Central Bank Digital Currency, Tax Evasion, and Central Bank Independence

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December 2, 2020

MOTIVATION

- Recently, Central Bank Digital Currency (CBDC) has inspired extensive research among central banks and international organizations
  - In particular, Swiss National Bank, Bank of Canada and People's Bank of China have been actively exploring the possibility of issuing CBDC and launched some pilot programs

- Our understanding about CBDC is still limited despite of its relevance to economic activities and macroeconomic policies
  - Existing papers have so far provided limited insight on it
  - There are still many questions that need to be addressed in the the perspectives of i) monetary policy, ii) financial stability, and iii) payment and settlement

CBDC AS DIGITAL CURRENCY

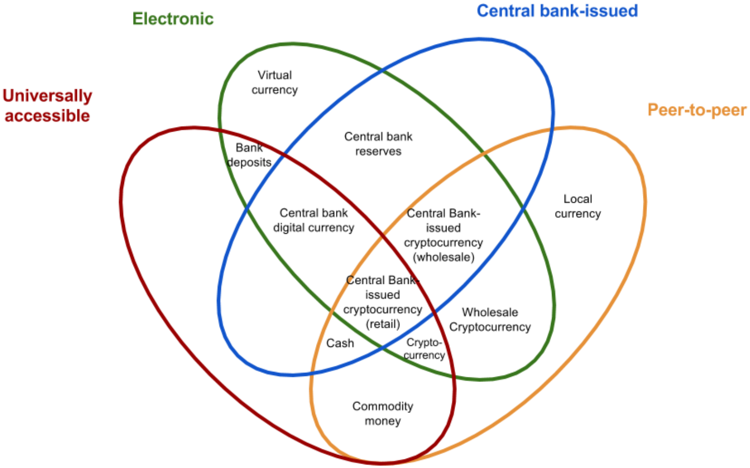
- CBDC, like other digital currencies, necessarily has electronic ledgers (and its record keeper), where the currency status and changes of ownership are electronically recorded

  1. A CBDC digital ledger can be shared with the fiscal authority for tax collection if necessary.
  2. CBDC can bear positive or negative interest
  3. Paying CBDC implies that Payment = Clearing = Settlement

Central Bank B/S	
Assets	Reserves Cash in circulation CBDC Other liability

TAXONOMY OF MONEY

- CBDC for retail



Source: BIS (2017)

OBJECTIVE

- This paper aims to examine how CBDC can affect welfare in an economy in which tax evasion exists in cash transactions
- We answer the following questions by constructing a parsimonious monetary search model with cash and CBDC as a medium of exchange (MOE)
    - What is the condition for the coexistence of cash and CBDC in equilibrium?
    - How does monetary policy affect economic activities such as trade volume by MOE type?
    - How does CBDC affect welfare? What is the optimal strategy of monetary policy?
    - How does the central bank independence affect this effect of CBDC?

MAIN RESULTS

- CBDC is endogenously used as a MOE at least when its real rate of return is greater than that of cash
- It depends on **central bank independence** whether introducing CBDC is welfare-improving
  - When the central bank is **not independent**, CBDC does **not necessarily help to achieve higher welfare**. Even in an economy with only cash, efficient consumption allocations can be achieved by collecting inflation tax for government spending
  - When the central bank is **independent**, CBDC **improves welfare**. CBDC with a positive interest can mitigate a distortion in the relative MU between tax-payed and tax-evaded cosumption that sales tax can generate
- Removing cash does not necessarily expand the feasible allocation set

LITERATURE

- Central Bank Digital Currency: Williamson (2019) and Davoodalhosseini (2018), Keister and Sanches (2019), Andolfatto (2018) and Chiu et al. (2019), Barrdear and Kumhof (2016)
- Dual Currency and Seigniorage: Zhang (2014)
- Tax Evasion and Optimal Inflation: Gomis-Porqueras et al. (2014), Koreshkova (2006), Nicolini (1998)
- Central Bank Independence and Inflation: Martin (2015), Alesina and Summers (1993), Rogo (1985), Wallace (1981)

