# 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 the distributed ledger technology (DLT) and of Bitcoin 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 DLT systems: Can potentially solve this problem.

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

# 2 What is a Digital Currency?

- Traditional electronic payment systems:
  - **Tiered** ledgers:
    - Payments are routed through and verified by specific third parties.
    - Third parties arranged in a hierarchical network.
  - Third parties hold deposits on behalf of end users.
  - Third parties are critical to the operation of the system.
- Digital currencies:
  - **Distributed** ledgers:
    - Payments are peer-to-peer and verified by multiple verifiers.
    - Verifiers arranged in a peer-to-peer network.
  - Transaction verifiers do not hold deposits on behalf of end users.
  - Transaction verifiers are not critical to the operation of the system.
- Bitcoin:
  - Combines a distributed ledger with an alternative monetary system.
  - CBDC in BoE research:
    - Rejects the monetary system of Bitcoin.
    - Takes inspiration from its payment system.

# Maintaining the Ledger

- Arriving at a consensus over the contents of the ledger is critical.
- In a permissionless system like Bitcoin (where entry is open), suggested additions to the ledger are **cheap talk**: Costless, non-binding and unverifiable.
- Cryptocurrencies (e.g. Bitcoin) make proposed changes costly:
  - Through a proof-of-work system:
    - Winner-takes-all.
    - Probability of winning increases in individual computing power.
    - Probability of winning decreases in aggregate computing power.
  - Result:
    - Negative externality: Too much investment in computing power.
    - O'Dwyer and Malone (2014): Bitcoin, in 2014, consumed 5GW.
    - As much electricity as the entire country of Ireland.
    - Deetman (2016): By 2020, it could be 15GW.
- A permissioned system (e.g. CBDC) makes proposed changes binding:
  - Transaction verifiers are regulated to ensure veracity.
  - Trust in central party replaces proof-of-work system.

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

- **Access to the central bank's balance sheet.**
- **Availability:** 24/7.
- **Universal:** Banks, firms and households.
- **Electronic:** For resiliency reasons, probably using DLT.
- **National-currency denominated:** 1:1 exchange rate.
- **Issued only through spending or against eligible assets:** Government bonds.
- **Interest-bearing:**
  - To equate demand and supply at 1:1 exchange rate.
  - Second tool of countercyclical monetary policy.
- **Coexisting with present banking system:**
  - Banks remain the creators of the marginal unit of domestic currency.
  - The vast majority of deposits would remain with banks, and be insured.
  - Credit provision would remain the purview of existing intermediaries.

# 4 The Model

## 4.1 Overview

- Based on Benes and Kumhof (2012) and Jakab and Kumhof (2015).
- Households:
  - Deposits: Obtained through bank loans.
  - CBDC: Obtained in exchange for government debt.
  - Deposits and CBDC jointly generate liquidity.
- Banks: Create new deposits by making new loans.
- Government:
  - Fiscal policy.
  - Traditional monetary policy.
  - CBDC monetary policy.

