Achieving Price Stability by Manipulating the Central Bank's Payment on Reserves

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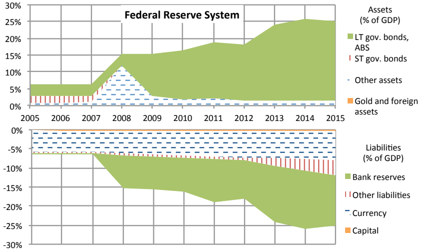
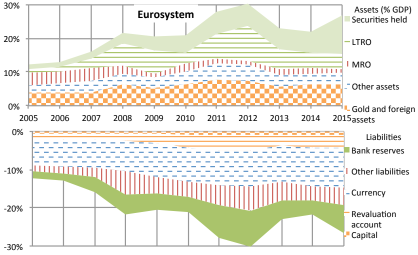
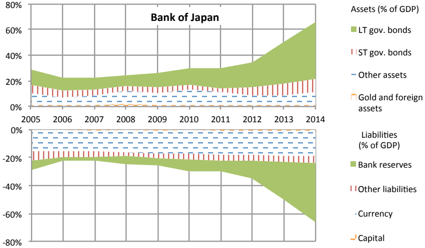
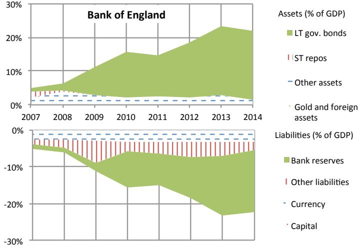
Reservism: satiated market, set interest









The process of monetary policy

- Fundamental central bank question: given a target rule p^*, how to set policy to reach it?
- This paper: new approach to control inflation.
- No need to measure "natural rates", just to observe market prices, and errors easily accommodated.
- Robust to pricing, liquidity, and financial frictions.

Isn't this a solved problem?

- $MV = PY$. Poor fit outside of hyperinflation

- Interest rate rules, combine arbitrage and policy rule

$$i_t = \mathbb{E}_t(\Delta p_{t+1}) + r_t$$
$$i_t = \hat{r}_t + \hat{p}^*_{t+1} - p^*_t + \phi(\Delta p_t - \Delta p^*_t)$$

Iterate forward to infinity with $\phi > 1$ to get:

$$\Delta p_t = \Delta p^*_t + \sum_{s=0}^{\infty} \phi^{-s-1}\, \mathbb{E}_t \left[r_{t+s} - \hat{r}_{t+s} + p^*_{t+1+s} - \hat{p}^*_{t+1+s} \right]$$

as long as $\lim_{T \to +\infty} \phi^{-T}\, \mathbb{E}_t \left(\Delta p_{t+T} - \Delta p^*_{t+T} \right) = 0.$

Problems :(i) mysterious boundary condition, (ii) arbitrage, expectations of infinite future, (iii) linearizations and ZLB.

- FTPL $B/P = EPV(surplus)$ hard to measure.

The robust payment-on-reserves process

Minimal Model

- Reserves are one-period debt claims on the central bank. They are the economy's unit of value, so real value $1/p$.
- No arbitrage Value of real payoff, y_{t+1} is $\mathbb{E}_t(m_{t,t+1}y_{t+1})$.
- Target p^*, observe safe nominal bill price, and real rate:

$$\frac{1}{1+i_t} = \mathbb{E}_t\left(m_{t,t+1}\frac{p_t}{p_{t+1}}\right) \quad \text{and} \quad \frac{1}{1+r_t} = \mathbb{E}_t(m_{t,t+1})$$

Real-payment-on-reserves process

Definition

A real payment-on-reserves monetary-policy process pays the holder of a unit of reserves $1 + x_t$ units of output next period; $1 + x_t$ is set in period t.

Return on reserves:

$$\frac{1 + x_t}{\frac{1}{p_t}} = (1 + x_t)p_t = 1 + r_t$$

Proposition

If the central bank sets the real payment on reserves to

$$1 + x_t = \frac{1 + r_t}{p_t^*},$$

the unique price level is $p_t = p_t^*$.

Intuition

- The market equalizes the return on reserves to the real interest rate.

