The Macroeconomics of Central Bank Issued Digital Currencies

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Disclaimer

The views expressed herein are those of the authors, and should not be attributed to the Bank of England.

1 Introduction

- The emergence of Bitcoin and associated technologies was a watershed moment in the history of 'e-monies'.

- It may, for the first time, be **technically feasible** for central banks to offer universal access to their balance sheet.
  - Existing centralized RTGS systems: Not robust for universal access.
  - New decentralized systems: Can potentially solve this problem.

- Question: Is universal access **economically desirable**?

2 What is a Digital Currency?

- Traditional Electronic Payment Systems - **Tiered** Ledgers:
  - Payment verification by specific third parties.
  - Hierarchical network.

- Digital Currencies - **Distributed** Ledgers:
  - Payment verification by multiple third parties.
  - Peer-to-peer network.

3 What is a Central-Bank Digital Currency (CBDC)?

- **Access to the central bank's balance sheet.**
- **Universal:** Banks, firms and households.
- **Electronic**.
- **National-currency denominated**.
- **Issued against government bonds** (or through spending).
- **Interest-bearing:**
  - To equate demand and supply at 1:1 exchange rate.
  - Second tool of countercyclical monetary policy.
- **Coexisting with the present banking system.**

4 The Model

4.1 Overview

- Based on Benes and Kumhof (2012) and Jakab and Kumhof (2015, 2020).
- The non-monetary model elements are standard.
- Households:
  - Deposits: Created by banks.
  - CBDC: Created by central bank.
  - Deposits and CBDC jointly serve as medium of exchange.
- Government:
  - Fiscal policy.
  - Traditional monetary policy.
  - CBDC monetary policy.

4.2 Banks Overview

- Loans: Bernanke, Gertler and Gilchrist (1999)
  - Difference 1: Pre-committed lending rates $\Rightarrow$ possible losses.
  - Difference 2: Minimum capital adequacy rules (MCAR).
  - Positive net worth: (a) Because of MCAR. (b) As shock absorber.
  - Four different loan types (calibrated to US data).

- Deposits: Schmitt-Grohé and Uribe (2004)
  - Transactions cost technology.
  - Difference: "Money" $=$ bank deposits $+$ CBDC.
  - Four different deposit types (calibrated to US data).

4.3 Wholesale Banks

- **Bank balance sheet:**

$$\check{\ell}_t^{\ell}(i) = \check{d}_t(i) + \check{n}_t^b(i)$$

  - Loans = Deposits + Net Worth.
  - Heterogeneity i reflects idiosyncratic non-credit risks.

- **Capital adequacy regulation:**
  - Penalty $\chi \check{\ell}_t^{\ell}(j)$ at $t+1$ if net worth $< \Upsilon *$ total assets.
  - $\Upsilon =$ minimum Basel ratio (8%).
  - In each period a fraction of banks violates this regulation and pays.

- **Bank optimization problem:** Maximize
  - Returns on loans.
  - Minus cost of deposits.
  - Minus net losses from retail lending banks.
  - Minus penalties on banks that violate Basel.

- **Bank optimality condition**, with spread $r^x_{\ell,t+1} - r_{d,t+1}$:

$$E_t \left\{ r^x_{\ell,t+1} - r_{d,t+1} - spread\left(\Upsilon, \chi, \zeta^x, \mathfrak{F}^b_{t+1}\right)\right\} = 0$$

  – Spread depends on the size of the MCAR, Υ.

  – Spread depends on the penalty coefficient for breaching MCAR, χ.

  – Spread depends on risk weights ζ^x.

  – Spread depends on the riskiness of banks, $F^b\left(\bar{\omega}^b_{t+1}\right)$ and $f^b\left(\bar{\omega}^b_{t+1}\right)$.

4.4 Retail Lending Banks (BGG)

- **Loan Contract ($x \in \{c, a, y, k\}$):**
  - Nominal loan amount $L_t^x(i)$.
  - Unconditional nominal lending rate $i_{r,t}^x$, payable if no default.
  - Willingness-to-lend coefficients $\kappa_t^{xr} \neq 1$ and $\kappa_t^{xr}\kappa_t^{xf} \neq 1$.
  - Collateral:
    * Real stocks: Capital, land.
    * Real flows: Output, labor income.
    * Financial stocks: Bank deposits, CBDC.

