Optimal Central Banking Policies: Envisioning the Post-Digital Yuan Economy with Loan Prime Rate-setting

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Introduction

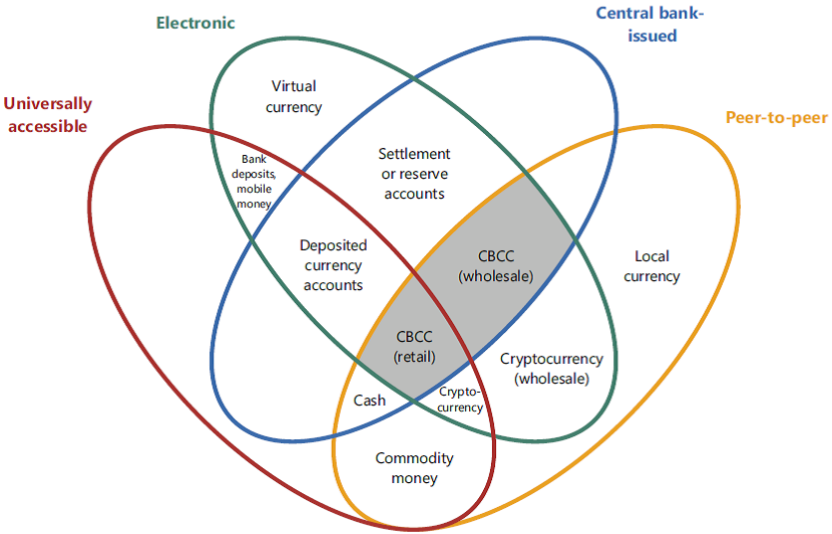
Two recent policy developments in the financial sector:

- Post-Aug 2019 Loan Prime Rate (LPR) reform; and
- Experimentation of Digital Currency Electronic Payment (DCEP)-China's own central bank digital currency (CBDC).

LPR reform - Benchmark LPR calculated by NIFC based on an adjusted average of preferential lending rates.
In essence, it provides PBOC with more direct control of market loan rates, but pseudo-macroprudential characteristics.

DCEP - CBDC that is account based, peer-to-peer, centralized (count towards PBOC's liabilities).
In essence, saving of paper money velocity-based transaction costs (Barrdear & Kumhof, 2016; Berentsen & Schär, 2018), in a position to pay negative interest rate (Buiter, 2009; Agarwal & Kimball, 2015), and potential financial stability tool.

Money Flower - Bech and Garratt, 2017



Outstanding issues wrt CBDC design in literature

Should CBDC be:
1. Token- or account-based? - DCEP is latter;
2. Interest rate/return of CBDC (Meaning et al., 2018) - Trading at par vis-à-vis other assets?
3. Point (2) also concerns its usefulness to act as a policy tool to address zero lower bound problem (Agarwal & Kimball, 2015; Rogoff, 2016).

Related literature

- Niepelt (2020) - CBDC as "Reserves for All" violates equivalence principle & have macro implications.
- Barrdear & Kumhof (2016) - CBDC could raise GDP by 3%; CBDC to act as a second MP instrument.
- Agur et al. (2021) - optimal design based on preferences over anonymity and security;
- Keister & Sanches (2019), A trade-off between welfare gains and other negative effects (investment reduction, bank-funding cost increase);
- Fernández-Villaverde et al. (2020) - more stable during crisis; Andolfatto (2021) - increases bank lending activities; Jia (2020) - adverse effects on investment and output.

Additional context to consider for modelling

Some contexts unique to China:

- A large share of domestic lending tied to housing sector - a "housing as collateral" set-up (Minetti et al., 2019);
- Conventional monetary policy for liquidity - M2 supply growth rule (Chang et al., 2019);
- Tough policy climate for Private Digital Currency (PDC) (2017 'Cryptocurrency Ban'), though private demand remains (90% global Bitcoin trades pre-ban) - PDC price a source of stochastic shock.

What we do and find

1. A DSGE model with cash and digital currencies (the former subject to cash velocity-related transation costs), plus a "housing as collateral for commercial bank loan" core.
2. A benchmark model vs. a "Post-CBDC world" model - prior to CBDC, the households pay digitally using PDC, albeit with significant holding/access cost. As such, pre-CBDC, 2 policy tools: (i) M2 growth rule; (ii) LPR. Post-CBDC, CBDC quantity to be determined via household optimization (with fixed quantity supplied), with rate set by Central Bank.

