A Macroeconomic Model of Central Bank Digital Currency

Pascal Paul[1] Mauricio Ulate[1] Cynthia Wu[2]

[1]Federal Reserve Bank of San Francisco

[2]University of Illinois Urbana-Champaign and NBER

October 1, 2024
Bundesbank Conference

The views expressed herein are solely those of the authors and do not necessarily reflect the views of the Federal Reserve Bank of San Francisco or the Federal Reserve System.

Motivation

- Introduction of Central Bank Digital Currency (CBDC) for retail consumers one of the most far-reaching innovations in central banking

- 11 countries have adopted a CBDC; 19 of G20 economies explore the topic → "Digital Euro"

Research Questions:

1. Is the introduction of a CBDC beneficial for an economy as a whole?

2. What's the optimal interest rate on CBDC, and how does it vary with the level of rates?

3. How does the presence of a CBDC affect the conduct of monetary policy?

This paper: Propose new general equilibrium model with realistic banking sector that is closely calibrated to empirical evidence

Motivation

- Introduction of Central Bank Digital Currency (CBDC) for retail consumers one of the most far-reaching innovations in central banking
- 11 countries have adopted a CBDC; 19 of G20 economies explore the topic $\rightarrow$ "Digital Euro"

Research Questions:

1. Is the introduction of a CBDC beneficial for an economy as a whole?
2. What's the optimal interest rate on CBDC, and how does it vary with the level of rates?
3. How does the presence of a CBDC affect the conduct of monetary policy?

This paper: Propose new general equilibrium model with realistic banking sector that is closely calibrated to empirical evidence

Motivation

- Introduction of Central Bank Digital Currency (CBDC) for retail consumers one of the most far-reaching innovations in central banking
- 11 countries have adopted a CBDC; 19 of G20 economies explore the topic → "Digital Euro"

Research Questions:

1. Is the introduction of a CBDC beneficial for an economy as a whole?
2. What's the optimal interest rate on CBDC, and how does it vary with the level of rates?
3. How does the presence of a CBDC affect the conduct of monetary policy?

This paper: Propose new general equilibrium model with realistic banking sector that is closely calibrated to empirical evidence

Outline & Results

1. **Static Partial Equilibrium Model**
   - Cash, deposits & CBDC provide HHs with liquidity benefits ⇒ imperfectly substitutable
   - Banks have market power in deposit markets ⇒ determines deposit spread
   - Result: CBDC competes with bank deposits, especially if i^{CBDC} close to i^{policy}

2. **Dynamic General Equilibrium Model** → New-Keynesian DSGE
   - Loan & bond markets, financial frictions → bank capital determines credit supply
   - CBDC: (+) liquidity benefits, (+) curtails market power, (-) credit disintermediation
   - Result #1: Welfare change displays inverted U-shape w.r.t CBDC rate i^{CBDC}
   - Result #2: Optimal $i^{CBDC} \approx max(0\%, i^{policy} - 1\%)$, large gains at high i^{policy}
   - Result #3: Responses to transitory macro-shocks largely unaffected

Outline & Results

1. **Static Partial Equilibrium Model**
   - Cash, deposits & CBDC provide HHs with liquidity benefits $\Rightarrow$ imperfectly substitutable
   - Banks have market power in deposit markets $\Rightarrow$ determines deposit spread
   - Result: CBDC competes with bank deposits, especially if i^{CBDC} close to i^{policy}
2. **Dynamic General Equilibrium Model** $\rightarrow$ New-Keynesian DSGE
   - Loan & bond markets, financial frictions $\rightarrow$ bank capital determines credit supply
   - CBDC: (+) liquidity benefits, (+) curtails market power, (-) credit disintermediation
   - Result #1: Welfare change displays inverted U-shape w.r.t CBDC rate i^{CBDC}
   - Result #2: Optimal $i^{CBDC} \approx max(0\%, i^{policy} - 1\%)$, large gains at high i^{policy}
   - Result #3: Responses to transitory macro-shocks largely unaffected

Outline & Results

1. **Static Partial Equilibrium Model**
   - Cash, deposits & CBDC provide HHs with liquidity benefits $\Rightarrow$ imperfectly substitutable
   - Banks have market power in deposit markets $\Rightarrow$ determines deposit spread
   - Result: CBDC competes with bank deposits, especially if i^{CBDC} close to i^{policy}
2. **Dynamic General Equilibrium Model** $\rightarrow$ New-Keynesian DSGE
   - Loan & bond markets, financial frictions $\rightarrow$ bank capital determines credit supply
   - CBDC: (+) liquidity benefits, (+) curtails market power, (-) credit disintermediation
   - Result #1: Welfare change displays inverted U-shape w.r.t CBDC rate i^{CBDC}
   - Result #2: Optimal $i^{CBDC} \approx max(0\%, i^{policy} - 1\%)$, large gains at high i^{policy}
   - Result #3: Responses to transitory macro-shocks largely unaffected

