V Money, Inflation and Monetary Policy (Continued)

7 The Science of Monetary Policy: A New Keynesian Perspective (Clarida, Gali and Gertler, 1999)

7.1 Introduction

- Resurgence of interest in the issue of how to conduct monetary policy.
- Empirical evidence: monetary policy significantly influences the real economy.
- Improvement in the theoretical frameworks used for policy analysis.
- This paper: broad principles, real complications and theory vs policy-making in practice.
- Assumptions: temporary nominal price rigidities lead to nonneutral effects of monetary policy; private sector behavior depends on current monetary policy and the expected course of monetary policy.
- Instrument of monetary policy: short-term interest rate.
- Optimal policy in the absence of commitment: the optimal policy embeds inflation targeting; the central bank should adjust the nominal interest rate more than one-for-one with expected future inflation; the central bank should offset demand shocks but accommodate supply shocks.

- Gains from commitment: eliminating the inflationary bias; improving the current output-inflation trade-off; gains from a rule can be approximated by an optimal policy under discretion (under certain circumstances).
- Practical problems: imperfect information and lags, model uncertainty, non-smooth preferences over inflation and output.
- Degree of persistence in inflation and output: this governs the output-inflation trade-off.
- Simple rules for monetary policy and policymaking in US.

7.2 A Baseline Framework and the Policy Objective Function

This is a dynamic general equilibrium model with money and temporary nominal price rigidities.

- As in the traditional Keynesian IS-LM framework, monetary policy affects the real economy in the short run.
- Different from the traditional Keynesian IS-LM model, the aggregate behavioral equations are based on optimization by households and firms.
- Current economic behavior depends critically on expectations of the future as well as on current policy.
- The model accommodates different views about the behavior of the macroeconomy (e.g., perfectly flexible vs fixed prices).
- The model abstracts from investment and capital accumulation.

7.2.1 A Baseline Framework

The baseline model consists of the following two equations:

$$x_t = -\varphi[i_t - E_t\pi_{t+1}] + E_t x_{t+1} + g_t, \tag{1}$$

$$\pi_t = \lambda x_t + \beta E_t \pi_{t+1} + u_t, \tag{2}$$

where

$$g_t = \mu g_{t-1} + \hat{g}_t, \quad \mu \in [0,1], \tag{3}$$

$$u_t = \rho u_{t-1} + \hat{u}_t, \quad \rho \in [0,1], \tag{4}$$

where all variables are in logs:

Notations:

- x_t = the output gap between the stochastic components of output y_t and the natural rate level of output z_t
- π_t = the period t inflation rate (deviation from its long-run level)
- i_t = the nominal interest rate (deviation from its long-run level)
- g_t and u_t = disturbances terms
- $\hat{g}_t$ and $\hat{u}_t$ = i.i.d. random variables with zero mean and variance σ_g^2 and σ_u^2, respectively
- φ = the intertemporal substitution of consumption
- β = the discount rate
- λ = the sensitivity of inflation to the output gap

Equation (1) is an "IS" curve that relates the output gap inversely to the real interest rate. Different from the traditional IS curve, current output depends on expected future output (in addition to the real interest rate).

- Why does current output depend on expected future output? The reason is: Expected output $\uparrow$ $\Rightarrow$ expected consumption $\uparrow$ $\Rightarrow$ current consumption (to smooth consumption) $\uparrow$ $\Rightarrow$ current output demand $\uparrow$.
- The real interest rate affects current output negatively due to the intertemporal substitution of consumption.
- The disturbance term g_t (demand shock) is a function of expected changes in government purchases relative to expected changes in potential output.

Iterating equation (1) forward, we have[1]

$$x_t = E_t \sum_{t=0}^{\infty} \{-[i_{t+i} - \pi_{t+1+i}] + g_{t+i}\} . \tag{5}$$

We can see easily that current output depends on: the current real interest rate and the current demand shock and their future paths. As a result, both current and expected policy changes affect aggregate demand.

Equation (2) is Phillips curve relating inflation positively to the output gap. This Phillips curve looks similar to a traditional expectations-augmented Phillips curve. Different from the traditional Phillips curve, expected future inflation $E_t\pi_{t+1}$ (rather than expected current inflation $E_{t-1}\pi_t$) appears in the equation.

