Central Bank Digital Currency: Implications for Monetary Policy and Financial Stability

Chris Hyland

September 26, 2022

University of Oxford

Table of contents

Intro

Central Bank Digital Currencies

CBDCs are receiving interest from many central banks.

BIS survey found that 90% of central bank respondents are engaged in work pertaining to CBDCs.

Recent technological advancements have now made CBDCs a viable prospect and can now offer central bank a new monetary policy tool.

The large design space for CBDCs can yield different tools and implications for monetary policy. How should we think about this?

Furthermore, there is a large gap in the literature examining the real economy effects of CBDCs.

Finally, there is a gap in the literature studying the effects on financial stability from CBDCs.

Thesis Contribution

We build a model to examine **retail CBDCs** which is a household (renumerated) account at the central bank.

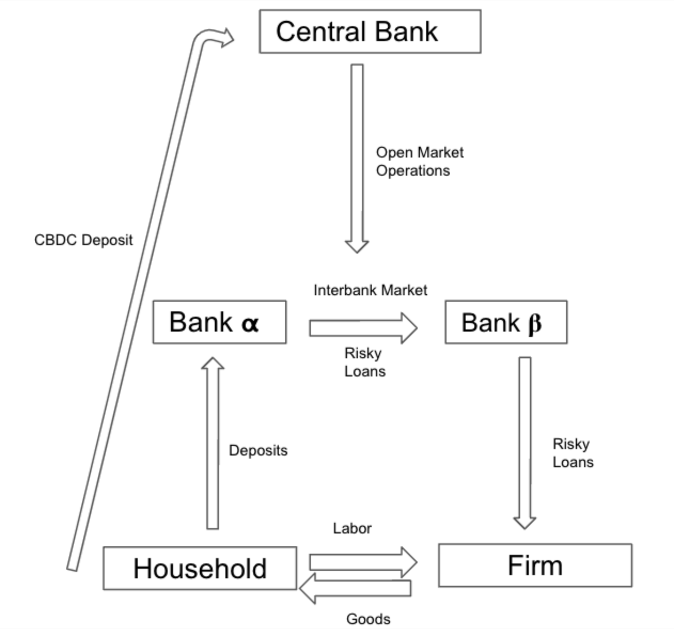
This thesis develops novel combination of channels examining the tradeoff between monetary policy transmission and financial fragility through the introduction of CBDCs.

We develop a stochastic general equilibrium model with incomplete markets comprising of a representative household, firm, central bank, and a monopsonistic commerical banking sector. We furthermore allow for endogenous default.

We find that CBDCs provide an outside option to households and disciplines the market power of the banking sector, achieving the perfect competition outcome.

This grants central bank greater transmission of monetary policy. However, the reduction in aggregate profitability of the banking sector increases financial stability through multiple channels.

Model Setup


Central Bank
CBDC Deposit
Open Market
Operations
Interbank Market
Bank α
Bank β
Risky
Loans
Deposits
Risky
Loans
Labor
Household
Firm
Goods

Households

1. Households work to earn income for consumption. Households may also use either commercial bank deposits or CBDCs as savings storage device.
2. Firms take out (defaultable) loans from commercial bank to pay for labour in order to produce consumption good. They sell this consumption good to households.

Banking Sector

1. Banks exhibit market power in deposit sector. They restrict the supply of deposits to pay savers a lower deposit rate compared to the interbank market rate (controlled by the central bank).
2. **Standard Deposit Channel** - A raise in the interbank market rate by the central bank leads to a less than 1-1 change in the deposit rate due to banks' market power.
3. Banks engage in risky lending to firms and (risk-free) credit provision to households. Banks solve a moral hazard problem by choosing to expend effort to monitor firms' credit worthiness.
4. Banks earn a spread between the deposit rates they pay to households and the loan rates extended to firms.

Introducing CBDC

1. Suppose now households can now hold CBDCs at the central bank directly which is renumerated.
2. **Direct Transmission of Monetary Policy** - The central bank has direct control of monetary policy transmission through adjusting deposit rates on CBDCs.
3. Commercial banks are forced to raise their deposit rates to compete with CBDCs. It can be shown that an introduction of a CBDC is equivalent to **perfect competition** in the deposit sector.