Static Bank Deposit Model

Deposit Supply

- Bank j faces deposit supply

$$d_j = \frac{1}{n}\left(\frac{1+i_j^d}{1+i^d}\right)^{\varepsilon^d} d$$

- where aggregate deposit rate i^d and deposit amount d are

$$1+i^d = \left(\sum_{j=1}^{n}\frac{1}{n}(1+i_j^d)^{\varepsilon^d+1}\right)^{\frac{1}{\varepsilon^d+1}}$$

$$d = \gamma_d\left(\frac{1+i^d}{1+i^{\mathcal{L}}}\right)^{\theta}\mathcal{L}$$

- and the gross rate on liquid instruments $i^{\mathcal{L}}$ is defined as

$$1+i^{\mathcal{L}} = \left(\gamma_m + \gamma_d(1+i^d)^{\theta+1} + \gamma_{cbdc}(1+i^{cbdc})^{\theta+1}\right)^{\frac{1}{\theta+1}}$$

Deposit Supply

- Bank j faces deposit supply

$$d_j = \frac{1}{n}\left(\frac{1+i_j^d}{1+i^d}\right)^{\varepsilon^d} d$$

- where aggregate deposit rate i^d and deposit amount d are

$$1+i^d = \left(\sum_{j=1}^{n}\frac{1}{n}(1+i_j^d)^{\varepsilon^d+1}\right)^{\frac{1}{\varepsilon^d+1}}$$

$$d = \gamma_d\left(\frac{1+i^d}{1+i^{\mathcal{L}}}\right)^{\theta}\mathcal{L}$$

- and the gross rate on liquid instruments $i^{\mathcal{L}}$ is defined as

$$1+i^{\mathcal{L}} = \left(\gamma_m + \gamma_d(1+i^d)^{\theta+1} + \gamma_{cbdc}(1+i^{cbdc})^{\theta+1}\right)^{\frac{1}{\theta+1}}$$

Deposit Supply

- Bank j faces deposit supply

$$d_j = \frac{1}{n}\left(\frac{1+i^d_j}{1+i^d}\right)^{\varepsilon^d} d$$

- where aggregate deposit rate i^d and deposit amount d are

$$1+i^d = \left(\sum_{j=1}^{n}\frac{1}{n}(1+i^d_j)^{\varepsilon^d+1}\right)^{\frac{1}{\varepsilon^d+1}}$$

$$d = \gamma_d\left(\frac{1+i^d}{1+i^{\mathcal{L}}}\right)^{\theta}\mathcal{L}$$

- and the gross rate on liquid instruments $i^{\mathcal{L}}$ is defined as

$$1+i^{\mathcal{L}} = \left(\gamma_m + \gamma_d(1+i^d)^{\theta+1} + \gamma_{cbdc}(1+i^{cbdc})^{\theta+1}\right)^{\frac{1}{\theta+1}}$$

Bank Problem

- Bank j maximizes

$$\max_{i_j^d, d_j, h_j} (1+i)h_j - (1+i_j^d)d_j$$

$$\text{s.t.} \quad \underbrace{h_j}_{\text{Reserves}} = \underbrace{f_j}_{\text{Equity}} + \underbrace{d_j}_{\text{Deposits}} \quad \text{\& deposit supply}$$

- yielding first-order condition

$$1 + i_j^d = \frac{\epsilon_j^d}{\epsilon_j^d + 1} \cdot (1 + i)$$

- where ϵ_j^d is the endogenous elasticity of deposits. with symmetric banks,

$$\epsilon^d = \frac{n-1}{n} \cdot \varepsilon^d + \frac{1}{n} \cdot \theta(1 - \omega_{\mathcal{L}}^d)$$

- where $\omega_{\mathcal{L}}^d = \frac{(1+i^d)d}{(1+i^{\mathcal{L}})\mathcal{L}} = \gamma_d \left(\frac{1+i^d}{1+i^{\mathcal{L}}}\right)^{\theta+1}$ is the endogenous deposit share

Bank Problem

- Bank j maximizes

$$\max_{i_j^d, d_j, h_j} (1+i)h_j - (1+i_j^d)d_j$$

$$\text{s.t.} \quad \underbrace{h_j}_{\text{Reserves}} = \underbrace{f_j}_{\text{Equity}} + \underbrace{d_j}_{\text{Deposits}} \quad \text{\& deposit supply}$$