Again, we iterate (2) forward to obtain

$$\pi_t = E_t \sum_{t=0}^{\infty} \beta^i [\lambda x_{t+i} + u_{t+i}]. \tag{6}$$

- Inflation depends entirely on current and expected future output gaps and cost push shocks.

[1]Taking expectations gives: $E_t x_t = -\varphi E_t\{[i_t - \pi_{t+1}] + g_t\} + F E_t x_t$ (where F is a forward operator), $\Rightarrow$ $(1 - F)E_t x_t = -\varphi E_t\{[i_t - \pi_{t+1}] + g_t\}$ $\Rightarrow$ $E_t x_t = -\varphi(1-F)^{-1} E_t\{[i_t - \pi_{t+1}] + g_t\} = -\varphi \sum_{i=0}^{\infty} F^i E_t E_t\{[i_t - \pi_{t+1}] + g_t\} = E_t \sum_{t=0}^{\infty} \{-[i_{t+i} - \pi_{t+1+i}] + g_{t+i}\}$. Note: $(1 - \alpha F)^{-1} = \sum_{i=0}^{\infty} \alpha^i F^i$.

- The variable x_{t+i} captures movements in marginal costs associated with variations in excess demand.
- The disturbance u_{t+i} captures all other factors that affect expected marginal costs.

7.2.2 The Policy Objective Function

Assume that the objective function is over the target variables x_t and π_t and takes the following form:

$$\max -\frac{1}{2} E_t \left\{ \sum_{0}^{\infty} \beta^i [\alpha x_{t+i}^2 + \pi_{t+i}^2] \right\}, \tag{7}$$

where α is the relative weight on output deviations.

7.2.3 The Policy Problem

The nominal interest rate i_t is the instrument of monetary policy. The central bank chooses a time path for i_t to engineer time paths of the target variables x_t and π_t that maximize the objective function (7), subject to the constraints (1) and (2).

Since the target variables depend on both current and expected future policies, credibility of future policy intentions becomes a critical issue.

Comparing optimal policy under rules vs discretion to see if credibility-enhancing commitments are desirable.

7.3 Optimal Monetary Policy without Commitment

Without commitment, the central bank chooses $\{x_t, \pi_t, i_t\}$ in each period. The central bank takes private sector expectations as given in solving the optimization problem and the private sector forms beliefs rationally (conditional on the central bank optimal rule). The optimization problem can be solved by two steps:

- Step 1: The central bank chooses $\{x_t, \pi_t\}$ to maximize (7) subject to (2). Under discretion, future inflation and output are not affected by current actions and the central bank cannot directly manipulate expectations. The solution is:

$$x_t = -\frac{\lambda}{\alpha}\pi_t. \tag{8}$$

  This gives a "lean against the wind" policy: Whenever inflation is above (below) target, contract (expand) demand below (above) capacity by raising (lowering) the interest rate. Combing (8) and (2) and imposing rational expectations give

$$x_t = -\lambda q u_t, \tag{9}$$

$$\pi_t = \alpha q u_t, \tag{10}$$

  where

$$q = \frac{1}{\lambda^2 + \alpha(1-\beta\rho)}.$$

- Step 2: Substituting (9) into (1) gives

$$i_t = \gamma_\pi E_t \pi_{t+1} + \frac{1}{\varphi} g_t, \tag{11}$$

where

$$\gamma_\pi = 1 + \frac{(1-\rho)\lambda}{\rho\varphi\alpha} > 1$$

$$E_t\pi_{t+1} = \rho\pi_t = \rho\alpha q u_t.$$

Key results:

Result 1 (Inflation-output variability trade-off): To the extent cost push inflation is present, there exists a short run trade-off between inflation and output variability.

From (9) and (10), we have

$$\sigma_x = \lambda q \sigma_u, \quad \sigma_\pi = \alpha q \sigma_u, \quad \frac{\sigma_x}{\sigma_\pi} = \frac{\lambda}{\alpha}.$$

$$\alpha \rightarrow 0: \quad \sigma_x = \frac{\sigma_u}{\lambda}, \quad \sigma_\pi = 0,$$

$$\alpha \rightarrow \infty: \quad \sigma_x = 0, \quad \sigma_\pi = \frac{\sigma_u}{1-\beta\rho}.$$

Note that if $\sigma_u = 0$, there is no trade-off.