Bank Mechanism

1. **Bank Lending Channel** - An increase in bank deposit rates leads to an increase in bank deposits. A higher deposit base leads to banks extending greater volume of loans to firms and borrowers via the **bank lending channel**.
2. **Bank Risk-Taking Channel** - A compression in banks spread between deposit rates and lending rates lead to banks exerting less effort in monitoring credit worthiness of loans to firms.

$\Rightarrow$ Banks extend a higher volume of subprime loans (Global Financial Crises?)

Mechanism

In the event of realisation of bad shocks:

1. Banks see a large number of loans made to firms default. Banks have lower profit margins to absorb these losses.
2. Banks may also default on interbank loans, leading to **financial contagion**.

Perfect competition leads to greater financial instability.

Household

Household Payments

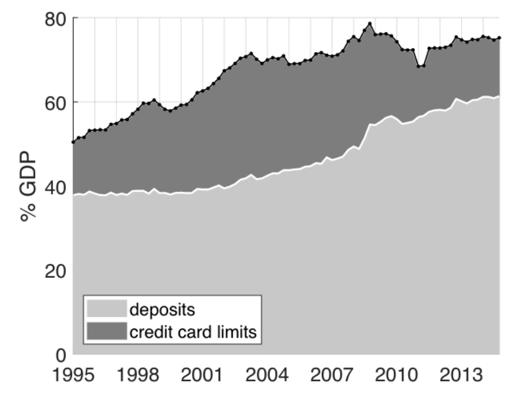


Figure 2: Piazzesi and Schneider (2022).

Households draw down credit line from banks in order to make payments.

Household Problem

Representative Household chooses intratemporal problem between consumption C_s^H and labour N_s^H.

Household also solves intertemporal consumption smoothing problem by investing in either bank deposits D^H or central bank digital currencies Z^H.

Households face cash-in-advance constraint (Lucas Jr and Stokey 1987).

Prices are formed via Shubik and Wilson (1977) trading mechanism.

Household intertemporal objective:

$$\max_{\{C_s^H, N_s^H, M_s^H\}_{s \in \overline{\mathcal{S}}}, D^H, Z^H} u(C_0^H, N_0^H) + \beta^H \sum_{s \in \mathcal{S}} \pi(s) u(C_s^H, N_s^H) \tag{1}$$

Household Constraints in First Period

Subject to:

$$M_0^H + D^H + Z^H \leq \frac{L_0^H}{1 + r_0^H} \tag{2}$$

Fiat Money + Bank Deposits + CBDC $\leq$ Bank Credit Line.

$$C_0^H \leq \frac{M_0^H}{p_0} \tag{3}$$

Consumption $\leq$ Amount of fiat money offered for good divided by price level (Shubik and Wilson 1977).

$$L_0^H \leq W_0 N_0^H \tag{4}$$

Bank Credit Line $\leq$ Wage from labour.

Household Constraints in Second Period

$$M_s^H \leq \frac{L_s^H}{1+r_s^H} + (1+r^D)D^H + (1+r^Z)Z^H, \quad \forall s \in \mathcal{S} \tag{5}$$

Fiat Money $\leq$ Bank Credit Line + Principal plus interest on bank deposits and CBDCs.

$$C_s^H \leq \frac{M_s^H}{p_s}, \quad \forall s \in \mathcal{S} \tag{6}$$

Consumption $\leq$ Amount of fiat money offered for good divided by price level (Shubik and Wilson 1977).

$$L_s^H \leq W_s N_s^H, \quad \forall s \in \mathcal{S} \tag{7}$$

Bank Credit Line $\leq$ Wage from labour.