- **Retail lending banks' ex-ante zero profit conditions** (as in BGG):

$$E_t \left\{ r_{\ell,t+1} \ell_t^x(j) - \left[\left(1 - \mathfrak{F}_t(\bar{\omega}_{t+1}^x) \right) r_{r,t+1}^x \ell_t^x(i) \right.\right.$$

$$\left.\left. + (1 - \xi^x) \int_0^{\bar{\omega}_{t+1}^x} \mathfrak{c}_t^x(i) \omega^x \mathfrak{f}_t^x(\omega^x) d\omega^x \right] \right\} = 0$$

- **Incorporated into household optimization problem.**

4.5 Households

$$E_0 \sum_{t=0}^{\infty} \beta_c^t \left\{ S_t^c (1 - \frac{v}{x}) \log(c_t^c(i) - v c_{t-1}^c) - \psi_h \frac{h_t^c(i)^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} + \psi_a \log(a_t(i)) \right\}$$

- Adjustment costs:
  - **Financial assets**:
    - 2bp per 1pp increase in government debt-to-GDP.
    - Laubach (2009).
  - **Prices and wages**:
    - Inflation adjustment costs.
    - Ireland (2001).
  - **Physical investment**:
    - Cost on rate of change of investment.
    - Christiano, Eichenbaum and Evans (2005).
  - **Monetary friction**:
    - Transactions cost technology.
    - Schmitt-Grohe and Uribe (2004).

- SGU (2004) TA Cost Technology:

$$s_t^x(i) = s_t^x\left(v_t^x(i)\right) = S_t^{md} A_x v_t^x(i) + \frac{B_x}{v_t^x(i)} - 2\left(A_x B_x\right)^{\frac{1}{2}}$$

- S_t^{md} = shock to demand for total liquidity = “flight to safety”.

- $v_t^x(i)$ = velocity (next page).

- Velocity:

$$v_t^x(i) = \frac{e_t^x(i)}{f_t^x(i)}$$

- $e_t^x(i) =$ sector-specific expenditure:
  - Consumption.
  - Investment.
  - Factor payments.
  - Real estate.

- $f_t^x(i) =$ sector-specific monetary transaction balances:

$$f_t^x = \left((1-\gamma)^{\frac{1}{\epsilon}} \left(Deposits_t^x\right)^{\frac{\epsilon-1}{\epsilon}} + \gamma^{\frac{1}{\epsilon}} \left(CBDC_t^x\right)^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}}$$

- Monetary Distortion Markups = Liquidity Taxes:

$$\tau_{x,t}^{\ell iq} = 1 + s_t^x + s_t^{x\prime} v_t^x$$

  - Their effects are equivalent to consumption and capital income taxes.

- What is the Distortion?

  - Shortage, relative to the Friedman rule, of liquidity.

  - This can never be completely eliminated because the cost of creating bank deposits can never go to zero.

- Consumption FOC:

$$\frac{S_t^c(1-\frac{v}{x})}{\check{c}_t^c - \frac{v}{x}\check{c}_{t-1}^c} = \check{\lambda}_t^c\left(1+\tau_{c,t}\right)\left(1+s_t^c+s_t^{c'}v_t^c\right)$$

  - Monetary wedge $1+s_t^c+s_t^{c'}v_t^c$.
  - Monetary wedge equivalent to a consumption tax.
  - Similar wedges for:
    * Investment.
    * Factor inputs.
    * Land.