CONTENTS

MODEL ENVIRONMENT

- Infinite horizon model $(t = 0, 1, \ldots \infty)$ with two sub-periods in each period: Centralized Market (CM) and Decentralized Market (DM)

- Population: Buyers and Sellers (unit mass)

- Preferences
  - Buyers: $E_0 \sum_{t=0}^{\infty} \beta^t \left[u(x_t) - H_t \right]$
  - Sellers: $E_0 \sum_{t=0}^{\infty} \beta^t \left[-h_t + X_t \right]$,

    where x_t is consumption of DM goods and H_t is the labor supply in the CM production. h_t is the labor supply in DM production and X_t is consumption of CM goods.

- Production Technology: one unit of labor produces one unit of perishable consumption goods

MODEL ENVIRONMENT

Centralizd Market (CM)

- A competitive Walrasian market
- Agents adjust their portfolios of cash and CBDC among all agents at their real prices of ϕ_t and ψ_t in terms of CM goods in period t, respectively
- The central bank injects (withdraws) money through lump-sum transfers to (taxes from) agents and the government
- Government provides public goods such as national defense and social infrastructure

MODEL ENVIRONMENT

Decentralized Market (DM)

- Because of anonymity and limited commitment, a MOE is necessary for a trade to occur
  - Cash and CBDC serve as MOE
- Each buyer makes a take-it-or-leave-it offer to the counterpart to determine terms of trade in a pairwise meeting
- A fraction ρ of meetings are not monitored, but the rest $1 - \rho$ are monitored by the fiscal authority
  - In monitored meetings, the fiscal authority imposes a proportional sales tax (τ), regardless of MOE type
  - In non-monitored meetings, it depends on MOE type. Only when buyers use CBDC as a MOE, the fiscal authority can use its record-keeping technology to impose the sales tax

MODEL ENVIRONMENT

- Central Bank supplies two types of currencies: cash (C_t) and CBDC (D_t)
  - $C_{t+1} = \mu_c C_t$ and $D_{t+1} = \mu_d D_t$
  - $\mu_i \geq \beta$ for $\{c, d\}$ for existence of monetary equilibria
  - The central bank budget constraints are given by

$$T_0 = S_0 = \phi_0 C_0 + \psi_0 D_0,$$

$$T_t \leq S_t = \phi_t \left(C_t - C_{t-1}\right) + \psi_t \left(D_t - D_{t-1}\right),$$

where S_t is seigniorage revenue and T_t is a transfer to Government

- Government finances its expenditure (G_t) through the sales tax (τ) and a transfer from the central bank (T_t),

$$G_t = \rho \tau x_t^n \mathbb{I}_{\{d_t^n > 0\}} + (1 - \rho) \tau x_t^m + T_t$$

MODEL ENVIRONMENT

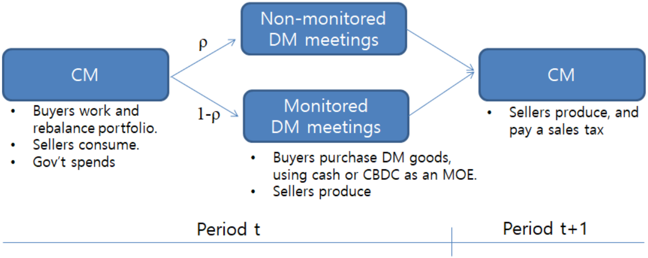


Figure: Market Timing

MAXIMIZATION PROBLEM

- In non-monitored meetings,

$$\max_{x_t^n, c_t^n, d_t^n} u(x_t^n) - c_t^n - (1+\tau)d_t^n,$$

subject to the seller's participation constraint given by

$$\frac{\beta\phi_{t+1}}{\phi_t}c_t^n + \frac{\beta\psi_{t+1}}{\psi_t}d_t^n - x_t^n \geq 0,$$