## 4.2 Endogenous Deposits and Exogenous CBDC

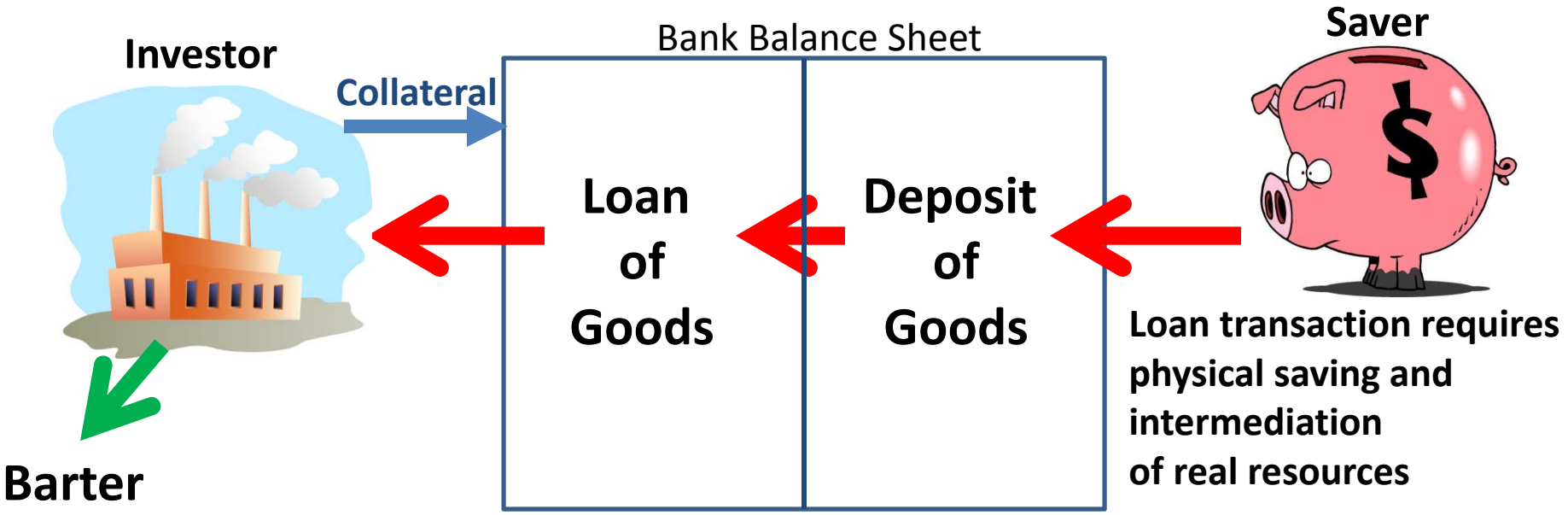
- Sidrauski-Brock monetary models of the 1980s/1990s:
  1. Representative household with a demand for money.
  2. Government exogenously supplies **all** money.

- The main problem is 2, not 1. Therefore, in our model:
  - Bank deposits (97% of all money) enter into TA cost technology.
  - Government money is omitted entirely.
  - Incorrect assumption: New bank deposits are deposited by non-banks.
  - Correct assumption: New bank deposits are created through new loans.

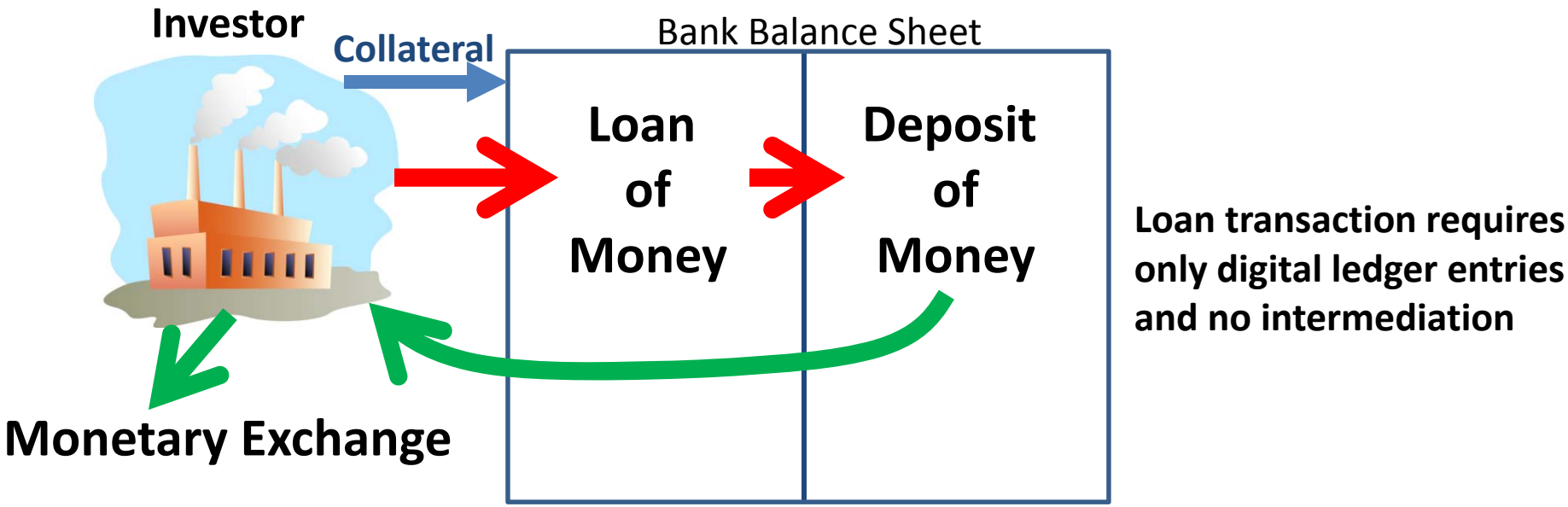
- CBDC puts exogenous government money back into the model. But:
  1. CBDC is universally accessible (unlike reserves).
  2. CBDC is interest-bearing (unlike cash).
  3. CBDC competes with bank deposits.