3 Bayesian-estimated (actual, *plus* converted monthly series) - variance decomposition & IRF shows that post-CBDC, (i) influence of PDC price shock reduced; (ii) LPR's influence on inflation diminished slightly. Nevertheless, in post-CBDC world procyclicality of most macroeconomic variables to most shocks is amplified.

4 Welfare optimal policy design: (i) interior solutions for both price & output stabilization mandates in setting CBDC rate; (ii) For LPR, we uncover non-zero welfare-optimal policy mandates wrt asset markets; (iii) potential *policy complementarity* between LPR and stock of CBDC.

Household problem - general form

With $\xi_{ht} \in (0,1)$ share of consumption paid by cash, an individual h maximizes:

$$U_t^h = \mathbb{E}_h \sum_{t=0}^{\infty} \beta^t \varepsilon_t^C \left[\begin{array}{c} \ln C_{ht} + \eta_H \ln H_{ht} \\ +\eta_M \ln(m_{ht}) - \eta_N \frac{(N_{ht})^{1+\varsigma_N}}{1+\varsigma_N}, \end{array} \right], \tag{1}$$

where ε_t^C is preference shock, $m_{ht} = m_{ht}^F + m_{ht}^B + m_{ht}^{CD}$, subject to

$$\begin{aligned} & C_{ht} + s_{ht}^F \xi_{ht} C_{ht} + \frac{P_t^H}{P_t} \Delta H_{ht} + b_{ht}^{HD} \\ & + m_{ht}^F + m_{ht}^{CD} + (1 - f_{ht}^B) e_{t+1} \mathbb{E}_t P_{t+1}^B m_{ht}^B + d_{ht} \\ & \leq \frac{m_{ht-1}^F}{(1+\pi_t)} + \frac{(1+i_{t-1}^{CD}) m_{ht-1}^{CD}}{(1+\pi_t)} + e_t P_t^B \frac{m_{ht-1}^B}{(1+\pi_t)} \\ & + \frac{(1+i_{t-1}^D)}{(1+\pi_t)} d_{ht-1} + \frac{(1+i_{t-1}^B)}{(1+\pi_t)} b_{ht-1}^{HD} \\ & + (w_t N_{ht} - T_{ht}) + \frac{\Pi_t^R}{P_t} + \frac{\Pi_t^K}{P_t} + \frac{\Pi_t^H}{P_t}. \end{aligned} \tag{2}$$

Monies and related costs

- Cash (m^F_{ht}): Increasing in velocity (v^F_{ht}) -

$$s^F_{ht} = s(v^F_{ht}), \text{ where } v^F_{ht} = \frac{\xi_{ht} P_t C_{ht}}{M^F_{ht}},$$

$$\text{with } s(v^F_{ht}) = s_{0,t} + A_F v^F_{ht} + B_F / v^F_{ht} - 2\sqrt{A_F B_F},$$

which, to ensure $v^F_{ht} > \underline{v}^F$ holds at all time ($\underline{v}^F = \sqrt{\underline{B}/\underline{A}} > 0$ satiation level, Schmitt-Grohé & Uribe, 2004), $A_F > \underline{A}$, $B_F > \underline{B}$ are assumed. $s_{0,t}$ **is a source of shock**.

- PDC's (m^B_{ht}) access cost:

$$f^B_{ht} = f^B_h(\chi^B_{ht}), \text{ where } \chi^B_{ht} = \frac{m^B_{ht}}{m_{ht}}, \text{ with } f^B_{ht}(\chi^B_{ht}) = f^B_0\left(\frac{1-\chi^B_{ht}}{1-\tilde{\chi}^B}\right)^{\zeta_1},$$