$x_t^n \geq 0$, $c_t^n \geq 0$ and $d_t^n \geq 0$

MAXIMIZATION PROBLEM

- In monitored meetings,

$$\max_{x_t^m, c_t^m, d_t^m} u(x_t^m) - (1+\tau)c_t^m - (1+\tau)d_t^m,$$

subject to the seller's participation constraint given by

$$\frac{\beta\phi_{t+1}}{\phi_t}c_t^m + \frac{\beta\psi_{t+1}}{\psi_t}d_t^m - x_t^m \geq 0,$$

$x_t^m \geq 0$, $c_t^m \geq 0$ and $d_t^m \geq 0$

SOLUTIONS TO BUYER'S PROBLEM

Lemma

Given the rates of return on cash and CBDC, $\frac{\phi_{t+1}}{\phi_t}$ *and* $\frac{\psi_{t+1}}{\psi_t}$*, and the sales tax rate,* τ*, in non-monitored meetings,*

i) *If* $\frac{1}{(1+\tau)}\frac{\psi_{t+1}}{\psi_t} < \frac{\phi_{t+1}}{\phi_t}$*, then* $x_t^n = f\left(\frac{1}{\beta}\frac{\phi_t}{\phi_{t+1}}\right)$, $c_t^n = \frac{1}{\beta}\frac{\phi_t}{\phi_{t+1}} f\left(\frac{1}{\beta}\frac{\phi_t}{\phi_{t+1}}\right)$*, and* $d_t^n = 0$*;*

ii) *If* $\frac{1}{(1+\tau)}\frac{\psi_{t+1}}{\psi_t} > \frac{\phi_{t+1}}{\phi_t}$*, then* $x_t^n = f\left(\frac{(1+\tau)}{\beta}\frac{\psi_t}{\psi_{t+1}}\right)$, $c_t^n = 0$*, and* $d_t^n = \frac{1}{\beta}\frac{\psi_t}{\psi_{t+1}} f\left(\frac{(1+\tau)}{\beta}\frac{\psi_t}{\psi_{t+1}}\right)$

Here, $f(\cdot) \equiv u'^{-1}(\cdot)$*. Next, in monitored meetings,*

i) *If* $\frac{\psi_{t+1}}{\psi_t} < \frac{\phi_{t+1}}{\phi_t}$*, then* $x_t^m = f\left(\frac{(1+\tau)}{\beta}\frac{\phi_t}{\phi_{t+1}}\right)$, $c_t^m = \frac{1}{\beta}\frac{\phi_t}{\phi_{t+1}} f\left(\frac{(1+\tau)}{\beta}\frac{\phi_t}{\phi_{t+1}}\right)$*, and* $d_t^m = 0$*;*

ii) *If* $\frac{\psi_{t+1}}{\psi_t} > \frac{\phi_{t+1}}{\phi_t}$*, then* $x_t^m = f\left(\frac{(1+\tau)}{\beta}\frac{\psi_t}{\psi_{t+1}}\right)$, $c_t^m = 0$*, and* $d_t^m = \frac{1}{\beta}\frac{\psi_t}{\psi_{t+1}} f\left(\frac{(1+\tau)}{\beta}\frac{\psi_t}{\psi_{t+1}}\right)$

STATIONARY EQUILIBRIUM

We focus on a steady state equilibrium where all real quantities are constant: $\phi_t C_t = \phi_{t+1} C_{t+1}$ and $\psi_t D_t = \psi_{t+1} D_{t+1}$

1. The decision rules of a representative agent optimally solves her/his individual maximization problem, taking the prices, the gov't spending, and the sales tax rate as given