- Capital FOC:

$$\check{\lambda}_t^c = \frac{\beta_c}{x} E_t \left\{ \check{\lambda}_{t+1}^c ret_{k,t+1} \left[\left(1 - \kappa_t^{kr} \Gamma_{k,t+1} \right) + \tilde{\lambda}_{t+1}^k \kappa_t^{kr} \left(\Gamma_{k,t+1} - \xi^k G_{k,t+1} \right) \right] \right\}$$

  - Collateral wedge $\left(1 - \kappa_t^{kr} \Gamma_{k,t+1} \right) + \tilde{\lambda}_{t+1}^k \kappa_t^{kr} \left(\Gamma_{k,t+1} - \xi^k G_{k,t+1} \right)$.
  - Similar wedges for:
    * Land (used as collateral).
    * Phillips curve (output used as collateral).
    * Hours worked (labor income used as collateral).
    * Deposits (used as collateral).
    * CBDC (used as collateral).

4.6 Financial Investors

$$E_0 \sum_{t=0}^{\infty} \beta_u^t \left\{ S_t^c (1 - \frac{v}{x}) \log(c_t^u(i) - \nu c_{t-1}^u) - \psi_h \frac{h_t^u(i)^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} + \psi_f \frac{\left(\frac{f_t^u(i)}{T_t}\right)^{1-\frac{1}{\vartheta}}}{1-\frac{1}{\vartheta}} \right\}$$

- Common parameters v, η, ψ_h are identical to those of households.
- Liquidity in utility:
  - To calibrate a very high interest semi-elasticity of deposit demand.

- Key financial investor FOCs:
  - Government bonds:

$$\check{\lambda}_t^u \left(1 + \phi_b \left(b_t^{rat} - \bar{b}_{ss}^{rat}\right)\right) = \frac{\beta_u}{x} E_t \left(\check{\lambda}_{t+1}^u r_{t+1}\right)$$

    * Small elasticity of real policy rate w.r.t. bond stock.
    * Bond stock affected by CBDC issuance.
  - Bank deposits:

$$\check{\lambda}_t^u \left(1 + \phi_b \left(b_t^{rat} - \bar{b}_{ss}^{rat}\right)\right) - \psi_f \left(\check{f}_t^u\right)^{-\frac{1}{\vartheta}} f_t^{u'dep} = \frac{\beta_u}{x} E_t \left(\check{\lambda}_{t+1}^u r_{d,t+1}\right)$$

  - High elasticity of deposits w.r.t. real deposit rate.
  - Ensures a fairly constant spread between deposit and policy rates.

- CBDC enters like government debt.
- But it is much cheaper.

4.7 Fiscal Policy

4.7.1 Government Budget Constraint

$$b_t^g + m_t^g = r_t b_{t-1}^g + r_{m,t} m_{t-1}^g + g_t + trf_t - \tau_t$$

4.7.2 Fiscal Policy Rule

- Overall Deficit Ratio:

$$gdx_t^{rat} = 100\frac{g\check{d}x_t}{g\check{d}p_t} = 100\frac{B_t^g + M_t^g - B_{t-1}^g - M_{t-1}^g}{GDP_t}$$

  - **Relevant stock change: Government Debt + CBDC.**
  - Insulates budget from potentially highly volatile CBDC seigniorage flows.

- Rule for Deficit Ratio (automatic stabilizers):

$$gdx_t^{rat} = gdx_{ss}^{rat} - 100d^{gdp}\ln\left(\frac{g\check{d}p_t}{gdp_{ss}}\right)$$

4.8 Monetary Policy - The Policy Rate

$$i_t = (i_{t-1})^{i_i} \left(i_{steady\ state}\right)^{(1-i_i)} \left(\frac{\pi^p_{4,t+3}}{\left(\pi^p_{tgt}\right)^4}\right)^{\frac{(1-i_i)i_{\pi^p}}{4}}$$

- This is a standard forward-looking Taylor rule with interest rate smoothing.

4.9 Monetary Policy - CBDC

- Why not target monetary aggregates? The 1980s debate versus CBDC.

- Three arguments against targeting monetary aggregates:
  1. Problems in defining the relevant aggregate: Does not apply to CBDC.
  2. Problems in controlling the aggregate: Does not apply to CBDC.
  3. Lower benefits of controlling the aggregate: Poole (1970).
     - Volatility increases if money demand shocks are important.
     - Does apply, but much more weakly than in Poole (1970).
     - Reason: Banks remain the creators of the marginal unit of money.