Household Optimality Conditions

Intratemporal Consumption-Labour Euler equation:

$$-\frac{u_N(C_s^H, N_s^H)}{u_C(C_s^H, N_s^H)} = \frac{W_s}{p_s(1 + r_s^H)}, \quad \forall s \in \overline{\mathcal{S}} \tag{8}$$

Intertemporal Consumption Smoothing via Deposits Euler equation:

$$\frac{u_C(C_0^H, N_0^H)}{p_0} = \frac{(1 + r^D)\beta^H \pi(s) u_C(C_s^H, N_s^H)}{p_s} \tag{9}$$

Intertemporal Consumption Smoothing via CBDCs Euler equation:

$$\frac{u_C(C_0^H, N_0^H)}{p_0} = \frac{(1 + r^Z)\beta^H \pi(s) u_C(C_s^H, N_s^H)}{p_s} \tag{10}$$

Household Optimality Conditions

$$\frac{u_C(C_0^H, N_0^H)}{p_0} = \frac{(1 + r^D)\beta^H \pi(s) u_C(C_s^H, N_s^H)}{p_s}$$

$$\frac{u_C(C_0^H, N_0^H)}{p_0} = \frac{(1 + r^Z)\beta^H \pi(s) u_C(C_s^H, N_s^H)}{p_s}$$

Proposition

An interior solution for bank deposits exists if and only if:

$$r^D \leq r^Z.$$

Proposition

The price level is determinate and given by:

$$p_s = \frac{M_s^H}{Y_s}, \quad \forall s \in \overline{\mathcal{S}}.$$

Firms

Firm Problem

Firms face a cash-in-advance constraint to pay workers. Firms therefore drawn down bank credit lines to pay workers.

Firms are then hit with productivity shock $A_s \in \{A^H, A^L\}$ where A^H is high productivity and A^L is low productivity.

Firms then produce goods.

Finally, firms may choose to **endogenously default** on bank loans if the marginal benefit to defaulting is greater than the marginal cost (Dubey et al. 2005).

However, they face a penalty $\Psi_s^F[\mathbb{I}_s]^+$ for defaulting.

Ψ_s^F is the default penalty which is a proxy for firm's credit worthiness (Wang 2022).

Firm Problem

$$\max_{N_s^H, \nu_s^f, L_s^F} \quad \sum_{s \in \overline{\mathcal{S}}} \left[\Pi_s^F - \Psi_s^F [\mathbb{I}_s]^+ \right] \tag{11}$$

Subject to:

$$W_s N_s^F \leq \frac{L_s^F}{(1 + r_s^F)}, \quad \forall s \in \overline{\mathcal{S}} \tag{12}$$

Wage Paid to Labour $\leq$ Bank Credit Line.

$$A_s \in \{A_s^H, A_s^L\}, \quad \forall s \in \overline{\mathcal{S}} \tag{13}$$

Productivity shock drawn from Markov process.

$$Y_s = A_s N_s^F, \quad \forall s \in \overline{\mathcal{S}} \tag{14}$$

Firm produces output according to linear technology.

Firm Problem

$$\Pi_s^F = p_s Y_s + \left[\frac{L_s^F}{(1+r_s^F)} - W_s N_s^F\right] - \nu_s^F L_s^F, \quad \forall s \in \overline{\mathcal{S}} \tag{15}$$

Firm's profit function is the revenue from producing the good plus leftover credit less the amount the firm decides to pay back on the loan $\nu_s^F \in [0,1]$.

The penalty to firm for defaulting is given by a quadratic cost (Tsomocos 2003).

$$[\mathbb{I}_t]^+ = \begin{cases} \left(\frac{(1-\nu_t^f)L_t^f}{P_t}\right)^2 & (1-\nu_t^f) > 0 \\ 0 & (1-\nu_t^f) = 0 \end{cases}$$

Firm's Optimality Conditions

Proposition

Firm's optimal default condition is:

$$\mathcal{M}_s^F = 2\Psi_s^F(1-\nu_s^F)L_s^F \tag{16}$$

The marginal benefit to default = Marginal cost to default.

$$W_s = \frac{p_s A_s}{(1+r_s^F)} \tag{17}$$

Wage is equal to Marginal product of Labour.

$$W_s N_s^F = \frac{L_s^F}{(1+r_s^F)} \tag{18}$$

Deposit in advance constraint binds.

Banking

Bank Structure

Bank α accepts deposits from household and issues interbank loans to bank β at the interbank market rate ρ.

Bank β issues risky loans to firms and credit lines to household. Bank β may endogenously default on the interbank loan.

Marginal source of funding for banks is from interbank market (Wang et al. 2022).

