Recent and Prospective Developments in Monetary Policy

Lars E.O. Svensson
Sveriges Riksbank

September 2007

Questions

- How to implement optimal monetary policy?
- How to reconcile theory and practice in monetary policy?

Outline

- Optimal policy
  - Traditional, optimal policy function
  - Projections, not policy functions
  - Forecast targeting (mean)
  - Judgment
  - Non-certainty equivalence: Distribution forecast targeting
- Possible technical problems
  - Determinacy (Woodford)
  - Commitment in a timeless perspective

Outline

- Decision process
  - Staff presents feasible alternatives to MPC
  - MPC chooses optimal projections
- Announcing optimal projections
- Measures of resource utilization
- Using explicit loss functions

Optimal monetary policy: Standard approach

- Linear model (decision in period t, X_t given, $\tau \geq 0$)

$$\begin{bmatrix} X_{t+\tau+1} \\ H\mathrm{E}_{t+\tau}x_{t+\tau+1} \end{bmatrix} = A \begin{bmatrix} X_{t+\tau} \\ x_{t+\tau} \end{bmatrix} + Bi_{t+\tau} + \begin{bmatrix} C \\ 0 \end{bmatrix} \varepsilon_{t+\tau+1}$$

  X_t predetermined variables, x_t forward-looking variables, i_t policy instrument(s), ε_t zero-mean i.i.d. shocks

- Determination of X_{t+1}, given X_t, x_t, i_t, ε_{t+1}:

$$X_{t+1} = A_{11}X_t + A_{12}x_t + B_1 i_t + C\varepsilon_{t+1}$$

  Determination of x_t, given $\mathrm{E}_t Hx_{t+1}$, X_t, i_t:

$$\mathrm{E}_t Hx_{t+1} = A_{21}X_t + A_{22}x_t + B_2 i_t$$

Optimal monetary policy: Standard approach

- Quadratic intertemporal loss function

$$\mathcal{L}_t = \mathrm{E}_t \sum_{\tau=0}^{\infty} (1-\delta)\delta^{\tau} L_{t+\tau}$$

Period loss

$$L_{t+\tau} = Y'_{t+\tau} \Lambda Y_{t+\tau}$$

Target variables

$$Y_{t+\tau} = D \begin{bmatrix} X_{t+\tau} \\ x_{t+\tau} \\ i_{t+\tau} \end{bmatrix}$$

- Flexible inflation targeting

$$L_t = (\pi_t - \pi^*)^2 + \lambda_y (y_t - \bar{y}_t)^2 + \lambda_{\Delta i} (i_t - i_{t-1})^2$$

$y_t - \bar{y}_t$ output gap, measure or resource utilization

Optimal monetary policy: Standard approach

- Optimal policy function (given X_t, Ξ_{t-1})

$$i_t = F_i \begin{bmatrix} X_t \\ \Xi_{t-1} \end{bmatrix}$$

- Solution (given X_t, Ξ_{t-1}, $\tau \geq 0$)

$$\begin{bmatrix} x_{t+\tau} \\ i_{t+\tau} \end{bmatrix} = \begin{bmatrix} F_x \\ F_i \end{bmatrix} \begin{bmatrix} X_{t+\tau} \\ \Xi_{t+\tau-1} \end{bmatrix}$$

$$\begin{bmatrix} X_{t+\tau+1} \\ \Xi_{t+\tau} \end{bmatrix} = M \begin{bmatrix} X_{t+\tau} \\ \Xi_{t+\tau-1} \end{bmatrix} + \begin{bmatrix} C \\ 0 \end{bmatrix} \varepsilon_{t+\tau+1}$$

- History dependence: Determination of Ξ_{t-1}

$$\Xi_{t-1} = M_{\Xi X} X_{t-1} + M_{\Xi\Xi} \Xi_{t-2} = \sum_{\tau=1}^{\infty} M_{\Xi\Xi}^{\tau-1} M_{\Xi X} X_{t-\tau}$$