# Intermediation of Loanable Funds (ILF) versus Financing Through Money Creation (FMC)

## Intermediation of Loanable Funds Model




## Financing Through Money Creation Model



**Deposits and loans are predetermined variables**

# Key Difference ILF-FMC: Budget Constraints

- Budget Constraints in ILF Model: Saver + Borrower Household
  - Saver Household

$$\Delta deposits_t^s = income_t^s - spending_t^s$$

  - Borrower Household

$$-\Delta loans_t^b = income_t^b - spending_t^b$$

- Budget Constraint in FMC+CBDC Model: Representative Household only

$$\Delta deposits_t^r - \Delta loans_t^r + \Delta CBDC_t^r = income_t^r - spending_t^r$$

**Deposits and loans are jump variables**

## 4.3 Banks

- Loans: Bernanke, Gertler and Gilchrist (1999)
  - Costly state verification.
  - Difference: Pre-committed lending rates.

- Deposits: Schmitt-Grohé and Uribe (2004)
  - Transactions cost technology.
  - Difference: "Money" = bank deposits + CBDC.
  - Monetary Distortion = Liquidity Taxes:

$$\tau_t^{liq} = 1 + s_t + s_t' v_t$$

  - **Equivalent to consumption taxes and capital income taxes.**
  - **Banks' effect on the real economy:**
    - **Through these taxes.**
    - **Not through intermediation of "loanable funds".**

## 4.4 The Liquidity-Generating Function (LGF)

- Combines the liquidity generated by bank deposits and CBDC.
- Functional form:

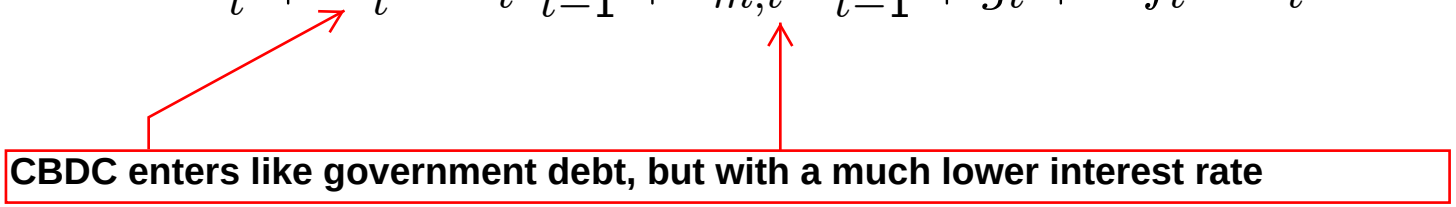
$$f_t^x = \left( (1-\gamma)^{\frac{1}{\epsilon}} \left(Deposits_t\right)^{\frac{\epsilon-1}{\epsilon}} + \gamma^{\frac{1}{\epsilon}} \left(T^{fintec} CBDC_t\right)^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}}$$

- Market clearing: Interest rates on loans, deposits and CBDC adjust.

## 4.5 Fiscal Policy

### 4.5.1 Government Budget Constraint

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



### 4.5.2 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:

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

## 4.6 Monetary Policy - The Policy Rate

$$i_t = (i_{t-1})^{i_i} \left( \frac{x\pi^p_{tgt} \left(1 + \phi_b \left(b^{rat}_t - \bar{b}^{rat}\right)\right)}{\beta_u} \right)^{(1-i_i)} \left( \frac{\pi^p_{4,t+3}}{\left(\pi^p_{tgt}\right)^4} \right)^{\frac{(1-i_i)i_{\pi^p}}{4}}$$

## 4.7 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.
     - This argument does apply in our model, 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.