Result 2 (Inflation targeting): The optimal policy incorporates inflation targeting (inflation converging to its target over time). Extremely inflation targeting (adjusting policy to immediately reach an inflation target) is optimal only if: (1) cost push inflation is absent (i.e., $\sigma_u = 0$) or (2) there is no concern for output deviations (i.e., $\alpha = 0$).

From (10) and (4), we have:

$$\lim_{i\to\infty} E_t\pi_{t+i} = \lim_{i\to\infty} \alpha q \rho^i u_t = 0.$$

- Gradual convergence of inflation as shown above.
- No cost push (i.e.,$\sigma_u = 0$): There is no trade-off. In this case, it is not costly to minimize inflation variability.
- No concern for output deviations (i.e., $\alpha = 0$): It is optimal to minimize inflation variability regardless of whether cost push inflation is present.
- Different views in the literature: Gradual convergence (e.g., Svensson, 1997; Ball, 1997) vs. extreme targeting (e.g., Goodfriend and King, 1997).

Result 3 (Nominal interest rates and expected inflation): Responding to a rise in expected inflation, nominal interest rates should rise sufficiently to raise real interest rates.

We can see from (11) that $\gamma_\pi > 1$, that is, nominal interest rates should rise more than one-to-one in response to an increase in expected inflation.

Result 4 (Nominal interest rates and shocks): The optimal policy calls for adjusting the interest rate to perfectly offset demand shocks (g_t), but perfectly accommodates shocks to potential output (z_t) by keeping the nominal rate constant.

- From (11), we can see that the nominal interest rate depends positively on g_t/φ, reflecting that the nominal interest rate should rise to offset demand shocks.
- Shocks to potential output (e.g. a permanent rise in productivity) change potential output and output demand in the same direction (due to the impact on permanent income), leaving the

output gap unchanged. There is no change in inflation, therefore, there is no need to adjust monetary policy.

- It is important to distinguish the sources of shocks: demand shocks vs. shocks to potential output.

7.4 Credibility and Gains from Commitment

- Persistent inflationary bias under discretion: A central bank desires to push output above its natural rate
- Cost of disinflation: Disinflation may be more costly than necessary if monetary policy is perceived as not devoted to fighting inflation.
- Central bank's credibility: If a central bank can establish credibility, it may be able to reduce inflation a lower cost.

7.4.1 The Classic Inflation Bias Problem

Suppose that the target for the output gap is $k > 0$ due to distortions (e.g., imperfect competition, taxes). The the central bank's objective function becomes

$$\max -\frac{1}{2}E_t\left\{\sum_0^\infty \beta^i[\alpha(x_{t+i}^2 - k) + \pi_{t+i}^2]\right\}, \tag{12}$$

Assuming that $\beta = 1$. Solving the optimization problem gives:

$$x_t^k = -\frac{\lambda}{\alpha}\pi_t^k + k, \tag{13}$$

$$x_t^k = x_t, \tag{14}$$

$$\pi_t^k = \pi_t + \frac{\alpha}{\lambda}k, \tag{15}$$

where x_t and π_t are respectively given by (9) and (10).

Key Results:

Result 5 (Inflationary bias): If the central bank desires to push output above potential (i.e, $k > 0$), then a suboptimal equilibrium may emerge with higher inflation and the same level of output.

- Positive implication: Persistently high inflation in the US from late 1960s to early 1980s.
- Normative implication: Potential gains from binding commitments or institutional adjustments that enhance the central bank's credibility.

Result 6 (Conservative central banker): Appointing a conservative central banker (with $\alpha^R < \alpha$) reduces the inefficient inflationary bias.

This can be seen from (15).

- Output variance: Reduction in inflation variance may come at the cost of increased output variance.
- Importance of inflationary bias in practice: Why was inflation low inflation in the US in the 1980s and 1990s?
- Plausibility of the inflationary bias story: Recognizing the long-run costs of misleading the public to pursue short-term gains is sufficient to constraint the central bank's behavior.

7.4.2 Improving the Short-Run Output Trade-off

There are gains from enhancing credibility even if $k = 0$. It is now assumed that the central bank's policy affects private sector expectations.

Consider *a special class of rules:*

$$x_t^c = -\omega u_t, \quad \omega > 0, \tag{16}$$

Note that the rule under discretion (i.e., $x_t = \lambda q$) is a special case.