- x_t is a payment, not a return. It is the promise of paying *above* the interest rate if the price level is below p^* and *below* the interest rate if the price level is above p^* that pegs the price level at 1.

- Not a commodity standard: that relies on law of one price equating value of the unit of account to the value of a real basket of goods. Here, it is the law of no arbitrage equating the value of identical claims on future payoffs that stabilize the price level.

But, but, but...

- ... how to deliver real goods?
- ... don't firms set prices?
- ...can the central bank keep to commitment?
- ...what about dynamic nominal rigidities?
- ...what if reserves provide liquidity?
- ...what if limits to arbitrage between reserves and bonds?

Alternative statements

An indexed-payment-on-reserves process

Definition

An indexed payment-on-reserves monetary-policy process pays the holder of a unit of reserves $1 + x_t$ *times the value of the price index* p_{t+1} *next period.*

Like inflation-indexed bonds, legal framework in place.

Proposition

If the central bank sets the indexed payment on reserves to

$$\left(\frac{1 + r_t}{p_t^*}\right) p_{t+1},$$

the unique price level is $p_t = p_t^*$.

A nominal payment on reserves rule

Definition

A nominal payment-on-reserves monetary-policy process pays the holder of a unit of reserves a nominal amount of drachmas next period; the amount is fixed today.

Proposition

If the central bank sets the nominal payment on reserves to

$$\frac{(1+i_t)p_t}{p_t^*},$$

the unique price level is $p_t = p_t^*$.

Equalizing the return between reserves and bills

$$1 + i_t = 1 + x_t = (1+i_t)\frac{p_t}{p_t^*}.$$

Summary

Process	*Payment*	*Units*	*Known at*	*Real*	*Value*
Real	$\frac{1+r_t}{p_t^*}$	Output	t	$\frac{1+r_t}{p_t^*}$	$\frac{1}{p_t^*}$
Indexed	$\frac{1+r_t}{p_t^*}p_{t+1}$	Drachmas	$t+1$	$\frac{1+r_t}{p_t^*}$	$\frac{1}{p_t^*}$
Nominal	$\frac{1+i_t}{p_t^*}p_t$	Drachmas	t	$\frac{1+i_t}{p_t^*}\frac{p_t}{p_{t+1}}$	$\frac{1}{p_t^*}$

Hypothetical spreads, real and nominal:

$$(1+r_t)\frac{p_t}{p_t^*} - (1+r_t) = (1+r_t)\left(\frac{p_t}{p_t^*} - 1\right)$$

$$\frac{1+i_t}{p_t^*}p_t - (1+i_t) = (1+i_t)\left(\frac{p_t}{p_t^*} - 1\right)$$

General equilibrium and price adjustment

Simple special model

- Representative household maximizes:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t (\log c_t - \ell_t)$$

$$c_t = \left(\int_0^1 c_t(\omega)^{\frac{\gamma-1}{\gamma}} d\omega \right)^{\frac{\gamma}{\gamma-1}}.$$

- Subject to:

$$\begin{aligned} & \int_0^1 p_{t+1}(\omega) c_{t+1}(\omega) d\omega + v_{t+1} + \frac{p_{t+1} k_{t+1}}{1 + r_{t+1}} + \frac{b_{t+1}}{1 + i_{t+1}} \\ \leq \quad & w_{t+1}\ell_{t+1} + z_{t+1} - \tau_{t+1} + p_{t+1}(1 + x_t) v_t + b_t + p_t k_t. \end{aligned}$$

- In equilibrium $c_t = y_t$ and $k_t = b_t = 0$.