Optimal monetary policy: Projections

- Projection (mean): Notation: $z^t \equiv \{z_{t+\tau,t}\}_{\tau=0}^{\infty}$
- Optimal (mean) projections $(\hat{X}^t, \hat{x}^t, \hat{\imath}^t, \hat{Y}^t)$ (conditional on current state of economy, model of transmission mechanism, loss function)

$$\begin{bmatrix} \hat{\imath}_{t+\tau,t} \\ \hat{x}_{t+\tau,t} \end{bmatrix} = \begin{bmatrix} F_i \\ F_x \end{bmatrix} \begin{bmatrix} \hat{X}_{t+\tau,t} \\ \hat{\Xi}_{t+\tau-1,t} \end{bmatrix}, \quad \hat{Y}_{t+\tau,t} = D \begin{bmatrix} \hat{X}_{t+\tau,t} \\ \hat{x}_{t+\tau,t} \\ i_{t+\tau,t} \end{bmatrix}$$

$$\begin{bmatrix} \hat{X}_{t+\tau+1,t} \\ \hat{\Xi}_{t+\tau,t} \end{bmatrix} = M \begin{bmatrix} \hat{X}_{t+\tau,t} \\ \hat{\Xi}_{t+\tau-1,t} \end{bmatrix}, \; \hat{X}_{t,t} \; = \; X_t$$

- Current state of economy, estimate $X_{t|t}$

$$\hat{X}_{t,t} = X_{t|t} \;\; \text{(instead of } \; \hat{X}_{t,t} = X_t)$$

Details: Svensson-Woodford 03, "Indicator Variables for Optimal Policy"

Optimal monetary policy: Projections

- Feasible set of projections (conditional on (estimate of) current state of economy, model of transmission mechanism)

$$(X^t, x^t, i^t, Y^t) \in \mathcal{T}(X_{t|t})$$

- Projection model

$$\begin{bmatrix} X_{t+\tau+1,t} \\ Hx_{t+\tau+1,t} \end{bmatrix} = A \begin{bmatrix} X_{t+\tau,t} \\ x_{t+\tau,t} \end{bmatrix} + Bi_{t+\tau,t}, \quad X_{t,t} = X_{t|t}. \qquad (1)$$

- Feasible set of projections

$$\mathcal{T}(X_{t|t}) \equiv \left\{ (X^t, x^t, i^t, Y^t) \mid (X^t, x^t, i^t, Y^t) \text{ satisfy } (1) \right\}$$

Optimal monetary policy: Projections

- Intertemporal loss function over projections (no E_t, no $1-\delta$)

$$\mathcal{L}(Y^t;\Lambda) \equiv \sum_{\tau=0}^{\infty} \delta^{\tau} L_{t+\tau,t}$$

  Period loss

$$L_{t+\tau,t} \equiv Y'_{t+\tau,t} \Lambda Y_{t+\tau,t}$$

- Optimal projection (given Λ)

$$(\hat{X}^t, \hat{x}^t, \hat{\imath}^t, \hat{Y}^t) = \arg\min \left\{ \mathcal{L}(Y^t;\Lambda) \,|\, (X^t, x^t, i^t, Y^t) \in \mathcal{T}(X_{t|t}) \right\}$$

- Efficient set of projections (for set of Λ):
  Vary Λ in $\mathcal{L}(Y^t;\Lambda)$ to generate set of efficient projections

Projections: Finite-horizon approximation

- Finite-horizon approximation:
  Reach steady state in finite time $T > 0$
- System of finite-dimensional equations
- Arbitrarily close approximation
- Computational advantage?
- Details:
  - Svensson IJCB 05: "Monetary Policy with Judgment: Forecast Targeting"
  - Svensson-Tetlow IJCB 05: "Optimal Policy Projections"

Forecast targeting (mean)

