The exam consists of three parts: A, B, and C. In the grading, part A has 20% weight, part B has 40% weight, and part C has 40% weight. Allocate your time accordingly.

Part A: Monetary Policy Report 1/24 (20%)

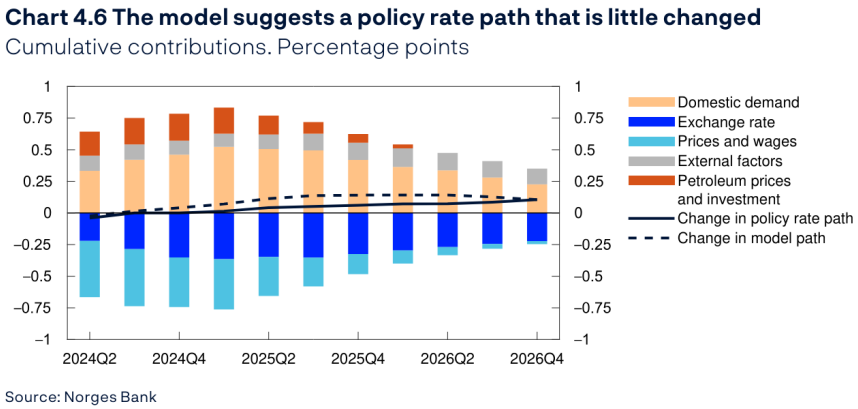


Figure 1: Accounting for changes in the interest rate forecast, MPR 1/24

Figure 1 displays the model-based accounting of changes in the interest rate path by Norges Bank at the interest rate meeting in March 2024. Discuss the contributors behind each of the five bars in the figure and why they contribute by raising or lowering the interest rate path.

Solution:

- **External factors:** market rates abroad have increased, mainland exports higher than projected, economic growth abroad broadly unchanged. Especially higher market rates abroad is a force towards a weaker krone, and thus higher interest rates in Norway.
- **Petroleum prices and investment:** oil spot and futures have increased somewhat, gas prices have fallen, and petroleum investment has been higher than projected. This gives somewhat of a push toward higher economic performance and, thus higher interest rates.
- **Exchange rate:** the krone exchange rate has been stronger than projected in the December report - resulting in lower than projected inflation and weaker export growth - forces toward a lower interest rate.
- **Domestic demand:** capacity utilisation is somewhat higher than projected in December, due to higher private consumption and public demand, forces toward a higher interest rate.
- **Prices and wages:** core inflation was lower than projected. Moreover, lower energy prices, weaker international price impulses and lower wage growth represent forces toward lower inflation, pushing the interest rate down.

Part B: Optimal Price Setting (40%)

In this problem, we are going to solve the firm problem with sticky prices. The firm problem is:

$$\max_{P_t^*, \{N_{t+k}, Y_{t+k}\}_{k=0}^{\infty}} E_t \sum_{k=0}^{\infty} (\beta\theta)^k \left\{ \frac{U_{c,t+k}}{U_{c,t}} \frac{P_t}{P_{t+k}} \left(P_t^*(i) Y_{t+k|t}(i) - W_{t+k} N_{t+k|t}(i) \right) \right\} \tag{1}$$

subject to

$$Y_{t+k}(i) = N_{t+k}(i)^{1-\alpha} \tag{2}$$

$$Y_{t+k|t}(i) = \left(\frac{P_t^*(i)}{P_{t+k}} \right)^{-\epsilon} Y_{t+k} \tag{3}$$

where P_t^* is the optimal price in period t, $U_{c,t+k}$ is the marginal utility of consumption in period $t+k$, W is the aggregate nominal wage, N is hours, Y is aggregate output, P is the aggregate price, α is the curvature of the production function, and the notation $\cdot_{t+k|t}$ denotes the value of that variable in period $t+k$ for a firm that last reset its price in period t.

a) The current period version of equation (3) is

$$Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon} Y_t. \tag{4}$$

Interpret equation (4).

b) Log-linearize equation (4).