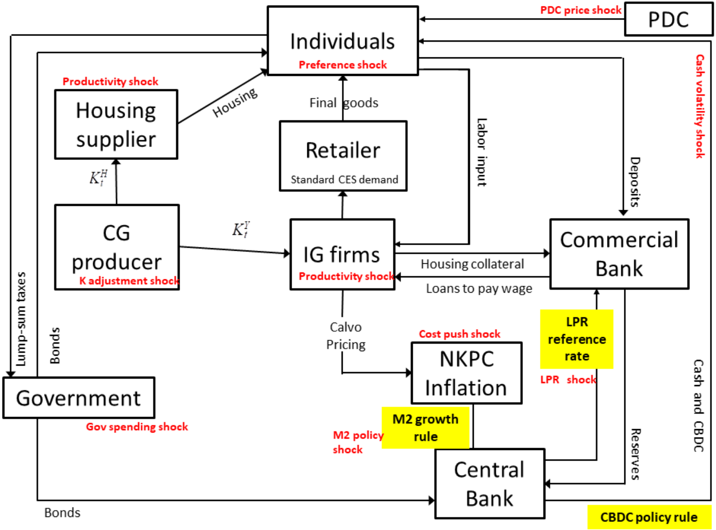
with its price **another source of shock**:

$$P^B_{t+1} = P^B_t + \varepsilon^B_t, \text{ where } \varepsilon^B_t = (1-\rho_B)\tilde{\varepsilon}^B + \rho_B \varepsilon^B_{t-1} + v^B_t, \quad v^B_t \,\tilde{}\, N(0, \sigma^2_B).$$

In summary, ...

	Cash M_t^F	PDC M_t^B	CBDC M_t^{CD}	Deposit D_t
Cash related monetary transaction cost (velocity-based, including all opportunity costs associated with holding & exchanging cash, etc.)	s_t^F	0	0	0
Cost of access & holding (include regulatory concealment costs, etc.)	0	f_t^B	0	0
Interest-bearing	No	No, but through change in market prices, $\frac{\mathbb{E}_t P_{t+1}^B}{P_t^B}$	$i_t^{CD} \in \mathbb{R}$	$i_t^D \geq 0$
Payment instrument	Yes	Yes	Yes	No
Issuer/ Liability of:	Central Bank	Exogenous to the model	Central Bank	Commercial Bank

Model in summary



Central Banking Policies

Balance sheet (with CBDC): $B_t^{CD} + J_t^{CB} + J_t^G = M_t^F + M_t^{CD} + R_t$.
M2 growth rule: For $\phi_t = (m_t^F + d_t)/(m_{t-1}^F + d_{t-1})$,
$\overline{GDP} = \tilde{Y} + \frac{\tilde{P}^H}{\tilde{P}}\tilde{I}^H$,

$$\phi_t = \tilde{\phi}(\frac{1+\pi_t}{1+\pi^T})^{\nu_1^m}(\frac{GDP_t}{\overline{GDP}})^{\nu_2^m}\varepsilon_t^{\phi}, \quad (3)$$

where ε_t^{ϕ} is policy-relevant shock.
LPR reference rate setting: (pseudo-macroprudential style)

$$1 + i_t^L = (1 + \tilde{\imath}^L)\left(\frac{l_t}{l_{t-1}}\right)^{\nu_1}\varepsilon_t^L, \quad (4)$$

where ε_t^L is corresponding shock.
In post-CBDC world, **benchmark CBDC rate** is simply set at
$1 + i_t^{CD} = (1 + i_t^D) - 0.08 < 1$ (below par).

Calibrated parameters

Parameter	Definition	Value
	Households and Money	
β	Household's discount factor	0.998
η_H	Housing preference	0.6
η_N	Disutility of labour	1
A_F	Paper currency transaction cost, 1	0.0098
B_F	Paper currency transaction cost, 2	0.25
ζ_1	PDC holding cost elasticity	30
	Production, Housing, and Capital	
δ^{KY}	Normal capital depreciation rate	0.01
δ^{KH}	Housing capital depreciation rate	0.0133
δ_H	House depreciation rate	0.005
α	Capital Share	0.35
θ	Elasticity of substitution, IG	5.9
ι	Housing production elasticity	0.2
	Banking and Policies	
φ	Probablity of default rate	0.0292
$\varkappa$	Loan-to-value (LTV) ratio	0.6
μ	Reserve requirement ratio	0.125
κ_1	CBDC policy response to inflation	0.5
κ_2	CBDC policy response to GDP	0.5