- Choose instrument-rate projection (i^t) so forecasts of target variables (Y^t) "look good"

$$\hat{\imath}^t = \arg\min \left\{ \mathcal{L}(Y^t; \Lambda) \mid (X^t, x^t, i^t, Y^t) \in \mathcal{T}(X_{t|t}) \right\}$$

- Look good: "Inflation forecast approaching inflation target, output-gap forecast approaching zero, good compromise between stabilizing inflation and the output gap"
- Certainty equivalence (linear model, quadratic loss, additive uncertainty):
  Mean forecast targeting

Judgment

- Deviation z_t (add factors)

$$\begin{bmatrix} X_{t+\tau+1} \\ Hx_{t+\tau+1|t+\tau} \end{bmatrix} = A \begin{bmatrix} X_{t+\tau} \\ x_{t+\tau} \end{bmatrix} + Bi_{t+\tau} + \begin{bmatrix} z_{t+1} \\ 0 \end{bmatrix}$$

- Assume moving-average stochastic process of finite order $T > 0$

$$z_{t+1} = \varepsilon_{t+1} + \sum_{j=1}^{T} \varepsilon_{t+1,t+1-j},$$

Innovation $\tilde{\varepsilon}_t \equiv (\varepsilon_t', \varepsilon^{t\,\prime})' \equiv (\varepsilon_t', \varepsilon_{t+1,t}', ..., \varepsilon_{t+T,t}')'$ is a zero-mean i.i.d. random $(T+1)n_X$-vector

Judgment

- Judgment $z^t = \{z_{t+\tau,t}\}_{\tau=0}^{\infty}$

$$z_{t+\tau,t} \equiv \mathrm{E}_t z_{t+\tau} = \varepsilon_{t+\tau,t} + z_{t+\tau,t-1}.$$

  $\varepsilon_{t+\tau,t} = z_{t+\tau,t} - z_{t+\tau,t-1}$ innovation in period t to the previous judgment $z_{t+\tau,t-1}$
  Dynamics of deviation z_t and judgment z^{t+1}

$$\begin{bmatrix} z_{t+1} \\ z^{t+1} \end{bmatrix} = A_z \begin{bmatrix} z_t \\ z^t \end{bmatrix} + \begin{bmatrix} \varepsilon_t \\ \varepsilon^{t+1} \end{bmatrix}, \tag{2}$$

- Replace $X_{t|t}$ by $(X'_{t|t}, z^{t\prime})'$ to incorporate judgment (expand vector of predetermined variables)
- Add (2) to model
- Details in
  - Svensson IJCB 05: "Monetary Policy with Judgment: Forecast Targeting"
  - Svensson-Tetlow IJCB 05: "Optimal Policy Projections"

Non-certainty equivalence: Distribution forecast targeting

- The above for certainty equivalence, mean projections sufficient
- Non-certainty equivalence (nonlinear model, nonquadratic loss, or nonadditive uncertainty)
- Interpret (X^t, x^t, i^t, Y^t), $X_{t|t}$ as probability distributions, $\mathcal{T}(X_{t|t})$ set of feasible probability distributions
- $\mathcal{L}(Y^t; \Lambda)$ loss function over distributions
- Optimal projections $(\hat{X}^t, \hat{x}^t, \hat{\imath}^t, \hat{Y}^t)$: Optimal probability distributions
- Details for MJLQ: Svensson-Williams 07
  "Monetary Policy with Model Uncertainty: Distribution Forecast Targeting,"
  "Bayesian and Adaptive Optimal Policy under Model Uncertainty"