c) Assume that $\theta = 0$ (i.e., flexible prices). The Lagrangian for the firm problem is then

$$\mathcal{L}_t = P_t(i) Y_t(i) - W_t N_t(i) - \zeta_t(i) \left(Y_t(i) - \left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon} Y_t \right) - \Psi_t(i) \left(Y_t(i) - N_t(i)^{1-\alpha} \right)$$

Find the first order conditions with respect to hours $N_t(i)$ and output $Y_t(i)$ and solve for $\Psi_t(i)$ and $\zeta_t(i)$, respectively. What is $\Psi_t(i)$? What is $\zeta_t(i)$?

d) What is the optimal price if $\theta = 0$ (flexible prices)?

e) The log-linearized optimal price setting equation for the problem with $\theta > 0$ is

$$p_t^* = \mu + (1 - \beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k E_t\{\psi_{t+k|t}\} \tag{5}$$

with $\mu = \log M$ and $\psi_{t+k|t} = \log \Psi_{t+k|t}$.

Use equation (5) to explain how prices are set when prices are sticky. Compare the solution with sticky prices (5) with the solution with flexible prices (problem d). How do the two solutions differ?

Solution:

a) Demand for good i is a function of (i) the relative price of good i and (ii) aggregate demand. A higher relative price leads to lower demand for good i, and this substitution effect is governed by ε, the elasticity of substitution between goods.

b) Take logs (lower case letters are logs):

$$y_t(i) = -\varepsilon p_t(i) + \varepsilon p_t + y_t.$$

c) The first-order condition with respect to $N_t(i)$ is

$$-W_t + \Psi_t(i)(1-\alpha)N_t(i)^{-\alpha} = 0 \Rightarrow \Psi_t(i) = \frac{W_t}{(1-\alpha)N_t^{-\alpha}} = \text{the nominal marginal cost.}$$

The first-order condition with respect to output is

$$P_t(i) - \zeta_t(i) - \Psi_t(i) = 0 \Rightarrow \zeta_t(i) = P_t(i) - \Psi_t(i) = \text{nominal marginal profits.}$$

d) Optimal price if $\theta = 0$ is the static price setting problem. Take the first-order condition with respect to $P_t(i)$ to get

$$Y_t(i) - \zeta_t(i)\varepsilon P_t(i)^{-1} \underbrace{\left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} Y_t}_{Y_t(i)} = 0 \Rightarrow P_t(i) = \varepsilon(P_t(i) - \Psi_t(i)) \Rightarrow P_t(i) = \frac{\varepsilon}{\varepsilon - 1}\Psi_t(i).$$

Hence, prices are set as a mark-up over marginal costs.

e) When prices are sticky, firms are forward-looking and set prices as a mark-up over the weighted average of current and future marginal costs. The weights depend on how likely the firm is to be stuck with the price in the future (θ^k) and how much the owner cares about the future period (β^k). In contrast, with flexible prices, future marginal costs are irrelevant and firms set prices only as a mark-up over current marginal costs.

Part C: Monetary policy in the New Keyensian Model (40%)

We are going to use the New Keynesian model to see how the economy responds to a demand shock under an interest rate rule. We assume that the model is

$$\pi_t = E_t\{\pi_{t+1}\} + \kappa x_t \tag{6}$$
$$x_t = E_t\{x_{t+1}\} - (i_t - E_t\{\pi_{t+1}\}) + d_t \tag{7}$$
$$i_t = \phi_\pi \pi_t \tag{8}$$
$$d_t = \rho d_{t-1} + \eta_t \tag{9}$$
$$\eta_t \sim N(0, \sigma_d) \tag{10}$$
$$\kappa = \left(1 + \frac{\phi + \alpha}{1 - \alpha}\right)\left(\frac{1 - \theta}{\theta}\right)(1 - \theta)\left(\frac{1 - \alpha}{1 - \alpha + \alpha\varepsilon}\right) \tag{11}$$

where x is the output gap, π is inflation, i is the nominal interest rate, and d is a demand shock. κ, ϕ_π, ρ, σ_d, ϕ, α, θ, and ε are known parameters.