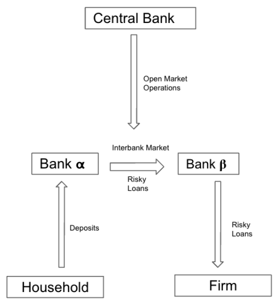
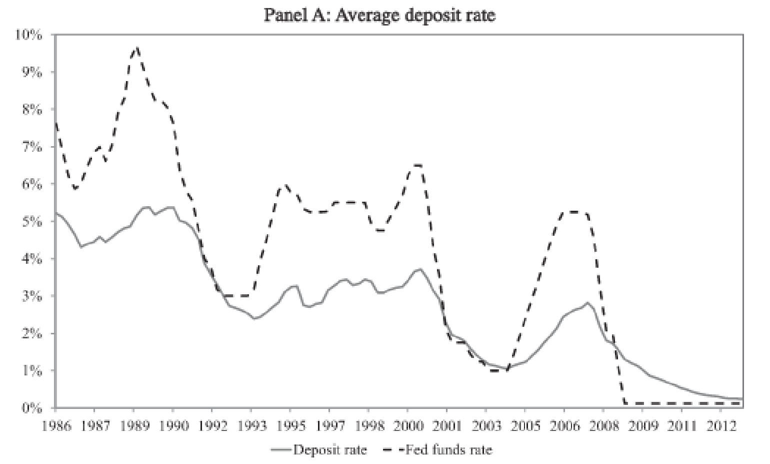


Figure 3: Banking Sector.

Deposit Bank α

Banks exhibit market power in deposit market (Dreschler et al. 2017).

Monopsony behaviour by keeping deposit rate below the fedral funds rate.



Deposit Bank α

Bank α chooses a quantity of deposits D^B to accept from households and a quantity of (risky) loans L^B to extend to bank β.

The quantity of deposits affects the deposit rate r^D whilst loans are extended at an exogenous interbank market rate ρ set by the central bank.

$$\max_{D^B, L^B} \sum_{s \in \mathcal{S}} \Pi_s^\alpha \tag{19}$$

Subject to:

$$L^B \leq D^B \tag{20}$$

Bank Loans extended $\leq$ Household Deposits taken in.

$$\Pi_s^\alpha = \nu_s^B (1 + \rho) L^B - (1 + r^D) D^B \tag{21}$$

Profit is the spread between (repaid) loans and deposit where ν_s^B is the fraction of loan repaid by bank β.

Deposit Bank α

Recall that $r^D \equiv r^D(D^B)$ and we can simplify the optimisation problem:

$$\max_{D^B} \sum_{s \in \mathcal{S}} \nu_s^B (1+\rho) D^B - (1 + r^D) D^B \tag{22}$$

First order condition gives us:

$$\nu_s^B (1+\rho) = (1 + r^D) + \frac{\partial r^D}{\partial D^B} \cdot D^B$$

Define the **supply elasticity of deposits**

$$\epsilon^D \equiv \frac{1 + r^D}{D^B} \cdot \frac{\partial D^B}{\partial r^D} \tag{23}$$

where $\epsilon^D > 0$.

Deposit Bank α Optimality Condition

Proposition

Bank α sets a **markdown** on the deposit rate:

$$(1 + r^D) = \frac{\nu_S^B(1+\rho)}{1 + \frac{1}{\epsilon^D}}. \tag{24}$$

The **Lerner index** is given by:

$$\frac{\nu_S^B(1+\rho) - (1+r^D)}{1 + r^D} = \frac{1}{\epsilon^D}. \tag{25}$$

Bank α restricts the supply of deposits to pay savers a lower deposit rate compared to the interbank market rate.

As $\epsilon^D \to \infty$, we arrive at **perfect competition**.

Dampening of the Transmission of Monetary Policy

Proposition

Due to bank α market power, there is a dampening of monetary policy transmission via the **standard deposit channel** as the central bank adjusts the interbank rate ρ:

$$\frac{\partial r^D}{\partial \rho} < 1. \tag{26}$$

Lender Bank β

Bank β chooses the amount of interbank loans to borrow from bank α at the interbank rate ρ. Bank β can endogenously default on the interbank loan.