Possible technical problems: Determinacy

- Problem (Woodford): Given instrument-rate path, possible indeterminacy (wrong eigenvalue configuration)
- Solution: Out-of-equilibrium commitment

$$\hat{\imath}_{t,t} = F_i \begin{bmatrix} X_{t|t} \\ \Xi_{t-1} \end{bmatrix}$$

$$i_t = \hat{\imath}_{t,t} + f_{ix}(x_t - \hat{x}_{t,t})$$

Choose f_{ix} so right eigenvalue configuration

$$\begin{aligned} i_t &= \hat{\imath}_{t,t} + \alpha\{(\pi_t - \pi^*) + \frac{\lambda}{\kappa}[(y_t - \bar{y}_t) - (y_{t-1} - \bar{y}_{t-1})]\} \\ i_t &= \hat{\imath}_{t,t} + \alpha(\pi_t - \pi_{t,t}) \end{aligned}$$

Details: Svensson-Woodford 05, "Implementing Optimal Policy through Inflation-Forecast Targeting"

Possible technical problems: Commitment in a timeless perspective

- How to implement commitment in a timeless perspective
- Modified loss function

$$\tilde{\mathcal{L}}(Y^t;\Lambda;\Xi_{t-1}) \equiv \mathcal{L}(Y^t;\Lambda) + \Xi'_{t-1}\frac{1}{\delta}H(x_{t,t} - x_{t,t-1})$$

Details: Svensson-Woodford 05

- Initial Ξ_{t-1} when no previous optimization?

Possible technical problems: Commitment in a timeless perspective - initial multipliers

1. Assume optimal policy in the past

$$\Xi_{t-1} = M_{\Xi X} X_{t-1} + M_{\Xi\Xi} \Xi_{t-2} \approx \sum_{\tau=1}^{T} M_{\Xi\Xi}^{\tau-1} M_{\Xi X} X_{t-\tau}$$

Possible technical problems: Commitment in a timeless perspective - initial multipliers

2. Assume any systematic policy in the past, not necessary optimal (use first-order condition to determine Ξ_{t-1})

$$\bar{A}' \begin{bmatrix} \xi_{s+1|t} \\ \Xi_s \end{bmatrix} = \frac{1}{\delta} \bar{H}' \begin{bmatrix} \xi_s \\ \Xi_{s-1} \end{bmatrix} + \bar{W} \begin{bmatrix} X_s \\ x_s \\ i_s \end{bmatrix}$$

$$\begin{bmatrix} \xi_{t-1} \\ \Xi_{t-1} \end{bmatrix} = \bar{B} \begin{bmatrix} \xi_{t-2} \\ \Xi_{t-2} \end{bmatrix} + \sum_{s=0}^{\infty} \bar{F}^s \Phi \bar{W} \begin{bmatrix} X_{t-1+s|t-1} \\ x_{t-1+s|t-1} \\ i_{t-1+s|t-1} \end{bmatrix}.$$

Details: Adolfson-Laséen-Lindé-Svensson 07, "Optimal Monetary Policy in an Operational Medium-Sized DSGE Model"

Choosing the instrument-rate projection

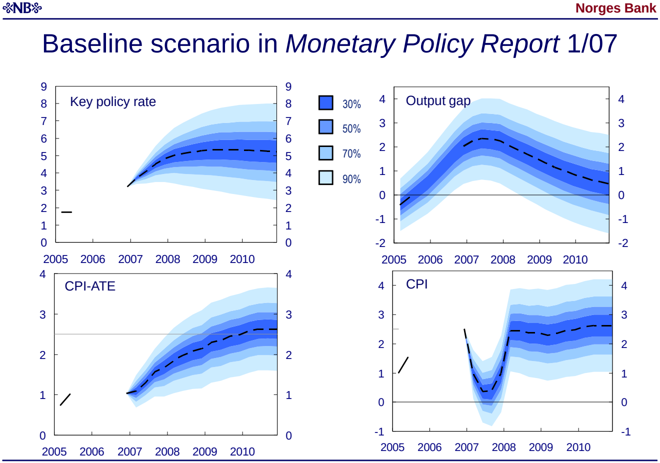
- Choice object
  - Instrument-rate projection $i^t = \{i_{t+\tau,t}\}_{\tau=0}^{T}$ ($T \geq 12$ qtrs); not explicit policy function
  - Current instrument rate $i_{t,t}$ (small) part of the decision
  - Implicitly