- To study the third argument, we need to define CBDC policy rules.

4.9.1 Quantity Rule for CBDC

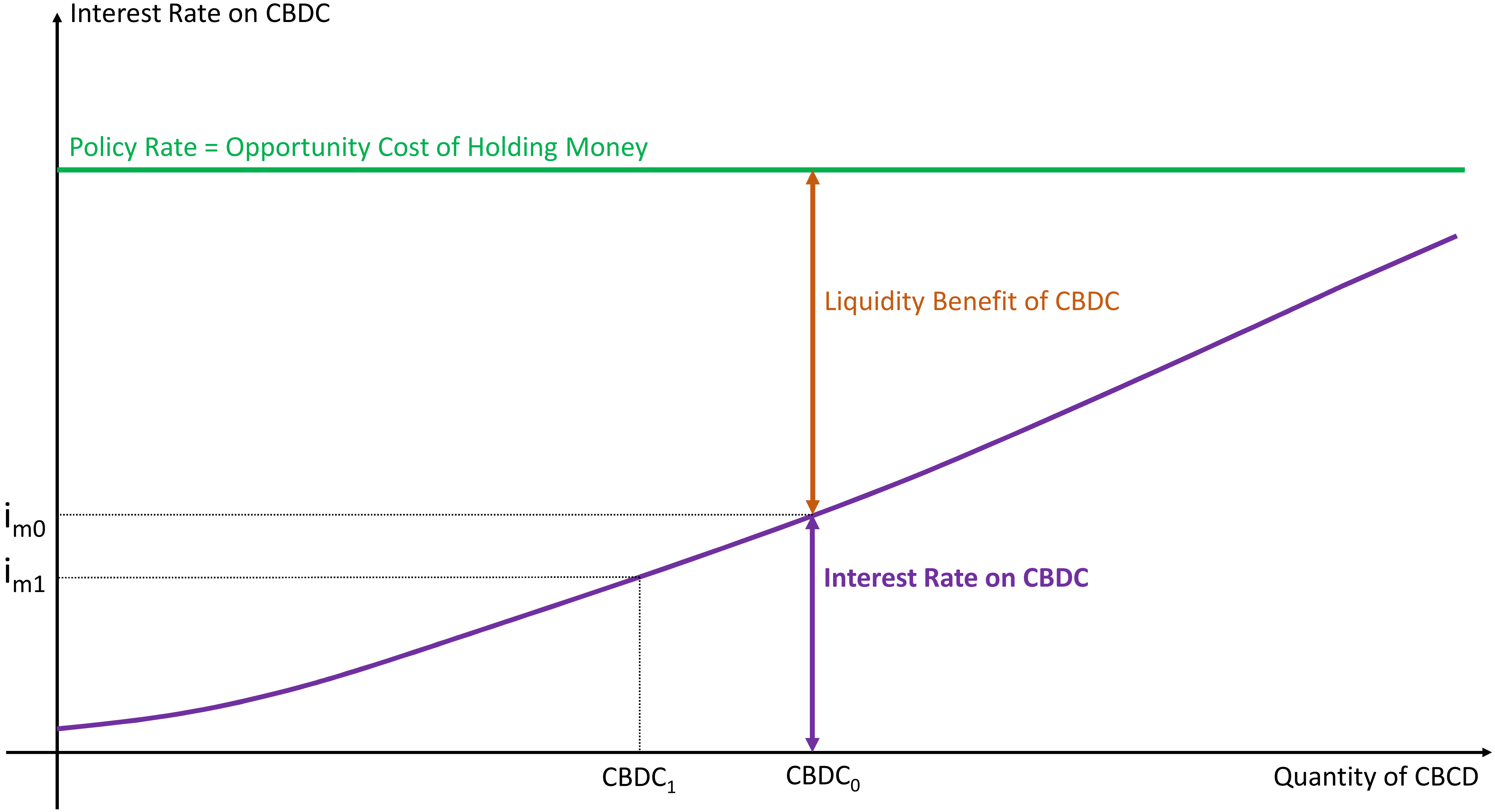
$$m_t^{rat} = m_{tgt}^{rat} S_t^{ms} - 100 m_{\pi^p} E_t \ln\left(\frac{\pi_{4,t+3}^p}{\left(\pi_{tgt}^p\right)^4}\right)$$

- Fix the quantity of CBDC, let CBDC interest rate clear the market.
- $m_{\pi^p} > 0$: Removes CBDC from circulation in a boom.