- yielding first-order condition

$$1 + i_j^d = \frac{\epsilon_j^d}{\epsilon_j^d + 1} \cdot (1+i)$$

- where ϵ_j^d is the endogenous elasticity of deposits, with symmetric banks,

$$\epsilon^d = \frac{n-1}{n} \cdot \varepsilon^d + \frac{1}{n} \cdot \theta(1 - \omega_{\mathcal{L}}^d)$$

- where $\omega_{\mathcal{L}}^d = \frac{(1+i^d)d}{(1+i^{\mathcal{L}})\mathcal{L}} = \gamma_d \left(\frac{1+i^d}{1+i^{\mathcal{L}}}\right)^{\theta+1}$ is the endogenous deposit share

Bank Problem

- Bank j maximizes

$$\max_{i_j^d, d_j, h_j} (1+i)h_j - (1+i_j^d)d_j$$

$$\text{s.t.} \quad \underbrace{h_j}_{\text{Reserves}} = \underbrace{f_j}_{\text{Equity}} + \underbrace{d_j}_{\text{Deposits}} \quad \text{\& deposit supply}$$

- yielding first-order condition

$$1 + i_j^d = \frac{\epsilon_j^d}{\epsilon_j^d + 1} \cdot (1+i)$$

- where ϵ_j^d is the endogenous elasticity of deposits. with symmetric banks,

$$\epsilon^d = \frac{n-1}{n} \cdot \varepsilon^d + \frac{1}{n} \cdot \theta(1 - \omega_{\mathcal{L}}^d)$$

- where $\omega_{\mathcal{L}}^d = \frac{(1+i^d)d}{(1+i^{\mathcal{L}})\mathcal{L}} = \gamma_d \left(\frac{1+i^d}{1+i^{\mathcal{L}}}\right)^{\theta+1}$ is the endogenous deposit share

Effects of CB Rates on Deposit Market

- Define deposit spread $(i - i^d)/(1 + i^d)$ which satisfies

$$\frac{i - i^d}{1 + i^d} = \frac{1}{\epsilon^d}$$

- Deposit spread is solely driven by endogenous deposit elasticity.

Proposition 1.

1. The deposit rate increases with the policy rate and the CBDC rate.
2. The deposit spread increases with the policy rate but decreases with the CBDC rate.
3. Aggregate deposits increase with the policy rate but decrease with the CBDC rate.

Effects of CB Rates on Deposit Market

- Define deposit spread $(i - i^d)/(1 + i^d)$ which satisfies

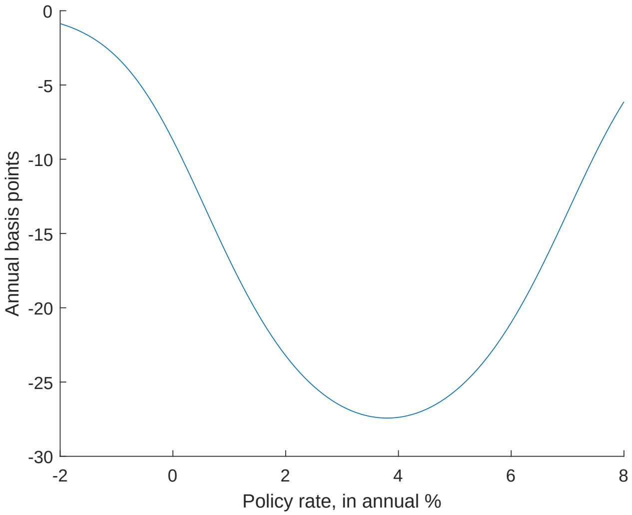
$$\frac{i - i^d}{1 + i^d} = \frac{1}{\epsilon^d}$$

- Deposit spread is solely driven by endogenous deposit elasticity.

Proposition 1.

1. The deposit rate increases with the policy rate and the CBDC rate.
2. The deposit spread increases with the policy rate but decreases with the CBDC rate.
3. Aggregate deposits increase with the policy rate but decrease with the CBDC rate.

CBDC Introduction at 0%: Changes in Deposit Spread



DSGE Model

Representative Household

- Household maximizes lifetime utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(u(C_t) - v(N_t) \right)$$

$$\text{s.t.} \quad \underbrace{P_t C_t}_{\text{Consumption}} + \underbrace{B_t}_{\text{Bonds}} + \underbrace{\Phi(\mathcal{L}_t) P_t}_{\text{Costs Liquidity}} = \underbrace{W_t N_t}_{\text{Income}} + \underbrace{AH_{t-1}}_{\text{Assets at Hand}} + \underbrace{T_t}_{\text{Transfers}}$$