$$i_{t,t} = F_{iX}X_t + F_{i\Xi}\Xi_{t-1} + F_{iz}z^t$$

Choosing the instrument-rate projection: Decision process

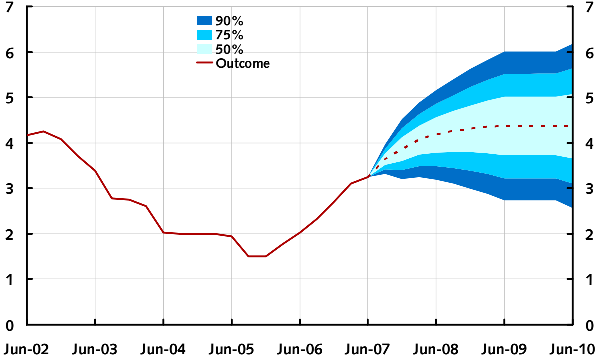
- Staff presents feasible alternatives to MPC
  - Illustrate $\mathcal{T}_t(X_{t|t}, z^t)$ for given $X_{t|t}, z^t$; choice set of MPC; alternative (Y^t, i^t)
  - Efficient set of $\mathcal{T}_t(X_{t|t}, z^t)$ for given $X_{t|t}, z^t$
  - Report $\mathcal{L}(Y^t; \Lambda; \Xi_{t-1})$ for alternative Λ
  - Scenarios for alternative $X_{t|t}, z^t$
  - Simulations to show distribution (probability bands)
  - Several iterations staff-MPC
- MPC chooses optimal projection $(\hat{Y}^t, \hat{\imath}^t)$

Example: Projections with uncertainty bands



Example: Instrument rate with uncertainty bands

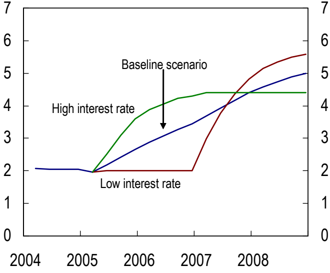
Figure 1. Repo rate with uncertainty bands
Per cent, quarterly averages



Source: The Riksbank

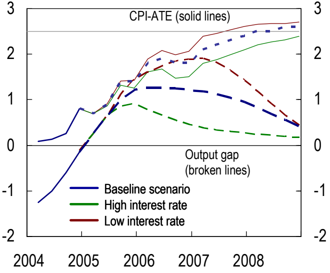
Example: Alternative instrument-rate projections

Chart 3.5a 3-month money market rate in the baseline scenario and in alternative scenarios with high and low interest rates. Quarterly figures. 04 Q1 – 08 Q4



Source: Norges Bank

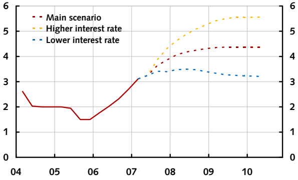
Chart 3.5b Projections for the CPI-ATE and the output gap in the baseline scenario and in alternative scenarios with high and low interest rates. Quarterly figures. Per cent. 04 Q1 – 08 Q4



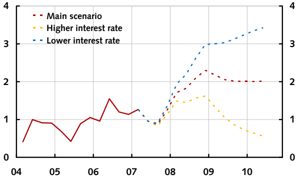
Sources: Statistics Norway and Norges Bank

Different interest rate scenarios

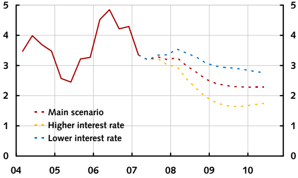
Repo rate
Per cent



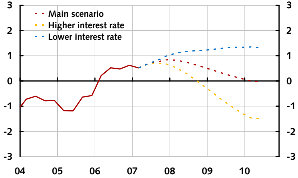
CPIX
Annual percentage change



GDP growth
Annual percentage change



Estimated output gaps
Percentage deviation from the HP trend



Note. Boken lines represent the Riksbank's forecast.