Bank β provides credit line to the household.

Bank β extends risky loans L_s^F to the firm, which the firm may default on. This introduces a **moral hazard problem** (Christiano and Ikeda 2013).

The bank can expend effort $M_{F,s}$ to monitor the credit worthiness of the firm and reduce likelihood of default by firm through imposing a higher default penalty cost.

The bank internalises the firm's optimal default condition.

Monitoring firm is quadratic cost for bank (Martinez-Miera and Repullo 2017).

Lender Bank β Problem

$$\max_{\{L_s^F, L^B, M_{F,s}, \nu_s^B\}_{s\in\overline{\mathcal{S}}}} \Pi_0^\beta - \frac{\gamma^F}{2} M_{F,0}^2 L_0^F + \sum_{s\in\mathcal{S}} \left\{ \Pi_s^\beta - \frac{\gamma^F}{2} M_{F,s}^2 L_s^F - \Psi_s^B (L^B - \nu_s^B L^B)^2 \right\} \tag{27}$$

Subject to:

$$L_0^H + L_0^F \leq \frac{L^B}{1+\rho} \tag{28}$$

Credit line to household + risky loan to firm $\leq$ interbank loan from bank α.

$$1 = 2\Psi_0^F (1 - \nu_0^F) L_0^F \tag{29}$$

Bank β internalises firm's optimal default condition.

Lender Bank β Problem

$$\Psi_s^F = M_{F,s}, \quad \forall s \in \overline{\mathcal{S}} \tag{30}$$

The default penalty to the firm on the loan is equal to the monitoring effort by the bank (Wang 2022).

$$\Pi_0^\beta = (1 + r_0^H)L_0^H + \nu_0^F(1 + r_0^F)L_0^F + \left[\frac{L^B}{1+\rho} - L_0^H - L_0^F\right] \tag{31}$$

Bank β profit is the return on household's credit lines plus the loans to the firm that are paid back.

$$e^\beta = \Pi_0^\beta \tag{32}$$

Bank β equity is the profit from first period.

Lender Bank β Problem

$$1 = 2\Psi_s^F(1-\nu_s^F)L_s^F \tag{33}$$

Bank β internalises firm's optimal default condition.

$$\Pi_s^\beta = (1+r_s^H)L_s^H + \nu_s^F(1+r_s^F)L_s^F - \nu_s^B L^B \tag{34}$$

Bank β profit is the return on household's credit lines plus the loans to the firm that are paid back less the amount that bank β decides to pay back on interbank loan.

Lender Bank β Optimality Condition

Proposition: Bank Lending Channel

Bank β extends more risky loans to firms as they borrow more from the interbank market:

$$\frac{\partial L_s^F}{\partial L^B} > 0. \tag{35}$$

Proposition: Risk-Taking Channel

Bank β exerts less effort into monitoring loans as the interbank market rate ρ increases:

$$\frac{\partial M_{F,s}}{\partial \rho} < 0. \tag{36}$$

Bank β extends more a higher quantity of risky loans as bank α supplies more loans into the interbank market.

Lender Bank β Optimality Condition

Proposition

Bank β profits decreases as the interbank market rate ρ increases:

$$\frac{\partial \Pi_s^{\beta}}{\partial \rho} < 0. \tag{37}$$

The combination of decrease profitability and the fact that bank β extend more risky loans due to an increase in the interbank rate ρ, bank β has less equity buffer to withstand negative shocks to the system.

Bank β is more likely to default on their interbank loan, leading to **financial contagion**.

Summary

Summary

Introducing CBDC grants the central bank greater control over the monetary policy transmission mechanism and induces perfect competition in the banking sector.

A higher bank deposit rate **crowds in** deposits into the banking sector.

By the **bank lending channel**, banks extend more credit.

However, a higher bank deposit rate reduces profitability of banks, reducing the incentive to monitor the credit worthiness of loans via the **risk-taking channel**.

The banks have less equity buffer to withstand negative shocks, thereby generating **financial contagion**.

Tradeoff between monetary policy control and financial stability.

Future Work

- Incorporate heterogenous households.
- Introduce housing stock.
- Introduce banking regulation.
- Infinite Period.