Series used for estimation and data treatments

Time series	Measurement	Source	Normalised by CPI?	Normalised by pop?	Natural logarithm?	Seasonally adjusted?	Data Frequency Conversion
GDP_t	Gross domestic product	NBSC	√	√	√	√	Converted to monthly using quadratic method
C_t	Private consumption	NBSC	√	√	√	√	Converted to monthly using quadratic method
I_t	Private investment, net of resid. investment	NBSC	√	√	√	√	Converted to monthly using quadratic method
P_t^B	Nominal bitcoin price	CMC	N.A.	N.A.	√	√	Actual monthly series available
IH_t	New housing flows	NBSC	N.A.	√	√	√	Converted to monthly using quadratic method
p_t^H	House Price Index (HPI)	CREIS	√	N.A.	√	√	Actual monthly series available
π_t	Month-on-month CPI inflation	FRED	N.A.	N.A.	N.A.	√	Actual monthly series available
N_t	Total labour hours	MLSS and NBSC	N.A.	√	√	√	Interpolated to monthly using implied monhly CAGR
i_t^L	Nominal market loan/lending rate / LPR	Bloomberg, & estimation	N.A.	N.A.	N.A.	√	Estimated, by summing actual monthly REPO with avg. interest spread of 4 largest comm. banks
pop_t	Working-age population index	NBSC	N.A.	N.A.	N.A.	√	Interpolated to monthly using implied monhly CAGR

NBSC - National Bureau of Statistics of China;
CMC - CoinMarketCap
FRED - Federal Reserve Bank of St. Louis
MLR - Ministry of Land and Resources, P.R.C.
MLSS - Ministry of Labour and Social Security, P.R.C.
PBoC - People's Bank of China;
CREIS - China Real Estate Index System

Estimated parameters

Parameter	Prior distribution Distribution	Mean	Std	Posterior Mean	Std
Structural Parameters					
ς_N	Gamma	1.5	0.5	3.529137	0.52454
η_M	Gamma	0.025	0.001	0.003847	0.000883
ϱ	Beta	0.5	0.2	0.304762	0.167374
ϖ	Beta	0.67	0.10	0.236015	0.044193
Θ_Y	Gamma	10	2.5	18.71734	1.142314
Θ_H	Gamma	10	2.5	6.506278	1.583897
ν_1	Normal	0.5	0.1	0.004374	0.004277
ν_1^m	Normal	-0.65	0.1	-0.7202	0.090581
ν_2^m	Normal	0.30	0.1	0.248963	0.092173
Shock Persistence Parameters					
ρ_s	Beta	0.5	0.2	0.967016	0.007899
ρ_B	Beta	0.5	0.2	0.390274	0.088563
ρ_{zH}	Beta	0.5	0.2	0.744193	0.028808
ρ_{zY}	Beta	0.5	0.2	0.991275	0.003793
ρ_π	Beta	0.5	0.2	0.867952	0.027395
ρ_ϕ	Beta	0.5	0.2	0.339692	0.149349
ρ_L	Beta	0.5	0.2	0.497857	0.065386
ρ_G	Beta	0.5	0.2	0.988768	0.013959
ρ_C	Beta	0.5	0.2	0.902584	0.014751
ρ_K	Beta	0.5	0.2	0.96157	0.013557
Shock Standard Deviation Parameters					
$100\sigma_s$	Inv. gamma	0.1	2	0.817824	0.178761
$100\sigma_B$	Inv. gamma	0.1	2	20.3425	1.673694
$100\sigma_{zH}$	Inv. gamma	0.1	2	1.362452	0.140315
$100\sigma_{zY}$	Inv. gamma	0.1	2	0.434834	0.035434
$100\sigma_\pi$	Inv. gamma	0.1	2	2.118383	0.55418
$100\sigma_\phi$	Inv. gamma	0.1	2	0.04408	0.014068
$100\sigma_L$	Inv. gamma	0.1	2	0.064201	0.005511
$100\sigma_G$	Inv. gamma	0.1	2	0.96191	0.079755
$100\sigma_C$	Inv. gamma	0.1	2	1.620919	0.167745
$100\sigma_K$	Inv. gamma	0.1	2	0.35165	0.05049

Observations from Variance Decomposition and IRFs

- Productivity, Preference and the Cash velocity-related shocks are 3 main drivers of economic volatility (both pre- and post-CBDC world).
- PDC price shock mainly contained within its own market, with non-existent (little) spillover to the production sector and credit (cash and inflation), except for private demand of bonds - unlikely to pose a threat to financial stability.