- where $\mathcal{L}_t$ is a liquidity aggregator and $\Phi(\mathcal{L}_t) < \mathcal{L}_t$ for small $\mathcal{L}_t \Rightarrow$ convenience benefit

$$\mathcal{L}_t = \left(\gamma_m^{-\frac{1}{\theta}} m_t^{\frac{\theta+1}{\theta}} + \gamma_d^{-\frac{1}{\theta}} d_t^{\frac{\theta+1}{\theta}} + \gamma_{cbdc}^{-\frac{1}{\theta}} cbdc_t^{\frac{\theta+1}{\theta}} \right)^{\frac{\theta}{\theta+1}} ; \; d_t = \left(\sum_{j=1}^{n} \alpha_j^{-\frac{1}{\varepsilon^d}} d_{j,t}^{\frac{\varepsilon^d+1}{\varepsilon^d}} \right)^{\frac{\varepsilon^d}{\varepsilon^d+1}}$$

$$AH_{t-1} = (1 + i_{t-1}) B_{t-1} + M_{t-1} + \sum_{j=1}^{n} (1 + i_{j,t-1}^{d}) D_{j,t-1} + (1 + i_{t-1}^{cbdc}) CBDC_{t-1}$$

Representative Household

- Household maximizes lifetime utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(u(C_t) - v(N_t)\right)$$

$$\text{s.t.} \quad \underbrace{P_t C_t}_{\text{Consumption}} + \underbrace{B_t}_{\text{Bonds}} + \underbrace{\Phi(\mathcal{L}_t) P_t}_{\text{Costs Liquidity}} = \underbrace{W_t N_t}_{\text{Income}} + \underbrace{AH_{t-1}}_{\text{Assets at Hand}} + \underbrace{T_t}_{\text{Transfers}}$$

- where $\mathcal{L}_t$ is a liquidity aggregator and $\Phi(\mathcal{L}_t) < \mathcal{L}_t$ for small $\mathcal{L}_t \Rightarrow$ convenience benefit

$$\mathcal{L}_t = \left(\gamma_m^{-\frac{1}{\theta}} m_t^{\frac{\theta+1}{\theta}} + \gamma_d^{-\frac{1}{\theta}} d_t^{\frac{\theta+1}{\theta}} + \gamma_{cbdc}^{-\frac{1}{\theta}} cbdc_t^{\frac{\theta+1}{\theta}}\right)^{\frac{\theta}{\theta+1}} \; ; d_t = \left(\sum_{j=1}^{n} \alpha_j^{-\frac{1}{\varepsilon^d}} d_{j,t}^{\frac{\varepsilon^d+1}{\varepsilon^d}}\right)^{\frac{\varepsilon^d}{\varepsilon^d+1}}$$

$$AH_{t-1} = (1 + i_{t-1}) B_{t-1} + M_{t-1} + \sum_{j=1}^{n} (1 + i^d_{j,t-1}) D_{j,t-1} + (1 + i^{cbdc}_{t-1}) CBDC_{t-1}$$

Household Equilibrium Conditions

- ... yielding first-order conditions

$$x_t = \gamma_x \left(\frac{1 + i_t^x}{1 + i_t^{\mathcal{L}}} \right)^{\theta} \mathcal{L}_t \text{ for } x = \{m, cbdc, d\} \quad ; \frac{1 + i_t^{\mathcal{L}}}{1 + i_t} = \Phi'(\mathcal{L}_t)$$

- with remaining deposit supply conditions similar to static model

$$1 + i_t^d = \left(\sum_{j=1}^{n} \alpha_j (1 + i_{j,t}^d)^{\epsilon^d + 1} \right)^{\frac{1}{\epsilon^d + 1}} \quad ; d_{j,t} = \alpha_j \left(\frac{1 + i_{j,t}^d}{1 + i_t^d} \right)^{\epsilon^d} d_t$$

$$1 + i_t^{\mathcal{L}} = \left(\gamma_m + \gamma_d (1 + i_t^d)^{\theta + 1} + \gamma_{cbdc} (1 + i_t^{cbdc})^{\theta + 1} \right)^{\frac{1}{\theta + 1}}$$

Household Equilibrium Conditions

- … yielding first-order conditions

$$x_t = \gamma_x \left(\frac{1+i_t^x}{1+i_t^{\mathcal{L}}} \right)^{\theta} \mathcal{L}_t \text{ for } x = \{m, cbdc, d\} \quad ; \frac{1+i_t^{\mathcal{L}}}{1+i_t} = \Phi'(\mathcal{L}_t)$$

- with remaining deposit supply conditions similar to static model

$$1+i_t^d = \left(\sum_{j=1}^{n} \alpha_j (1+i_{j,t}^d)^{\varepsilon^d+1} \right)^{\frac{1}{\varepsilon^d+1}} ; d_{j,t} = \alpha_j \left(\frac{1+i_{j,t}^d}{1+i_t^d} \right)^{\varepsilon^d} d_t$$

$$1+i_t^{\mathcal{L}} = \left(\gamma_m + \gamma_d (1+i_t^d)^{\theta+1} + \gamma_{cbdc} (1+i_t^{cbdc})^{\theta+1} \right)^{\frac{1}{\theta+1}}$$