4.9.2 Price Rule for CBDC

$$i_{m,t} = \frac{i_t}{\mathfrak{sp}} \left(\frac{\pi_{4,t+3}^p}{\left(\pi_{tgt}^p\right)^4}\right)^{-i_{\pi^p}^m}$$

- Fix interest rate on CBDC, let the quantity of CBDC clear the market.
- $i_{\pi^p}^m > 0$: Makes CBDC less attractive in a boom.



Interest Rate on CBDC
Policy Rate = Opportunity Cost of Holding Money
Liquidity Benefit of CBDC
Interest Rate on CBDC
i_{m0}
i_{m1}
$CBDC_1$
$CBDC_0$
Quantity of CBCD

5 Steady State Effects of the Transition to CBDC

- Assumptions:
  - Issue CBDC against government debt.
  - Magnitude: 30% of GDP.

- Results:

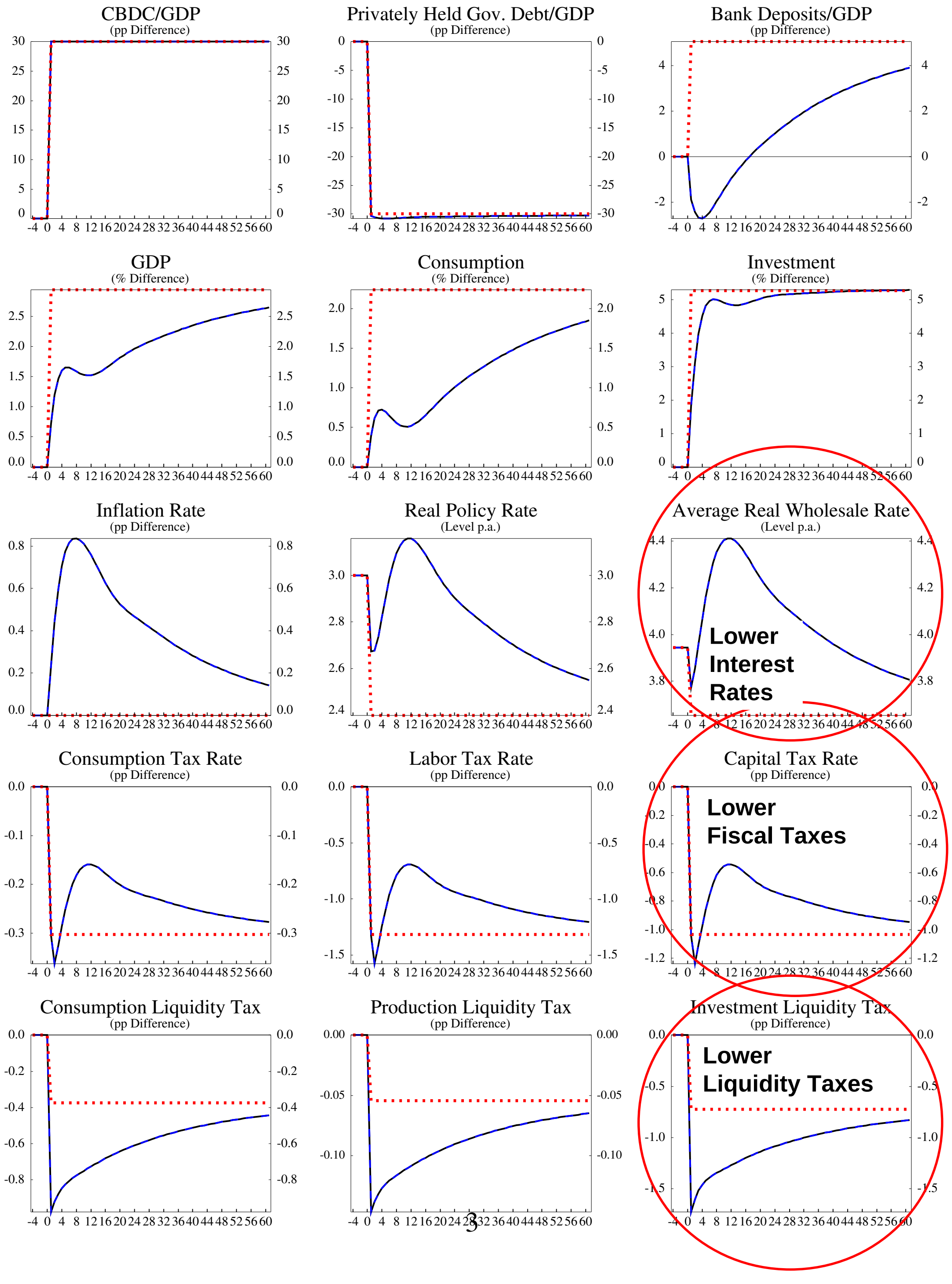
	Steady State Output Effect
1. Lower Real Policy Rates	+1.8%
2. Higher Deposit Rates Relative to Policy Rates	-0.9%
3. Reductions in Fiscal Tax Rates	+1.1%
4. Reductions in Liquidity Tax Rates	+0.9%
Total	+2.9%