### 4.7.1 Quantity Rule for CBDC

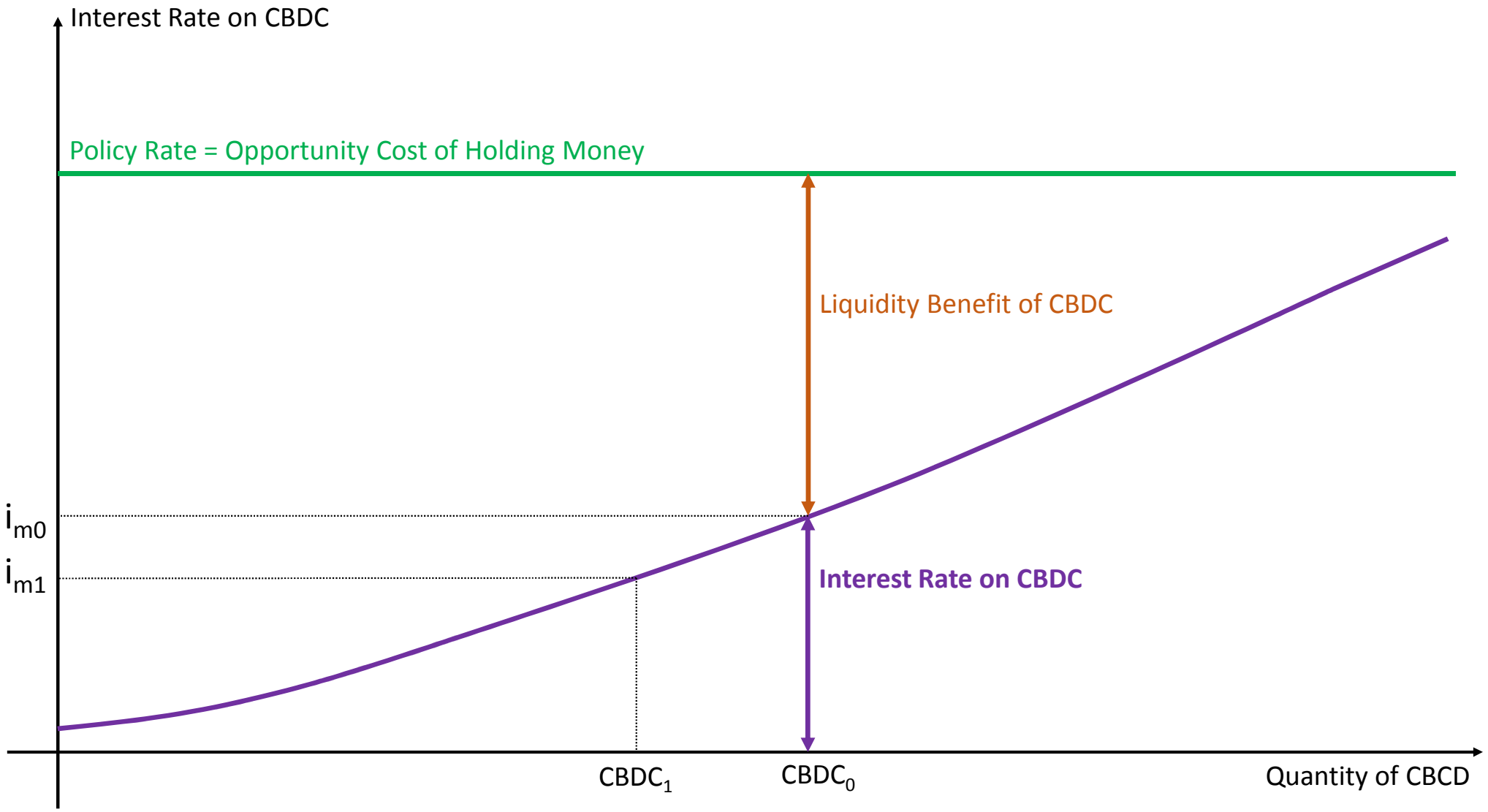
$$m_t^{rat} = m_{tgt}^{rat} S_t^{ms} - 100 m_{\pi^p} E_t \ln \left( \frac{\pi^p_{4,t+3}}{\left(\pi^p_{tgt}\right)^4} \right)$$

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

### 4.7.2 Price Rule for CBDC

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

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


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

## 4.8 Implications for the ZLB

- What happens as you approach the ZLB from above?