Corporate Sector & Government

- Intermediate good firm has Cobb-Douglas production function

$$Y_t^m = A_t K_t^{\alpha} N_t^{1-\alpha}$$

- K_t consists of pledgeable capital K_t^P & nonpleadgeable capital K_t^{NP}

$$K_t = \left((1-\psi)^{\frac{1}{\theta^k}} \left(K_t^{NP}\right)^{\frac{\theta^k-1}{\theta^k}} + \psi^{\frac{1}{\theta^k}} \left(K_t^{P}\right)^{\frac{\theta^k-1}{\theta^k}} \right)^{\frac{\theta^k}{\theta^k-1}} \; ; K_t^P = \left(\sum_{j=1}^{n} (\alpha_j^l)^{\frac{1}{\epsilon^l}} \left(K_{j,t}^P\right)^{\frac{\epsilon^l-1}{\epsilon^l}} \right)^{\frac{\epsilon^l}{\epsilon^l-1}}$$

- K_t^P is financed with bank loans, while K_t^{NP} is financed with bond borrowing

- Other firms: Retailers subject to nominal rigidities, final good & capital good producers
- Government: Central bank follows Taylor rule, fiscal spending constant fraction of output

Corporate Sector & Government

- Intermediate good firm has Cobb-Douglas production function

$$Y_t^m = A_t K_t^{\alpha} N_t^{1-\alpha}$$

- K_t consists of pledgeable capital K_t^P & nonpleadgeable capital K_t^{NP}

$$K_t = \left((1-\psi)^{\frac{1}{\theta^k}} \left(K_t^{NP}\right)^{\frac{\theta^k-1}{\theta^k}} + \psi^{\frac{1}{\theta^k}} \left(K_t^P\right)^{\frac{\theta^k-1}{\theta^k}} \right)^{\frac{\theta^k}{\theta^k-1}} \; ; K_t^P = \left(\sum_{j=1}^{n} (\alpha_j^l)^{\frac{1}{\varepsilon^l}} \left(K_{j,t}^P\right)^{\frac{\varepsilon^l-1}{\varepsilon^l}} \right)^{\frac{\varepsilon^l}{\varepsilon^l-1}}$$

- K_t^P is financed with bank loans, while K_t^{NP} is financed with bond borrowing

- Other firms: Retailers subject to nominal rigidities, final good & capital good producers

- Government: Central bank follows Taylor rule, fiscal spending constant fraction of output

Corporate Sector & Government

- Intermediate good firm has Cobb-Douglas production function

$$Y_t^m = A_t K_t^\alpha N_t^{1-\alpha}$$

- K_t consists of pledgeable capital K_t^P & nonpleadgeable capital K_t^{NP}

$$K_t = \left((1-\psi)^{\frac{1}{\theta^k}} \left(K_t^{NP}\right)^{\frac{\theta^k - 1}{\theta^k}} + \psi^{\frac{1}{\theta^k}} \left(K_t^P\right)^{\frac{\theta^k - 1}{\theta^k}} \right)^{\frac{\theta^k}{\theta^k - 1}} ; K_t^P = \left(\sum_{j=1}^{n} (\alpha_j^l)^{\frac{1}{\varepsilon^l}} \left(K_{j,t}^P\right)^{\frac{\varepsilon^l - 1}{\varepsilon^l}} \right)^{\frac{\varepsilon^l}{\varepsilon^l - 1}}$$

- K_t^P is financed with bank loans, while K_t^{NP} is financed with bond borrowing
- Other firms: Retailers subject to nominal rigidities, final good & capital good producers
- Government: Central bank follows Taylor rule, fiscal spending constant fraction of output

Representative Bank

- Bank solves $\max \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda_{t,t+s+1} DIV_{j,t+s+1}$ with budget constraint

$$\underbrace{L_{j,t}}_{\text{Loans}} + \underbrace{H_{j,t}}_{\text{Reserves}} = \underbrace{F_{j,t}}_{\text{Equity}} + \underbrace{D_{j,t}}_{\text{Deposits}}$$

- Bank faces costs of (i) operation, (ii) issuing loans & deposits, (iii) leverage deviations

$$\underbrace{S_{j,t+1}}_{\text{Resources}} = \underbrace{(1 + i^l_{j,t} - \mu^l)L_{j,t}}_{\text{Profits Loans}} + \underbrace{(1 + i_t)H_{j,t}}_{\text{Profits Reserves}} \underbrace{-(1 + i^d_{j,t} + \mu^d)D_{j,t}}_{\text{Costs Deposits}} \underbrace{-\varsigma F_{j,t}}_{\text{Costs Operation}} \underbrace{-\Psi\left(\frac{L_{j,t}}{F_{j,t}}\right)F_{j,t}}_{\text{Costs Leverage}}$$