Reasons for Steady State Output Gains

1. **Lower real interest rates:**
   - Assumption: CBDC issued against government debt.
   - CBDC is not defaultable, government debt is.
   - CBDC carries a lower interest rate than government debt.

2. **Lower fiscal tax rates:**
   - Much larger central bank balance sheet.
   - Therefore much larger seigniorage flows.
   - Assumption: Seigniorage is used to reduce distortionary taxes.

3. **Lower liquidity tax rates:**
   - Modern money is 95%+ created by private banks.
   - This is costly: Spreads, regulation, bank market power, collateral.
   - CBDC can significantly reduce these costs.
   - Result: Greater money supply at reduced cost.

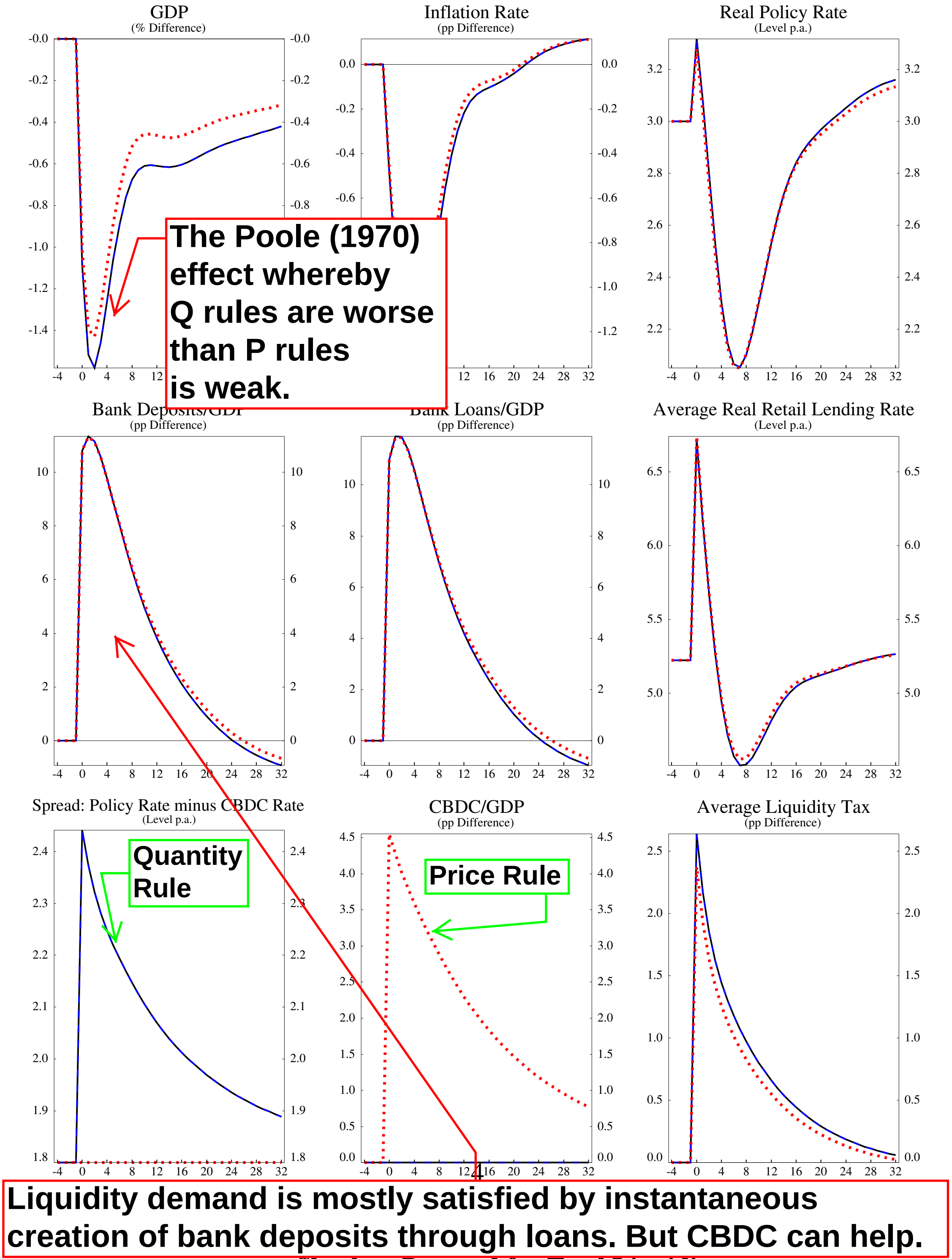


Transition to Steady State with CBDC

solid line = actual transition ; dotted line = change in long-run steady state

6 Quantity Rules or Price Rules for CBDC

A Poole (1970) contractionary money demand shock.