The IS relation

- Intratemporal first order conditions:

$$\begin{aligned} p_t c_t &= w_t \\ c_t(\omega) &= c_t(p_t(\omega)/p_t)^{-\gamma} \text{ and } p_t^{1-\gamma} = \int_0^1 p_t(\omega)^{1-\gamma} d\omega \end{aligned}$$

- Intertemporal conditions, with $m_{t,t+1} = \beta c_t / c_{t+1}$

$$\begin{aligned} \mathbb{E}_t \left[m_{t,t+1}(1+r_t) \right] &= 1 \\ \mathbb{E}_t \left[m_{t,t+1} \frac{(1+i_t)p_t}{p_{t+1}} \right] &= 1 \\ \mathbb{E}_t \left[m_{t,t+1}(1+x_t)p_t \right] &= 1. \end{aligned}$$

- The IS curve:

$$E_t \left(\frac{y_t}{y_{t+1}} \right) p_t = \frac{1}{\beta(1+x_t)}.$$

The Phillips curve

- Firms are monopolistic producers that maximize

$$\left(\frac{\gamma}{\gamma-1}\right) p_t(\omega) y_t(\omega) - w_t \ell_t(\omega) \text{ s.t.}$$

$$y_t(\omega) = \ell_t \text{ and } y_t(\omega) = c_t(\omega) = c_t \left(\frac{p_t(\omega)}{p_t}\right)^{-\gamma}$$

- Only fraction λ of firms sets prices to marginal costs (w_t). Remaining $1-\lambda$ set their prices to $E_t(w_{t+1})$:

$$p_{t+1}^{1-\gamma} = \lambda w_{t+1}^{1-\gamma} + (1-\lambda)\,\mathbb{E}_t(w_{t+1}^{1-\gamma})$$

- Combining and rearranging

$$y_{t+1}^{1-\gamma} = \frac{1}{\lambda} - \frac{(1-\lambda)\,\mathbb{E}_t(p_{t+1} y_{t+1})^{1-\gamma}}{\lambda p_{t+1}^{1-\gamma}}$$

A R.E. EQUILIBRIUM

A *rational-expectations equilibrium* is then a solution for the stochastic processes $\{p_t, y_t\}$ as a function of the entire history of the exogenous stochastic process $\{p_t^*\}$, that satisfy:

$$
\begin{aligned}
y_{t+1}^{1-\gamma} &= \frac{1}{\lambda} - \frac{(1-\lambda)\,\mathbb{E}_t(p_{t+1}y_{t+1})^{1-\gamma}}{\lambda p_{t+1}^{1-\gamma}} \\
1 + x_t &= \frac{1}{p_t \beta\,\mathbb{E}_t\left(y_t/y_{t+1}\right)} \\
p_t^*(1+x_t) &= \frac{1}{\beta E_t\left(y_t/y_{t+1}\right)}
\end{aligned}
$$

- There is a unique pair of processes $\{p_t, y_t\}$ that are a RE equilibrium.
- Unexpectedly higher p_{t+1}^* comes with higher y_{t+1} the lower is λ. Shift from consumption to savings.

Recursive equilibrium

- Assume now that x_t is exogenous and that it is iid.

- A *recursive equilibrium* is a pair of functions $\{p(x,\xi), y(x,\xi)\}$ such that the following two equations must hold:
$$\begin{aligned} p(x,\xi) &= \frac{\mathbb{E}(1/y(x',\xi'))^{-1}}{\beta(1+x)y(x,\xi)}, \\ y(x',\xi')^{1-\gamma} &= \frac{1}{\lambda} - \frac{(1-\lambda)\,\mathbb{E}(p(x',\xi')y(x',\xi'))^{1-\gamma}}{\lambda p(x',\xi')^{1-\gamma}}. \end{aligned}$$
The expectations operator is conditional on (x,ξ).

- IS shows that a higher x implies a lower nominal income py. The Phillips curve in the second equation then determines how the higher x is split into higher prices and output separately. This happens uniquely, regardless of ξ.

Central bank financial stability

Central bank solvency

- Can central bank pay interest on reserves while keeping to price level target? Central bank solvency given its resource constraint:

$$v_{t+1} = p_{t+1}[(1 + x_t)v_t - s_{t+1} + d_{t+1}] - b_t + \left(\frac{1}{1 + i_{t+1}}\right) b_{t+1}.$$

- Central bank net worth: $n_t p_t = b_t/(1 + i_t) - v_t$, if kept constant by rebating net income to fiscal authority every period, then:

$$d_{t+1} = s_{t+1} + r_t n + \frac{b_t}{p_t}\left(\frac{p_t}{p_{t+1}} - \frac{1 + r_t}{1 + i_t}\right)$$

Dynamic Models of Nominal Rigidities

Firms set prices

- More general statement of price-level non-neutrality: $r_t(p_t)$. Proposition unchanged:

$$1 + x_t = \frac{1 + r_t(p_t^*)}{p_t^*}$$

- Subtle complication: agents perceive that policymaker thinks that real interest rate is z_t insensitive to prices:

$$p_t = \frac{1 + r_t(p_t)}{1 + z_t} p_t^*.$$

  Maybe multiple solutions. Must do dynamics.