- Bank pays constant fraction of profits as dividends each period
- Frictions imply that bank capital is slow-moving & determines credit supply

Representative Bank

- Bank solves $\max \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda_{t,t+s+1} DIV_{j,t+s+1}$ with budget constraint

$$\underbrace{L_{j,t}}_{\text{Loans}} + \underbrace{H_{j,t}}_{\text{Reserves}} = \underbrace{F_{j,t}}_{\text{Equity}} + \underbrace{D_{j,t}}_{\text{Deposits}}$$

- Bank faces costs of (i) operation, (ii) issuing loans & deposits, (iii) leverage deviations

$$\underbrace{S_{j,t+1}}_{\text{Resources}} = \underbrace{(1 + i^l_{j,t} - \mu^l)L_{j,t}}_{\text{Profits Loans}} + \underbrace{(1 + i_t)H_{j,t}}_{\text{Profits Reserves}} \underbrace{-(1 + i^d_{j,t} + \mu^d)D_{j,t}}_{\text{Costs Deposits}} \underbrace{-\varsigma F_{j,t}}_{\text{Costs Operation}} \underbrace{-\Psi\left(\frac{L_{j,t}}{F_{j,t}}\right)F_{j,t}}_{\text{Costs Leverage}}$$

- Bank pays constant fraction of profits as dividends each period
- Frictions imply that bank capital is slow-moving & determines credit supply

Representative Bank

- Bank solves $\max \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda_{t,t+s+1} DIV_{j,t+s+1}$ with budget constraint

$$\underbrace{L_{j,t}}_{\text{Loans}} + \underbrace{H_{j,t}}_{\text{Reserves}} = \underbrace{F_{j,t}}_{\text{Equity}} + \underbrace{D_{j,t}}_{\text{Deposits}}$$

- Bank faces costs of (i) operation, (ii) issuing loans & deposits, (iii) leverage deviations

$$\underbrace{S_{j,t+1}}_{\text{Resources}} = \underbrace{(1 + i^l_{j,t} - \mu^l) L_{j,t}}_{\text{Profits Loans}} + \underbrace{(1 + i_t) H_{j,t}}_{\text{Profits Reserves}} \underbrace{-(1 + i^d_{j,t} + \mu^d) D_{j,t}}_{\text{Costs Deposits}} \underbrace{-\varsigma F_{j,t}}_{\text{Costs Operation}} \underbrace{-\Psi \left(\frac{L_{j,t}}{F_{j,t}} \right) F_{j,t}}_{\text{Costs Leverage}}$$

- Bank pays constant fraction of profits as dividends each period
- Frictions imply that bank capital is slow-moving & determines credit supply

Bank Equilibrium Conditions

- Decision separated into a deposit sub-problem and a loan sub-problem, yielding

$$1 + i^d_{j,t} = \frac{\epsilon^d_{j,t}}{\epsilon^d_{j,t} + 1}(1 + i_t - \mu^d)$$

- where endogenous deposit elasticity $\epsilon^d_{j,t}$ takes similar form as in static model, and

$$1 + i^l_{j,t} = \frac{\epsilon^l_{j,t}}{\epsilon^l_{j,t} - 1}\left[1 + i_t + \mu^l + \Psi'\left(\frac{L_{j,t}}{F_{j,t}}\right)\right]$$

- where endogenous loan elasticity $\epsilon^l_{j,t}$ is weighted average between ϵ^l and share of pledgeable capital in total capital expenditure

Bank Equilibrium Conditions

- Decision separated into a deposit sub-problem and a loan sub-problem, yielding

$$1 + i^d_{j,t} = \frac{\epsilon^d_{j,t}}{\epsilon^d_{j,t} + 1}(1 + i_t - \mu^d)$$

- where endogenous deposit elasticity $\epsilon^d_{j,t}$ takes similar form as in static model, and

$$1 + i^l_{j,t} = \frac{\epsilon^l_{j,t}}{\epsilon^l_{j,t} - 1}\left[1 + i_t + \mu^l + \Psi'\left(\frac{L_{j,t}}{F_{j,t}}\right)\right]$$

