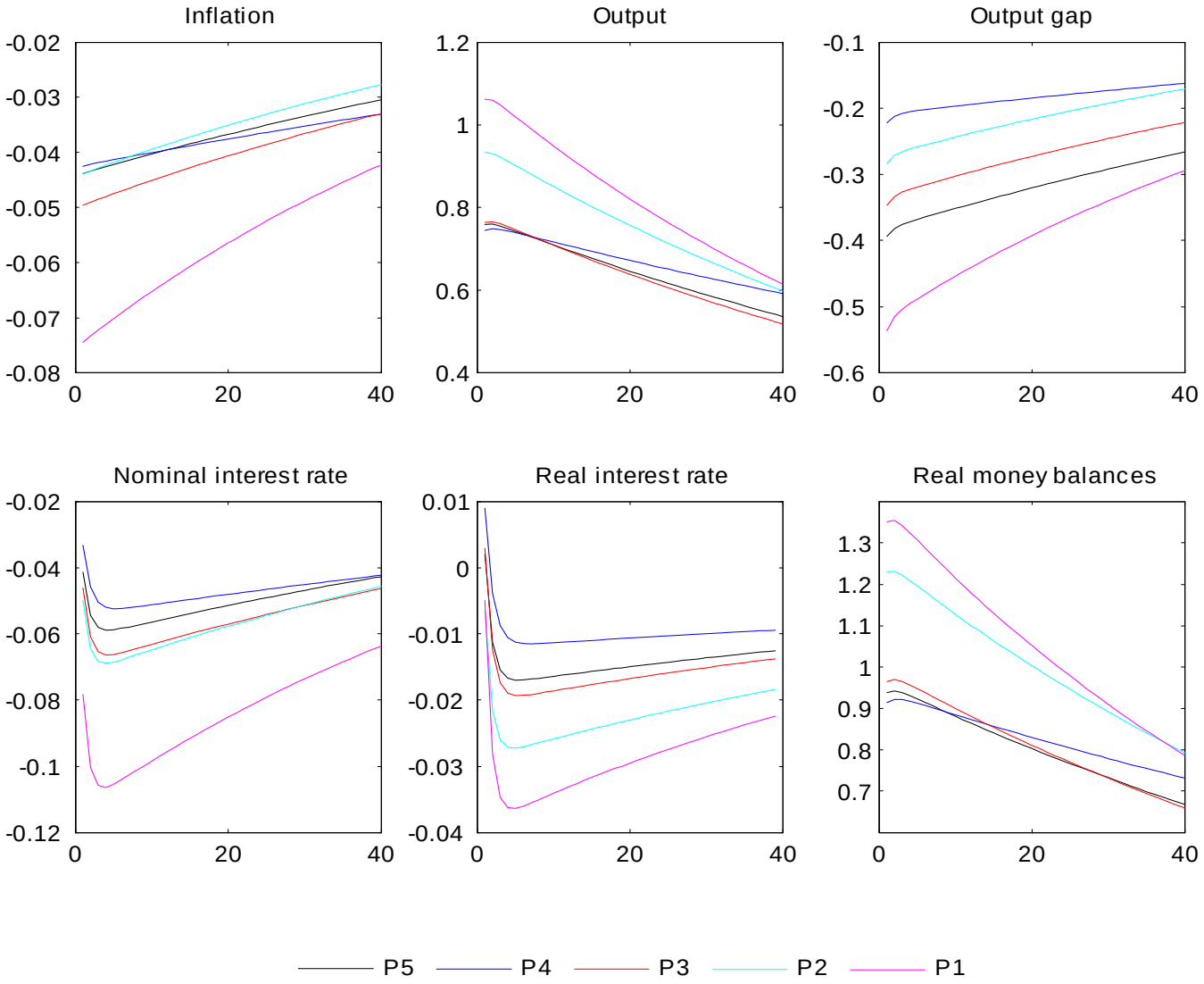


Figure: Impulse response function with respect to a technology shock