- Key observations:
  - This means you are in a slump and want to stimulate the economy.
  - The CBDC interest rate would hit the ZLB first.
  - The CBDC interest rate is a rate on money.
  - To stimulate the economy, the rate on money must **rise**.

- Implication: Optimal CBDC policy would drive you away from the ZLB.

- It makes no sense to sell CBDC as a way to pay negative interest rates.

# 5 Steady State Effects of the Transition to CBDC

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

- Results:

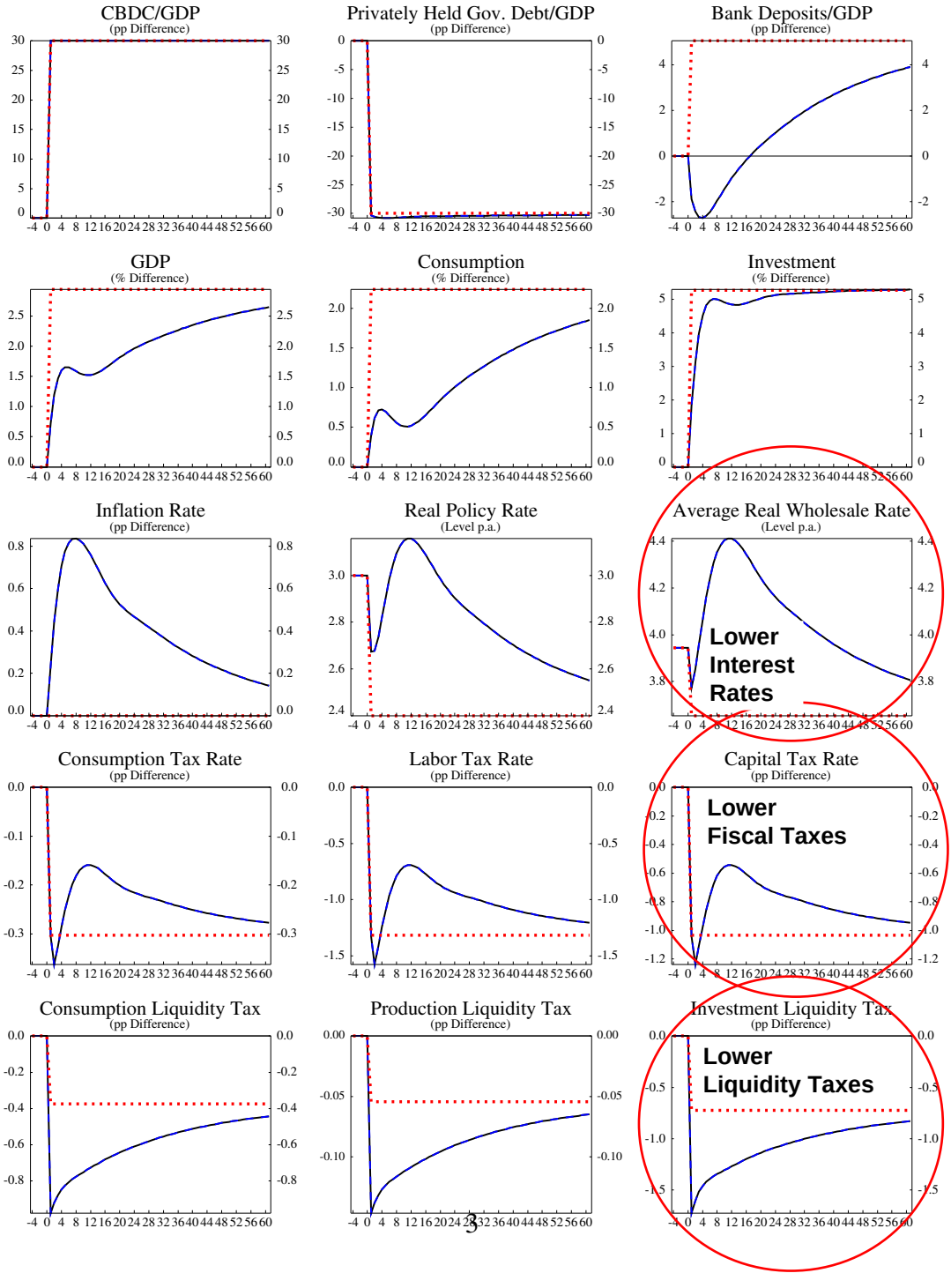
| | **Steady State Output Effect** |
|---|---|
| 1. Lower Real Policy Rates | +1.8% |
| 2. Higher Deposit Rates Relative to Policy Rates | -0.9% |
| 3. Reductions in Fiscal Tax Rates | +1.1% |
| 4. Reductions in Liquidity Tax Rates | +0.9% |
| **Total** | +2.9% |