a) Insert (8) into (7) and guess that

$$\begin{aligned} x_t &= \psi_{xd} d_t \\ \pi_t &= \psi_{\pi d} d_t \\ E_t\{x_{t+1}\} &= \rho \psi_{xd} d_t \\ E_t\{\pi_{t+1}\} &= \rho \psi_{\pi d} d_t. \end{aligned}$$

Find the solutions for ψ_{xd} and $\psi_{\pi d}$.

b) Figure 2 shows the impulse responses of the output gap, inflation, the real interest rate, the nominal interest rate, and the demand shock to an initial shock to ϵ_0^d of -0.5. We have used the following calibration: $\phi = 5$, $\alpha = 0.25$, $\epsilon = 9$, $\theta = 0.75$, $\phi_\pi = 1.5$, and $\rho = 0.75$. Explain why the demand shock affects the economy the way it does in Figure 2.

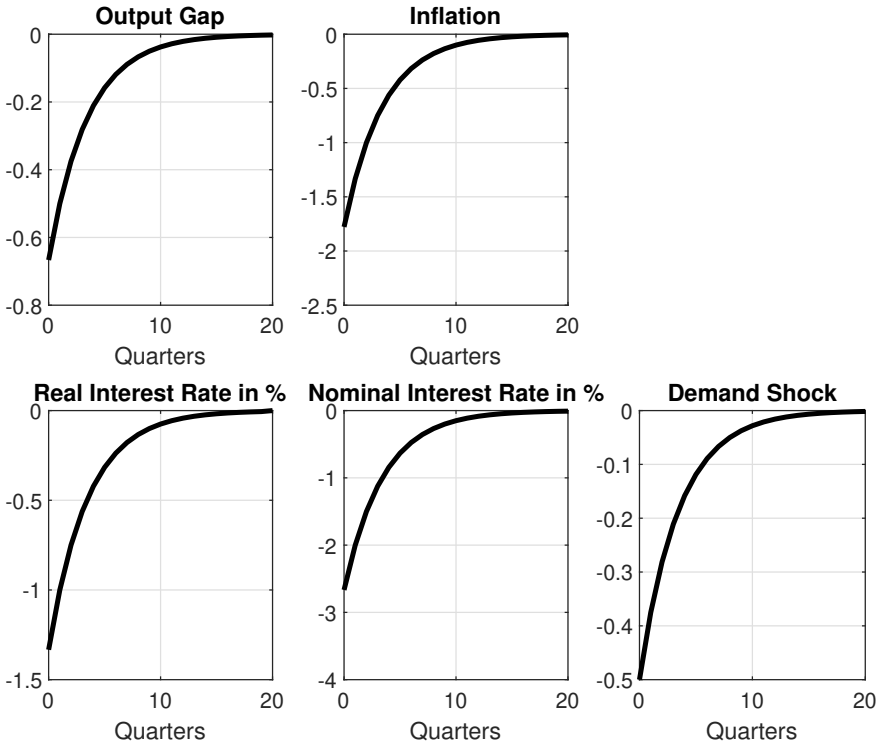


Figure 2: Impulse responses to a demand shock

c) We now change the calibration by lowering ε from 9 to 2. All other parameters are the same as in problem b. Figure 3 presents the impulse responses in the benchmark scenario and in the new calibration. Explain what ε is, how it changes the economic environment and how agents alter their behavior. Next, explain why the aggregate responses of the economy change in the way presented in Figure 3.