Sources: Statistics Sweden and the Riksbank

Choosing the instrument-rate projection: Possible problems

- Deciding on a path vs. a point
- Previously RBNZ 97, Norges Bank 05
- Riksbank 07: New: 6 board members
- If it works for 6, it should work for 9, 12, 19, ...
- How to decide?
  - Majority voting
  - Median path, iterating (Svensson 03, 06, 07)
  - Simpler: Limit number of alternatives: Main scenario + one or two alternatives
  - Interaction staff-MPC to determine these alternatives

Announcing the instrument-rate projection

- Best way to manage expectations
- Expectations about entire instrument-rate path (i^t) matters, not current instrument rate $(i_{t,t})$
- Natural part of package of inflation and output(-gap) forecasts $(\pi^t, y^t - \bar{y}^t, i^t)$
- Most transparent

Announcing the instrument-rate projection: Possible problems

- Market misunderstanding: Commitment or forecast conditional on current information?
  - Not problem in New Zealand or Norway
  - Emphasize uncertainty and conditional nature: Probability bands

Announce the instrument-rate projection; not the policy function

- Policy function too complicated
  - Arguments X_t and Ξ_{t-1} (alternatively current and lagged shocks): High-dimensional, complicated. Also z^t!
- Private sector only needs mean forecasts of inflation, output, and instrument rate (Svensson-Woodford 05)
- MPC only needs graphs to see policy alternatives
- Leave policy function implicit

Implementing flexible inflation targeting

- Stabilizing both inflation gap and resource utilization (output gap)

$$L_t = (\pi_t - \pi^*)^2 + \lambda_y (y_t - \bar{y}_t)^2 + \lambda_{\Delta i} (i_t - i_{t-1})^2$$

- Hierarchical vs. dual mandate
  - Long-run means (1st moments): Hierarchical
    - Inflation target subject to choice; potential output subject to estimation
  - Variability (2nd moments): Dual
    - Stabilize both inflation gap and output gap

Measures of resource utilization

- Potential output, output gap
- Use all info (employment, unemployment, capacity utilization, flexprice output) to estimate and forecast potential output
- Potential vs. efficient (socially optimal) output
- Gap between efficient (socially optimal) and potential output: Constant or variable?

Flexible inflation targeting: Explicit loss function

- Welfare based?
  - No
  - Riksbank's mandate is flexible inflation targeting (price stability + stabilizing real economy), not general welfare
  - Welfare measures: Model-dependent, partial
  - Welfare not operational as objective for central banks
- Simple traditional loss function (flexible inflation targeting)

$$L_t = (\pi_t - \pi^*)^2 + \lambda_y (y_t - \bar{y}_t)^2 + \lambda_{\Delta i}(i_t - i_{t-1})^2$$

- Instrument-rate smoothing?
- Voting about parameters
- Experiment internally before going public
- Staff reports losses for projections

Conclusions

- Think of MPCs as choosing projections rather than the current instrument rate
- Optimal monetary policy: The optimal projection in the set of feasible projections (rather than the optimal policy function; too complicated)
- Mean forecast targeting goes a long way
- Distribution forecast targeting is possible
- Judgment can be incorporated systematically and with discipline
- Determinacy is not problem for given instrument-rate projections
- Commitment in a timeless perspective can be implemented

Conclusions

- A committee can decide on an optimal interest-rate projection
- The number of alternative interest-rate projections can be restricted
- Misunderstanding of interest-rate projections as commitments is not a problem
- It is sufficient to announce optimal instrument-rate projections; neither necessary nor feasible to announce the optimal policy function

Conclusions

- Hierarchical vs. dual mandate: A red herring
- Measures and estimation of resource utilization need work
- Explicit loss functions can be used
- MPCs can vote on loss-function parameters
- Interest-rate smoothing problematic
- Experiment internally before going public