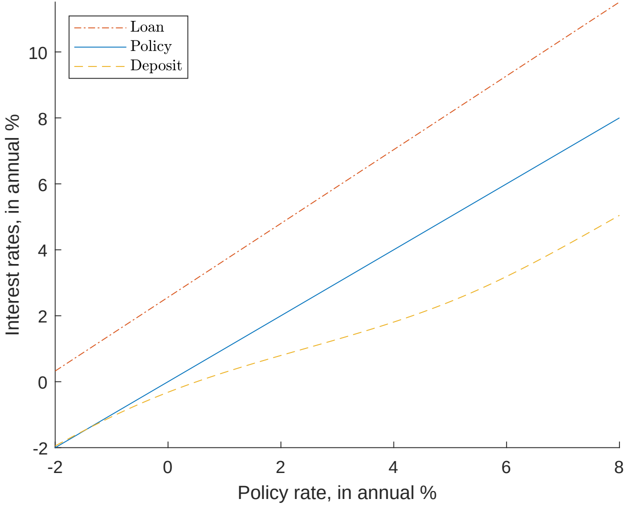
- where endogenous loan elasticity $\epsilon^l_{j,t}$ is weighted average between ε^l and share of pledgeable capital in total capital expenditure

Calibration

Calibration

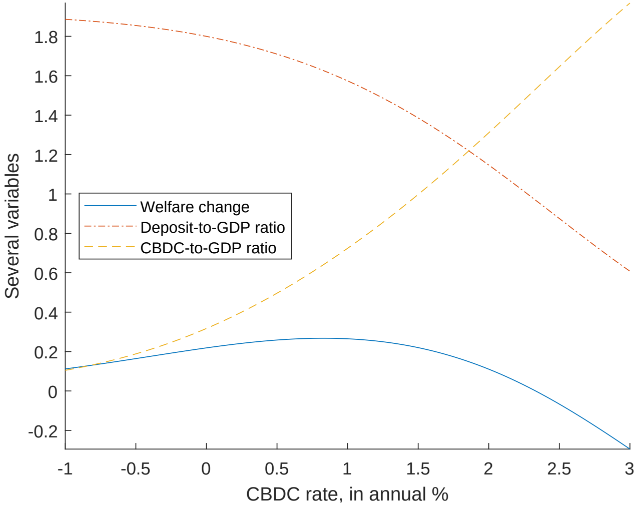
Param.	Value	Description	Target or source
Deposit side			
γ_m	0.3005	Importance of cash in liquidity	$\gamma_m + \gamma_d + \gamma_{cbdc} = 1$
γ_d	0.3990	Importance of deposits in liquidity	$D/\mathcal{L} = 0.8$ at $i = 2\%$
γ_{cbdc}	0.3005	Importance of CBDC in liquidity	$\gamma_{cbdc} = \gamma_m$ (Bidder et al.)
n	1.1685	Number of banks	Deposit rate target #1
θ	554.21	E.o.S. between instruments in liquidity	Deposit rate target #2
ε^d	661.36	E.o.S. between banks in deposits	Deposit rate target #3
μ^d	-0.20%	Cost of issuing deposits	Deposit rate target #4
Loan side			
ψ	0.3000	Importance of pledgeable capital	Crouzet (2021)
ϱ	0.70%	Extra cost of corporate-bond borrowing	Schwert (2020)
μ^l	0.35%	Cost of issuing loans	Schwert (2020)

Loan and Deposit Spreads

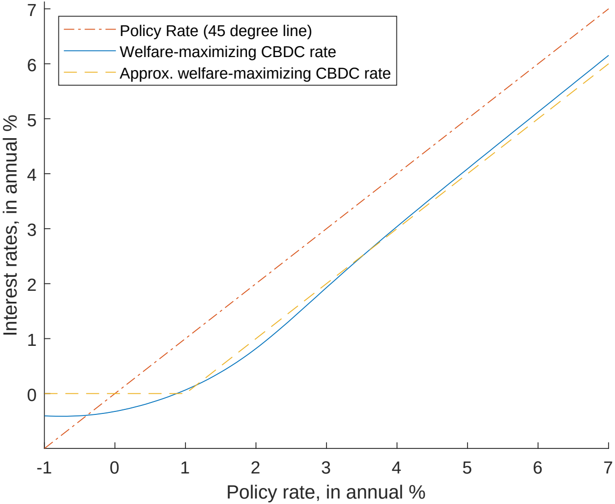


Results

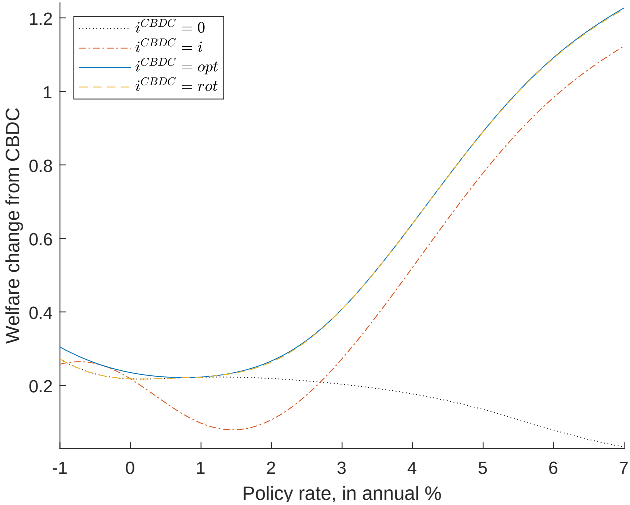
CBDC Introduction for Different CBDC Rates