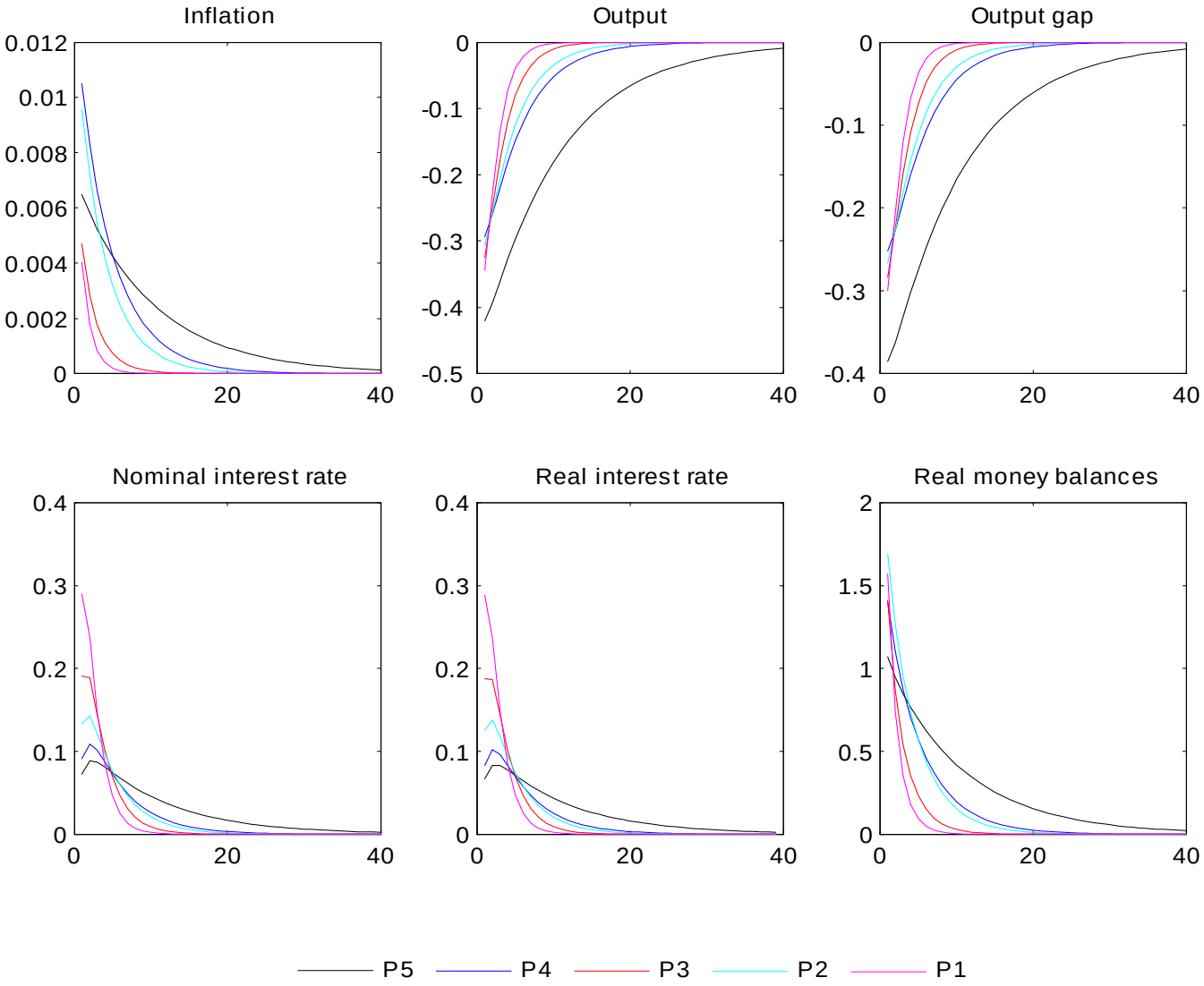


Figure: Impulse response function with respect to a risk aversion shock