Nominal and real interest rate

$$i_t = r_t + \pi_{t+1|t}$$

Output gap and real-interest-rate gap

$$\begin{aligned} y_t - \bar{y}_t &= y_{t+1|t} - \bar{y}_{t+1|t} - \sigma(r_t - \bar{r}_t) \\ &= -\sigma \textstyle\sum_{h=0}^{\infty}(r_{t+h|t} - \bar{r}_{t+h|t}) \end{aligned}$$

Inflation

$$\begin{aligned} \pi_t - \bar{\pi} &= \delta(\pi_{t+1|t} - \bar{\pi}) + \kappa(y_t - \bar{y}_t) + z_t \\ &= \kappa \textstyle\sum_{j=0}^{\infty} \delta^j (y_{t+j|t} - \bar{y}_{t+j|t}) + \sum_{j=0}^{\infty} \delta^j z_{t+\tau+j|t} \\ &= -\sigma\kappa \textstyle\sum_{j=0}^{\infty} \delta^j \sum_{h=0}^{\infty}(r_{t+j+h|t} - \bar{r}_{t+j+h|t}) + \sum_{j=0}^{\infty} \delta^j z_{t+\tau+j|t} \end{aligned}$$

Period loss function

$$L_t = (\pi_t - \bar{\pi})^2 + \lambda_y (y_t - \bar{y}_t) + \lambda_{\Delta i}(i_t - i_{t-1})^2$$

Intertemporal loss function

$$\mathcal{L}_t = \sum_{\tau=0}^{\infty} (1-\delta)\delta^{\tau} L_{t+\tau|t}$$

Decision period t, horizon $\tau \geq 0$
Exogenous projections $\bar{y}^t$, $\bar{r}_t$; endogenous projections y^t, π^t, r^t, i^t
Monetary-policy stance (output gap, Wicksell): $r^t - \bar{r}^t$

$$i_{t+\tau,t} = r_{t+\tau,t} + \pi_{t+1+\tau,t}$$

$$\begin{aligned} y_{t+\tau,t} - \bar{y}_{t+\tau,t} &= y_{t+1+\tau,t} - \bar{y}_{t+1+\tau,t} - \sigma(r_{t+\tau,t} - \bar{r}_{t+\tau,t}) \\ &= -\sigma \sum_{h=0}^{\infty}(r_{t+\tau+h,t} - \bar{r}_{t+\tau+h,t}) \end{aligned}$$

$$\begin{aligned} \pi_{t+\tau,t} - \bar{\pi} &= \delta(\pi_{t+1+\tau,t} - \bar{\pi}) + \kappa(y_{t+\tau,t} - \bar{y}_{t+\tau,t}) + z_{t+\tau,t} \\ &= \kappa \sum_{j=0}^{\infty} \delta^j (y_{t+\tau+j,t} - \bar{y}_{t+\tau+j,t}) + \sum_{j=0}^{\infty} \delta^j z_{t+\tau+j,t} \\ &= -\sigma\kappa \sum_{j=0}^{\infty} \delta^j \sum_{h=0}^{\infty}(r_{t+\tau+j+h,t} - \bar{r}_{t+\tau+j+h,t}) + \sum_{j=0}^{\infty} \delta^j z_{t+\tau+j,t} \end{aligned}$$

Period loss $L_{t+\tau,t}$

$$L_{t+\tau,t} = (\pi_{t+\tau,t} - \bar{\pi})^2 + \lambda_y (y_{t+\tau,t} - \bar{y}_{t+\tau,t}) + \lambda_{\Delta i} (i_{t+\tau,t} - i_{t-1+\tau,t})^2$$

Intertemporal loss $\mathcal{L}_t$

$$\mathcal{L}_t = \sum_{\tau=0}^{\infty} \delta^\tau L_{t+\tau,t}$$