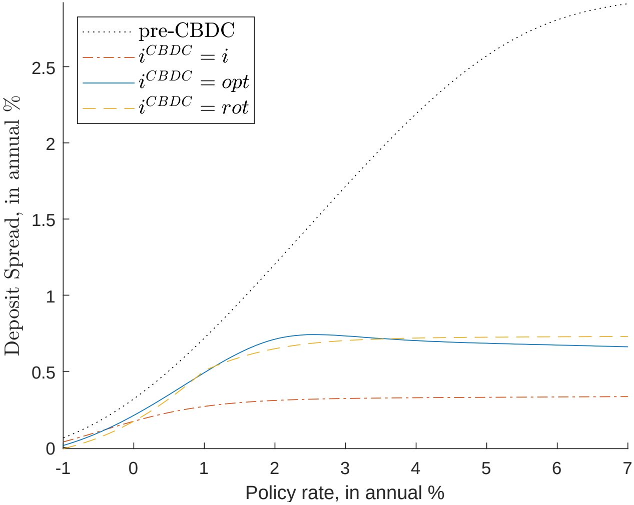
Welfare-Maximizing CBDC Rate Across Policy Rates



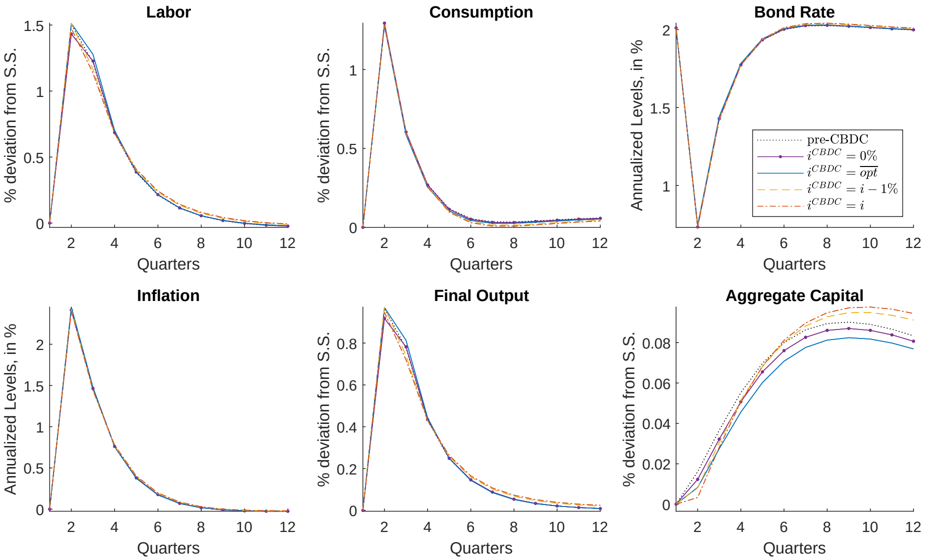
Welfare-Maximizing CBDC Rate Across Policy Rates



Welfare-Maximizing CBDC Rate Across Policy Rates



Responses to Monetary Policy Shock



Conclusion

- Introduction of CBDC debated worldwide, but practical experience remains scarce
  $\Rightarrow$ analysis based on theoretical models needed

- **This paper**: provides such guidance and delivers a simple practical message

- Substantial welfare improvements from introducing CBDC based on a rule-of-thumb: optimal CBDC rate $i^{CBDC} \approx max(0\%, i^{policy} - 1\%)$

- Can be easily communicated to the public and avoids political-economy concerns related to paying negative rates on CBDC

- Introduction of CBDC most beneficial for economies with high interest rates
  $\Rightarrow$ bank market power in deposit markets sharply reduced

- Introduction of CBDC debated worldwide, but practical experience remains scarce
  $\Rightarrow$ analysis based on theoretical models needed

- **This paper**: provides such guidance and delivers a simple practical message

- Substantial welfare improvements from introducing CBDC based on a rule-of-thumb: optimal CBDC rate $i^{CBDC} \approx max(0\%, i^{policy} - 1\%)$

- Can be easily communicated to the public and avoids political-economy concerns related to paying negative rates on CBDC

- Introduction of CBDC most beneficial for economies with high interest rates
  $\Rightarrow$ bank market power in deposit markets sharply reduced