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- Based on IRF of LPR polcy shock, LPR policy-setting may migitate this by exhibiting stabilization properties in the post-CBDC world.

Optimal Policy Design - LPR-setting rule

Due to its novelty, we first pin down a welfare-optimal policy design for LPR-setting in the benchmark:

Loan Prime Rate (LPR) policy function	Benchmark model	Optimal policy parameters	
	Bayesian-estimated policy parameters	Benchmark model No CBDC	Post-CBDC world With CBDC
Baseline functional form:			
Elasticity: Loan Growth	0.004	0.000	0.000
Alternative policy mandates:			
Elasticity: Loan Growth	n.a.	n.a	n.a
Elasticity: Housing market	n.a.	0.052	0.046
Elasticity: Capital asset market	n.a.	-0.100	-0.108
Elasticity: m^{CD}	n.a.	n.a.	0.461

Instead of loan growth, a more efficient policy function should base on housing market stabilization mandate, while cutting LPR when the capital asset market is in a bearish state.

Optimal Policy Design - LPR-setting rule

• In the "no CBDC" benchmark model, we find a welfare-optimal design of LPR policy function to be

$$1 + i_t^L = (1 + \tilde{\imath}^L) \left(\frac{P_{t+1}^H H_t}{P_t^H H_{t-1}} \right)^{0.052} \left(\frac{P_{t+1}^K K_t}{P_t^K K_{t-1}} \right)^{-0.100} \varepsilon_t^L, \tag{5}$$

where $P_{t+1}^K K_t = P_{t+1}^{KH} K_t^H + P_{t+1}^{KY} K_t^Y \ \forall t$.

• Likewise, in the post-CBDC world, we have a welfare-optimal design of

$$1 + i_t^L = (1 + \tilde{\imath}^L) \left(\frac{P_{t+1}^H H_t}{P_t^H H_{t-1}} \right)^{0.046} \left(\frac{P_{t+1}^K K_t}{P_t^K K_{t-1}} \right)^{-0.108} \left(\frac{m_t^{CD}}{m_{t-1}^{CD}} \right)^{0.461} \varepsilon_t^L. \tag{6}$$

Optimal Monetary Policy Design

• Having pinned down an optimal policy function for LPR-setting, we then search for an optimal policy design for monetary policies—both traditional M2 growth rule and a potential CBDC policy rule.

• In searching for a welfare-optimal design of a potential CBDC policy rule, we also consider a "price-targeting benchmark rule" suggested by Bordo and Levin (2017), as in:

$$1 + i_t^{CD} = (1 + i_{Policy}^{CD})(\frac{1 + \pi_t}{1 + \pi^T})^{\kappa_1}(\frac{GDP_t}{\overline{GDP}})^{\kappa_2}, \quad (7)$$

where $\kappa_1, \kappa_2 \in \mathbb{R}$, and $i_{Policy}^{CD} = \tilde{\imath}^{CD} \in \mathbb{R}$ is a CBDC benchmark rate.

Optimal Monetary Policy Design

Money Supply (M2) Growth Rule and CBDC Policy Function

Monetary policy function	Benchmark model: Bayesian-estimated policy parameters	Optimal policy parameters: Conditional search	Optimal policy parameters: Joint-search of 4 parameters
M2 growth rule			
Elasticity: inflation gap	-0.720	0.000	0.000
Elasticity: output gap	0.249	0.190	0.000
CBDC policy rule			
Baseline form	$i_t^{CD} = i_t^D - 0.08$	$i_t^{CD} = i_t^D - 0.08$	
Elasticity: inflation gap			0.930
Elasticity: output gap			1.732

Note: For welfare-optimal search, LPR policy function is "locked into" the welfare optimal form identified in Table 6.

Optimal Monetary Policy Design

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- This suggests that only one form of active monetary policy should be used after the full implementation of CBDC, if both cash and CBDC are existing concurrently in the Chinese economy.

Concluding Remarks

- A DSGE model with (i) cash and digital currencies; (ii) M2 supply growth rule & LPR policy; for both pre- and (iii) post-CBDC implementation.

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Thank You