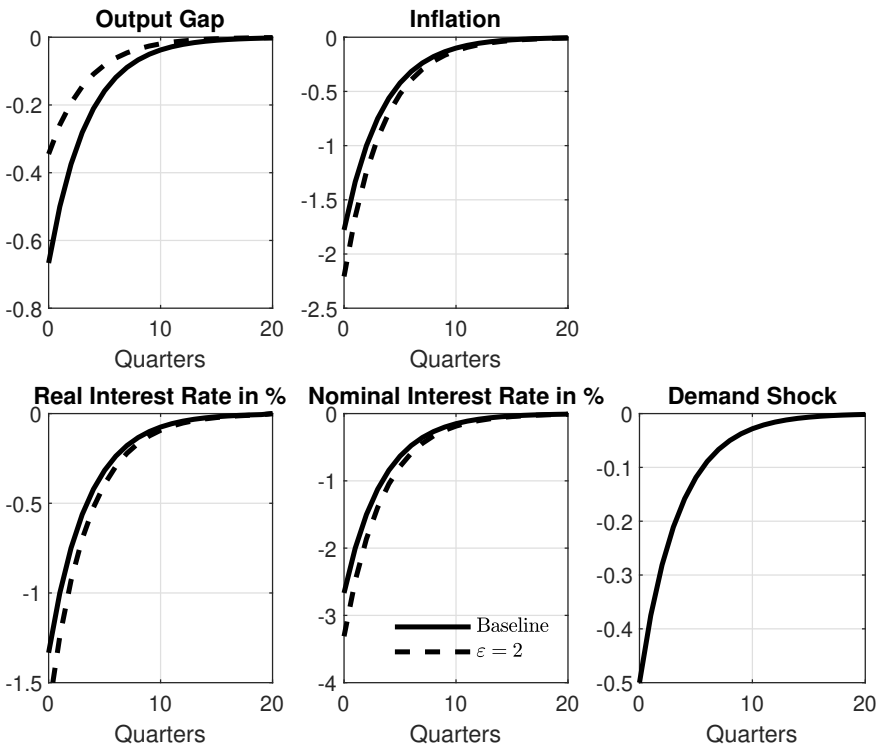


Figure 3: Impulse responses to a demand shock: variation in ε.

d) Assume now that the central bank follows optimal monetary policy instead of a Taylor rule (8) where the central bank cares about inflation and the output gap. The loss function is

$$\mathcal{L}_t = \frac{1}{2} \sum_{k=0}^{\infty} \left(\pi_{t+k}^2 + \lambda x_{t+k}^2 \right)$$

where $\lambda > 0$ is a parameter.

Show that the solution for optimal monetary policy under discretion is

$$\lambda x_t = -\kappa \pi_t. \tag{12}$$

and interpret equation (12).

e) Show that the optimal solution for the interest rate is

$$i_t = d_t$$

and explain the intuition for the implied interest rate rule.

Solution:

a) The solutions are

$$\psi_{xd} = \frac{1-\rho}{(1-\rho)(1-\rho)+\kappa(\phi_\pi-\rho)},$$
$$\psi_{x\pi} = \frac{\kappa}{(1-\rho)(1-\rho)+\kappa(\phi_\pi-\rho)}.$$

Note that $\beta = 1$ and $\sigma = 1$ compared to the standard solution.

b) The demand shock is negative, pushing output down. Via the Phillips curve, this implies that inflation also falls. The central bank responds to the decrease in inflation by reducing the interest rate so much that the real interest rate also decreases. When the real interest rate is negative, this stimulates demand and dampens the impact of the demand shock somewhat.

c) When ε is lower, the demand for a firm's good is less sensitive to the relative price. This makes firms less reluctant to change prices when not all other firms change (because when they change the price, their demand falls less, raising their marginal product of capital by less, and reducing their marginal cost by less), steepening the Phillips curve.

The effect of a steeper Phillips curve is that the initial effect from output to prices is strengthened. This central bank thus responds by lowering the interest rate (and the real interest rate) by more, thus dampening the impact on output by more.

d) The problem is

$$\min_{x_t,\pi_t} \frac{1}{2}(\pi_t^2 + \lambda x_t^2) + F_t - \gamma(\pi_t - \kappa x_t + f_t)$$

where f_t and F_t contains all irrelevant terms. The solution is

$$\pi_t - \gamma = 0$$
$$\lambda x_t + \gamma\kappa = 0$$

which becomes

$$\lambda x_t = -\kappa\pi_t.$$

Intuition: the central bank weighs the marginal cost of a recession (λx_t) against the marginal benefit of a recession in terms of reducing inflation ($-\kappa\pi_t$).

e) It is a demand shock and the solution is $x_t = \pi_t = 0$. This can be achieved by setting

the interest rate so that it exactly cancels out the demand shock. This is a result of monetary policy also being a demand shock.