Sticky information

- Dynamic model with $\lambda \in (0,1)$ and $\alpha, \sigma > 0$.

$$\hat{p}_t = \lambda \sum_{j=0}^{\infty} (1-\lambda)^j \mathbb{E}_{t-j}(\hat{p}_t + \alpha \hat{y}_t)$$

$$\hat{y}_t = \mathbb{E}_t(\hat{y}_{t+1}) - \frac{1}{\sigma}\hat{r}_t$$

$$\hat{p}_t - \hat{p}_t^* = \hat{r}_t - \hat{z}_t$$

- Check if sunspot system is explosive

$$\tilde{p}_t = \left[\frac{\frac{(1-\lambda)^t}{\alpha[1-(1-\lambda)^t]} + \frac{1}{\sigma}}{\frac{(1-\lambda)^{t+1}}{\alpha[1-(1-\lambda)^{t+1}]}} \right] \tilde{p}_{t-1} \equiv A_t \tilde{p}_{t-1}$$

Yes, since $A_t > 1$ for any finite t

True for other models too

- Calvo Phillips curve:

$$\tilde{\pi}_t = \beta \mathbb{E}_t(\tilde{\pi}_{t+1}) + \kappa \tilde{y}_t$$

with $\beta \in (0, 1)$ and $\kappa > 0$.

- Backward-looking Phillips curve:

$$\tilde{\pi}_t = \tilde{\pi}_{t-1} + \kappa \tilde{y}_t$$

- Hybrid model with $\phi \in [0, 1]$.

$$\tilde{\pi}_t = \phi \tilde{\pi}_{t-1} + (1 - \phi) \mathbb{E}_t(\tilde{\pi}_{t+1}) + \kappa \tilde{y}_t$$

- For all, payment on reserves leads to determinacy.

Reserves that Provide Liquidity Services

Market for reserves

- Assumption: reserves priced like an other assets. Yes, saturated market, but going forward?
- No arbitrage condition with liquidity services provided by reserves:

$$1 = p_t \, \mathbb{E}_t \left(m_{t,t+1}(v_t/p_t; v_{t+1}/p_{t+1})(1 + x_t) \right) + \phi_t$$

Proposition

With a liquidity premium, if the central bank sets the real payment on reserves to

$$1 + x_t = \frac{(1 + r_t)(1 - \phi_t)}{p_t^*},$$

the unique price level is $p_t = p_t^*$.

Microfoundations?

1. Money-in-the-utility function model

$$\max_{c_t, \frac{v_t}{p_t}, b_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U\left(c_t, \frac{v_t}{p_t}\right)$$

$$\text{s.t.} \quad p_t c_t + \frac{b_t}{1+i_t} + v_t \leq p_t y_t + b_{t-1} + v_{t-1}(1+x_{t-1})p_t,$$

2. Transaction costs model:

$$\max_{c_t, \frac{v_t}{p_t}, b_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(c_t)$$

$$\text{s.t.} \quad p_t c_t(1-\tau(v_t/p_t)) + \frac{b_t}{1+i_t} + v_t \leq b_{t-1} + v_{t-1}(1+x_{t-1})p$$

3. Lagos-Wright (2005) model of money demand to engage in transactions in decentralized market.

All three models fit into proposition

1. Money-in-the-utility function model

$$m_{t+1} = \beta U_c(c_{t+1}, v_{t+1}/p_{t+1})/U_c(c_t, v_t/p_t)$$
$$\phi_t = U_v(c_t, v_t/p_t)/U_c(c_t, v_t/p_t)$$