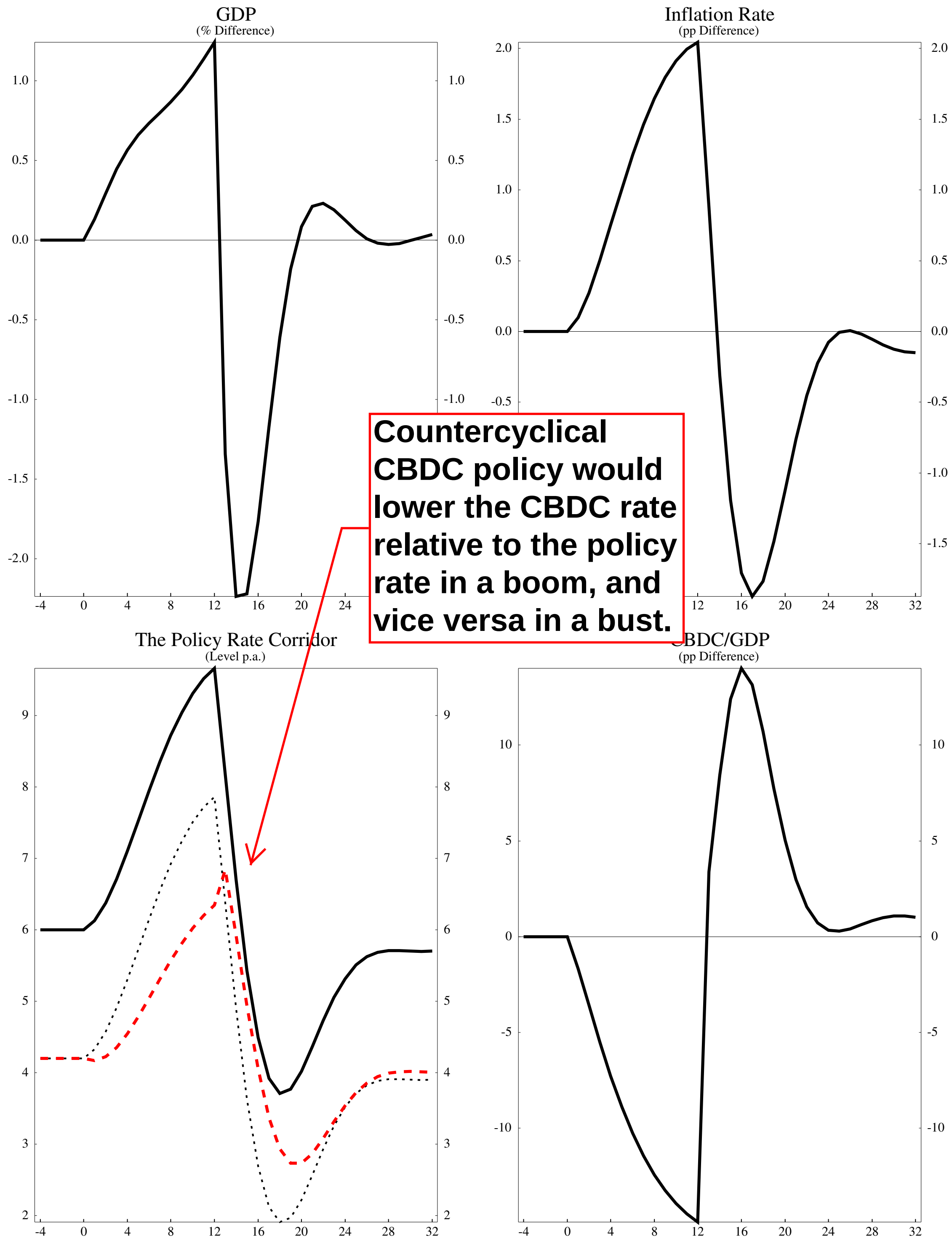


Shock to Demand for Total Liquidity

solid line = quantity rule ; dotted line = price rule

7 Countercyclical CBDC Rules

A Christiano-Motto-Rostagno (2014) boom-bust credit cycle.

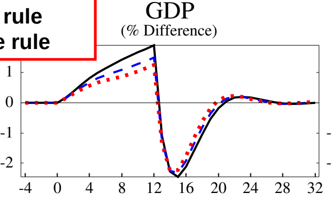


Credit Cycle Shock - Price Rule - Policy Rate Corridor

Bottom Left: Nominal Policy and CBDC Rates

Solid Line = Policy Rate, Dotted Line = Policy Rate minus Fixed Spread, Dashed Line = CBDC Rate

- Solid line = fixed rule
- Dashed line = c'cyclical rule
- Dotted line = aggressive rule



8 Financial Stability: CBDC Bank Runs?

- Our proposed issuance arrangements are key.
- They make deposits-to-CBDC runs very difficult **in aggregate**. 2 reasons:
  1. Aggregate increases in CBDC demand do not affect bank deposits:
     - Central bank sells CBDC only against government debt.
     - **Not** against bank deposits: No unconditional LoLR guarantee.
     - CBDC purchases among non-banks are irrelevant for deposits.
  2. CBDC policy rules can further discourage volatile CBDC demand.
     - Quantity rule:
       * CBDC supply fixed, CBDC interest rate clears the market.
       * **Lower political bound on CBDC rate?** Switch to price rule.
     - Price rule:
       * CBDC supply endogenous, CBDC quantity clears the market.
       * **Running out of government bonds?** Switch to other securities.

9 Conclusions

1. Steady state efficiency:
   - Lower interest rates, higher seigniorage, more and cheaper liquidity.
   - Increase in steady-state GDP could be as much as 3%.

2. Business cycle stability:
   - Second policy instrument.
   - Improved ability to stabilize inflation and the business cycle.

3. Financial stability:
   - CBDC should reduce many financial stability risks.
   - But if it is not designed well it may introduce others.
   - The “run risk” can be mostly eliminated by sound system design.

- Critical issue: Design of a smooth transition.

THANK YOU