# The Main Factors Explained

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 distortionary taxes:**
   - Much larger central bank balance sheet.
   - Therefore much larger seigniorage flows.
   - Also: Lower interest costs (see above).
   - Assumption: Seigniorage is used to reduce distortionary taxes.

3. **Lower transactions costs:**
   - Modern money is 95%+ created by private banks.
   - This is costly: Spreads, regulation, bank market power, collateral.
   - You can therefore never reach the Friedman rule.
   - But with CBDC you can get much closer.

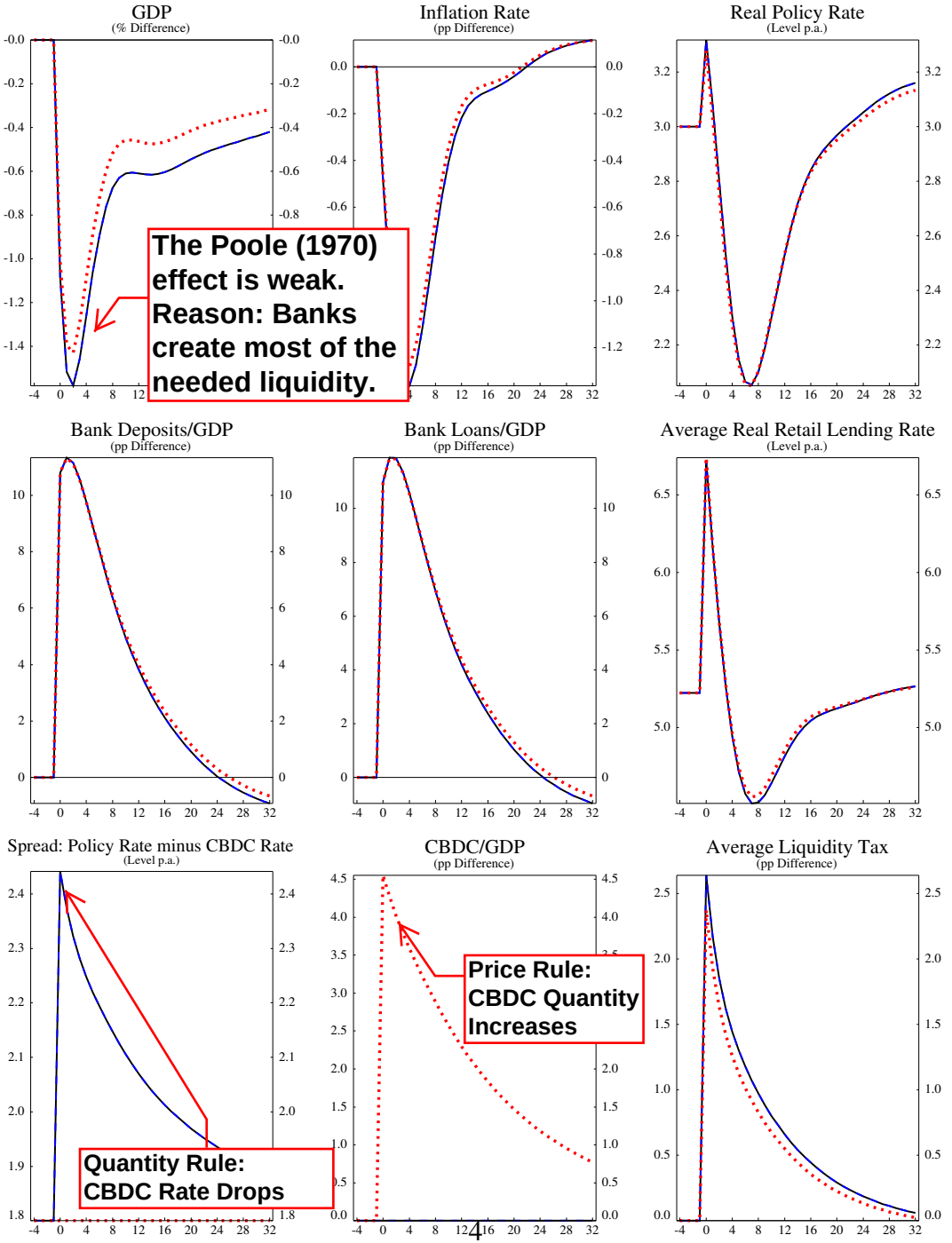