2. Transaction costs model:

$$m_{t+1} = \beta U_c(c_{t+1}, v_{t+1}/p_{t+1})(1 - \tau(v_{t+1}/p_{t+1}))/U_c(c_t, v_t/p_t)(1$$
$$\phi_t = c_t \tau'(v_t/p_t)$$

3. Search model:

$$m_{t+1} = \beta U'(c_{t+1})/U'(c_t)$$
$$\phi_t = \left(\frac{\sigma\beta}{U'(c_t)}\right) \mathbb{E}_t \left(\frac{u'(q_{t+1}) - e'(q_{t+1})}{g'(q_{t+1})}\right)$$

Segmented Financial Markets

Reserves are special

- Unit of account, never default, and the central bank controls both their quantity as well as their remuneration.
- Also, only financial institutions can hold them.
- Market segmentation and *value premium*:

$$1 = p_t \, \mathbb{E}_t \left(m^b_{t,t+1} (1 + x_t \right)$$

$$1 + \chi_t \equiv \mathbb{E}_t \left(m^b_{t,t+1} \right) (1 + r_t)$$

Proposition

With a reserves value premium, if the central bank sets the real payment on reserves to

$$1 + x_t = \frac{(1 + r_t)}{(1 + \chi_t) p^*_t},$$

the unique price level is $p_t = p^*_t$.

Microfoundations from models of banks

- Costly-state monitoring. Reserves don't need to be monitored. If bank is the financier, monitoring loans, then $\chi_t = 0$. If bank is the entrepreneur, being monitored by depositors, then χ_t is the external-finance spread.

- Limited commitment (Gertler-Kiyotaki). Spread between projects and deposits because of scarce net worth. If creditors can seize reserves, $\chi_t = 0$. If not, then χ_t is the same premium as loans.

- Fiscal default on bonds, banks have access to scarce safe asset. χ_t is both sovereign default premium, and value of safe asset. Maybe zero for US, lots of work on it for Eurosystem.

Multiple interest rates

Interest rates

1. Key is that deposits at the central bank are the unit of account, regardless of floor or corridor, RRP or IOR.

2. Maturity of reserves: 90-days versus overnight

3. Mismeasuring interest rates: if report $1 + r_t = (1 + r_t^e)(1 + \epsilon_t)$, then rule leads to $p_t = p_t^*(1 + \epsilon_t)$.

4. Currency and ZLB: If $\log(c_t) - \ell_t + H(h_t/p_t)$, then have new FOC: $c_t H'(h_t/p_t) \leq \frac{i_t}{1+i_t}$. Therefore, $i_t \geq 0$, so:

$$1 + x_t \geq (1 + r_t)\mathbb{E}_t \left(\frac{m_{t,t+1}}{p_{t+1}^*} \right)$$

Literature and conclusion

Generally

- Boundary conditions (Woodford, 2003, Cochrane, 2016, Barthelemy and Mengus, 2018).
- Arbitrage over multiple periods, just between today and next period, so long-run expectations not as crucial (Garcia-Schmidt and Woodford, 2015, Gabaix, 2016, Barrdear, 2016).
- No linearizations (Benhabib, Schmitt-Grohe, Uribe, 2002, Christiano, Eichenbaum, Johannsen, 2016).
- Liquidity, credit frictions (Cagan, 1956, Schmitt-Grohe, Benhabib, Uribe, 2001, Williamson, 2015).
- Appeal to government budget constraint as an equilibrium project (Sims, 2013)

More specific

- Hall (1997) following Irving Fisher:
  - Proposed making the monetary unit a floating-rate note paying the current real interest rate.
  - Payment-on-reserves process is a more natural policy, relies on existing asset, easier to implement, flexibly allows for an elastic price or inflation standard.

- Adao Correia Teles (2011) and Loisel (2009) rules:

$$i_t = r_t + \mathbb{E}_t(p_{t+1}) - p_t^*$$

Relies on coefficient exactly 1, any deviation fails.

Conclusion

- New monetary policy process: relies on reserves, relies on arbitrage, robust to liquidity, credit, expectational frictions.
- Global uniqueness in three versions, and deviations linked to measurement errors.