Substituting (16) into (2) gives

$$\pi_t^c = \lambda x_t^c + \beta E_t \pi_{t+1}^c + u_t = \left(\frac{1 - \lambda\omega}{1 - \beta\rho} \right) u_t, \tag{17}$$

Rewriting (17) as

$$\pi_t^c = \left(\frac{\lambda}{1 - \beta\rho} \right) x_t^c + \left(\frac{1}{1 - \beta\rho} \right) u_t,). \tag{18}$$

Comparing (18) and (2), we can see that the ability to commit to the policy improves the short-run trade-off between output and inflation: With commitment, reducing x_t by one unit decreases π by $\lambda/(1-\beta\rho)$ units (without commitment, the fall in inflation is λ).

Under the policy rule: $x_t^c = -\omega u_t$, the central bank's objective function can be written as

$$\max -\frac{1}{2} \left[\alpha (x_t^c)^2 + (\pi_t^c)^2 \right] L_t, \quad L_t \equiv E_t \left\{ \sum_{t=0}^{\infty} \beta^i (u_{t+i}/u_t)^2 \right\}, \tag{19}$$

Choosing ω to maximize (19) subject to (18) gives

$$x_t^c = -\left(\frac{\lambda}{\alpha^c} \right) \pi_t^c, \quad \alpha^c \equiv \alpha(1 - \beta\rho) < \alpha. \tag{20}$$

The equilibrium solutions are then given by

$$x_t^c = -\lambda q^c u_t, \tag{21}$$

$$\pi_t^c = \alpha^c q^c u_t, \tag{22}$$

$$i_t^c = \gamma_\pi^c E_t \pi_{t+1}^c + \frac{1}{\varphi} g_t, \tag{23}$$

where

$$q^c \equiv \frac{1}{\lambda^2 + \alpha^c(1 - \beta\rho) > q}$$

$$\gamma_\pi^c \equiv 1 + \frac{(1-\rho)\lambda}{\rho\varphi\alpha^2} > \gamma_\pi.$$

- Discretion vs. rules: The solution obtained under the rule is the same as that obtained under discretion with α being replaced by α^c.
- Adjustments in the interest rate: Relative to the case of discretion, the central bank raises the nominal interest rate by a larger amount in response to a rise in expected inlfation.
- Welfare: Commitment to the policy rule raises welfare.
- Gains from commitment: Gains from commitment are not related to the desire to push output above potential, they are due to the forward-looking nature of inflation (and the importance of expectations about future policy).

Key results:

Result 7 (Gains from commitment): (i) If price-setting depends on expectations of future economic conditions, then a central bank that can credibly commit to a rule faces an improved short-run trade-off between output and inflation; (ii) the gain from commitment arises even if $k = 0$; and (iii) the solution obtained under the rule is the same as that obtained under discretion with α being replaced by α^c.

Now consider the general solution for the optimal policy under commitment. The central bank chooses a state-contingent sequence of $\{x_{t+i},\ \pi_{t+i}\}$ to maximize (7) subject to (2). Use the following Lagrangian:

$$\max -\frac{1}{2}E_t\left\{\sum_{t=0}^{\infty}\beta^i\left[\alpha x_{t+i}^2+\pi_{t+i}^2\right.\right.$$
$$\left.\left. +\ \phi_{t+i}(\pi_{t+i}-\lambda x_{t+i}-\beta\pi_{t+i+1}-u_{t+i})\right]\right\}, \tag{24}$$

where $\phi_{t+i}/2$ is the state-contingent multiplier associated with the constraint at $t+i$. The first-order conditions are:

$$x_{t+i}-x_{t+i-1}=\frac{\lambda}{\alpha}\pi_{t+i}, \quad \text{for} \quad i=1,2,3,... \tag{25}$$

$$x_t=-\frac{\lambda}{\alpha}\pi_t. \tag{26}$$

- The optimal policy under commitment is in general not simply a function of the contemporaneous state variable u_{t+i}.
- The optimal policy is to continue to reduce x_{t+i} as long as π_{t+i} is above target. (Under discretion, the central bank reduces x_t, but does not adjust x_{t+i}.)
- The globally optimal policy is not time consistent.
- It is in general not possible to approximate the globally optimal policy with an appropriately chosen central banker operating with discretion.
- The interest rate rule that implements the optimal policy may have side effects.

Results:

Result 8 (Globally optimal policy with commitment): (i) The central bank partially adjusts demand; (ii) Appointing a conservative central banker does not seem to attain the globally optimal policy; and (iii) there may be some practical complications in implementing the globally optimal interest rate rule.