**Transition to Steady State with CBDC**

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

# 6 Quantity Rules or Price Rules for CBDC?





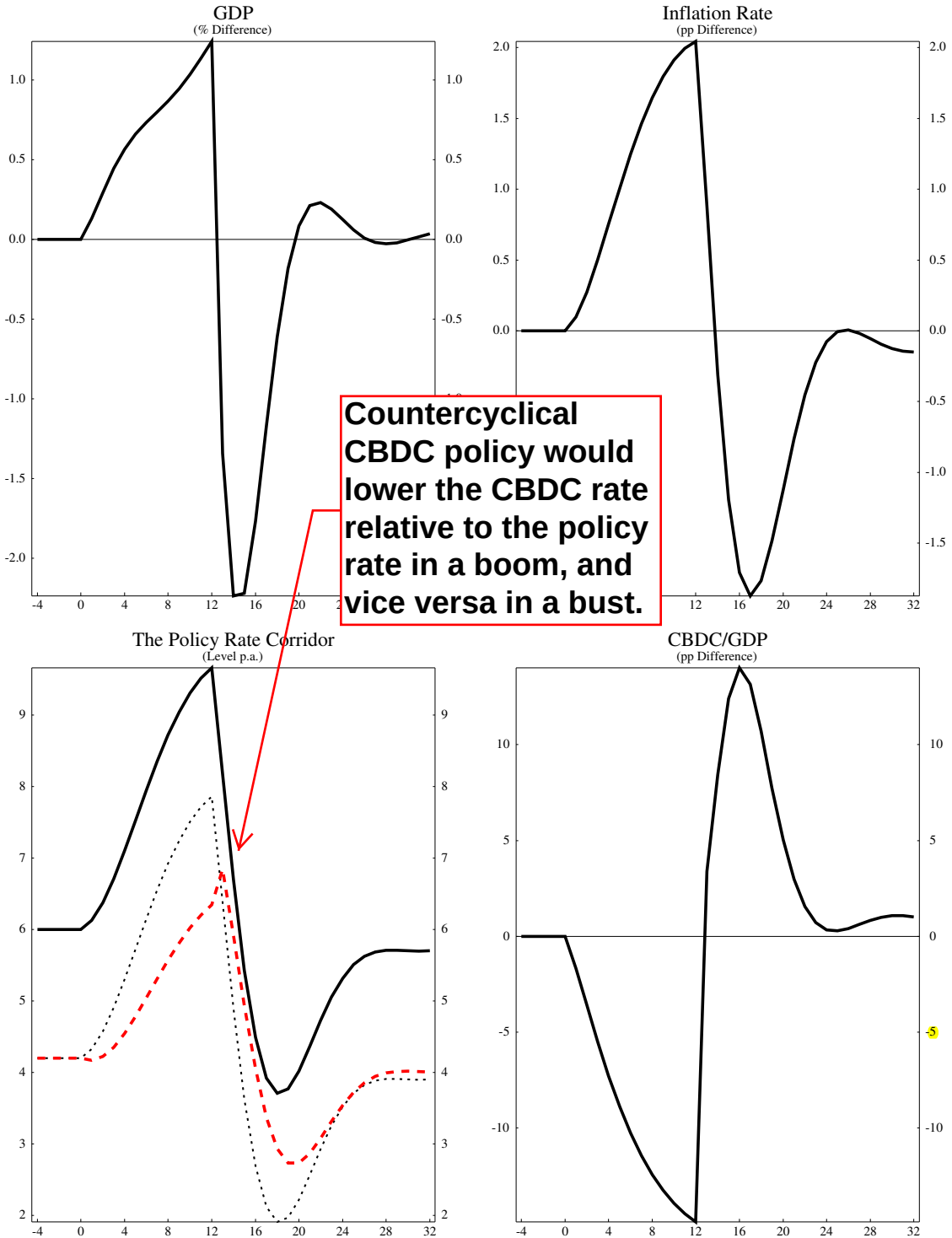

**Shock to Demand for Total Liquidity**

solid line = quantity rule ; dotted line = price rule

# 7 Financial Stability: CBDC Bank Runs?

- There is no easy way to run from bank deposits to CBDC **in aggregate**.
- Two reasons:
  1. Aggregate increases in CBDC demand do not affect bank deposits:
     - Central bank sells CBDC only against government debt.
     - **Not** against bank deposits.
     - CBDC purchases among non-banks are irrelevant.
  2. CBDC policy rules can further discourage volatile CBDC demand.

# 8 Countercyclical CBDC Rules

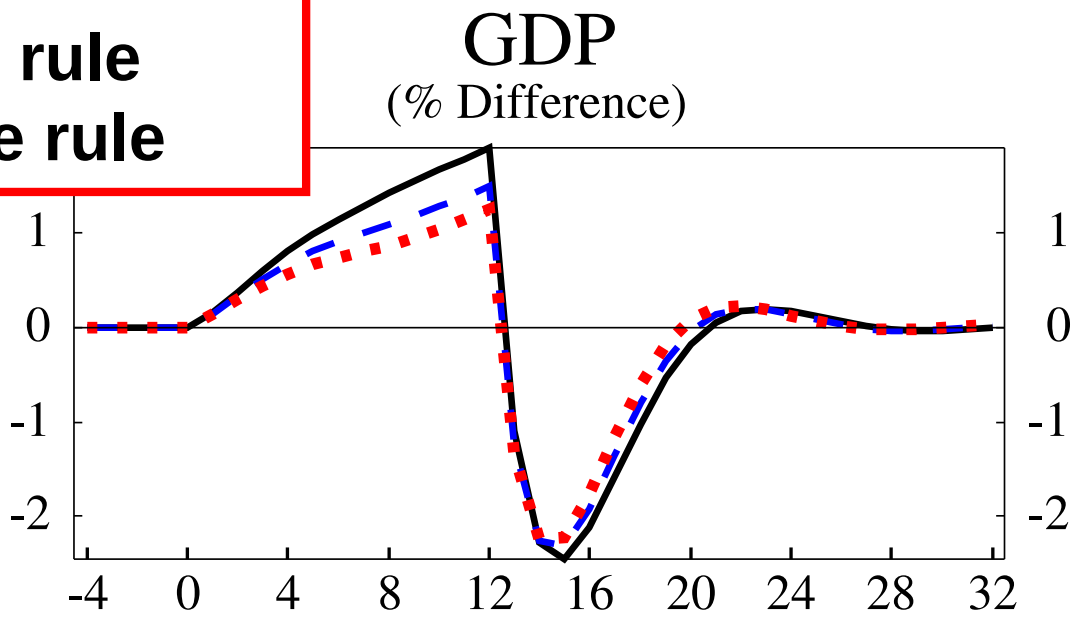



**Credit Cycle Shock - Price Rule - Policy Rate Corridor**

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



# 9 Conclusions

- CBDC has significant benefits $\Longrightarrow$ further research is worthwhile.
- Increase in steady-state GDP could be as much as 3%.
- Improved ability to stabilize inflation and the business cycle.
- Should reduce some FS risks, but may introduce others.
- The design of a successful transition is the critical issue.