2. Markets clear

$$\rho c^n + (1-\rho)(1+\tau)c^m = \phi_t C_t,$$
$$\rho(1+\tau)d^n + (1-\rho)(1+\tau)d^m = \psi_t D_t,$$

for all $t \geq 1$

STATIONARY EQUILIBRIUM

3 The government and central bank budget constraints hold as follows

$$
\begin{aligned}
G &= \rho\tau\frac{\beta}{\mu_d}d^n + (1-\rho)\tau\left(\frac{\beta}{\mu_c}c^m + \frac{\beta}{\mu_d}d^m\right) + T, \\
T \leq S &= (1-\frac{1}{\mu_c})\left[\rho c^n + (1-\rho)(1+\tau)c^m\right] \\
&\quad + (1-\frac{1}{\mu_d})\left[\rho(1+\tau)d^n + (1-\rho)(1+\tau)d^m\right]
\end{aligned}
$$

TYPES OF EQUILIBRIA

Corollary

Cash and CBDC coexist in equilibrium when $\mu_d \leq \mu_c \leq (1+\tau)\mu_d$.

- When $\tau > 0$, there exist five different types of equilibria which are feasible for monetary policy combinations of (μ_c, μ_d)

Table: Possible Equilibria

Monitored / Non-monitored	Cash only ($\mu_c < \mu_d$)	CBDC only ($\mu_c > \mu_d$)	Both ($\mu_c = \mu_d$)
Cash only ($\mu_c < \mu_d(1+\tau)$)	O (P)	O (S)	O (PP)
CBDC only ($\mu_c > \mu_d(1+\tau)$)	X	O (P)	X
Both ($\mu_c = \mu_d(1+\tau)$)	X	O (PP)	X

Notes: P, PP and S represent Pooling, Partially Pooling and Separating, repectively

SALES AND INFLATION TAX REVENUE

Sales Tax Revenue

$$T^s \equiv \rho \tau f\left(\frac{\mu_d(1+\tau)}{\beta}\right) + (1-\rho)\tau f\left(\frac{\mu_j(1+\tau)}{\beta}\right)$$

for $j \in \{c, d\}$.

Lemma (*Laffer* curve for sales tax collection)

Given μ_j for $j \in \{c, d\}$, $\frac{\partial T^s}{\partial \tau} > 0$ holds in $\tau \in [0, \bar{\tau})$.

SALES AND INFLATION TAX REVENUE

Inflation Tax Revenue

$$S = \rho\left(\frac{\mu_i - 1}{\beta}\right) f\left(\frac{\mu_i}{\beta}\right) + (1-\rho)\left(\frac{\mu_j - 1}{\beta}\right)(1+\tau) f\left(\frac{\mu_j(1+\tau)}{\beta}\right) \geq 0$$

for $i, j \in \{c, d\}$.

Lemma

Given τ and μ_j, $\frac{\partial S}{\partial \mu_i} > 0$ holds in $\mu_i \in [\beta, \bar{\mu}_i)$. Similarly, given τ and μ_i, $\frac{\partial S}{\partial \mu_j} > 0$ holds in $\mu_j \in [\beta, \bar{\mu}_j)$.

WELFARE COMPARISON

- Welfare is defined as

$$W = \rho\{u(x^n) - x^n\} + (1-\rho)\{u(x^m) - x^m\}$$

- We define $\zeta \equiv \frac{\mu_d}{\mu_c}$. Then, $\frac{1}{\zeta} - 1$ can be interpreted as an interest rate on CBDC

- The central bank independence is defined as $T \leq 0$. Given $G > 0$, since it is not efficient to collect the sales tax to make a transfer from the fiscal authority to the central bank, the transfer is zero, i.e. $T = 0$, in equilibrium

WELFARE COMPARISON

Without the Central Bank Independence

- The consolidated government budget constrain is

$$G = \underbrace{\rho\left(u^{'}(x^n) - \frac{1}{\beta}\right)x^n}_{\text{seigniorage from non-monitored}}$$
$$+ \underbrace{(1-\rho)\left(u^{'}(x^m) - \frac{1}{\beta}\right)x^m - (1-\rho)\frac{1}{\beta}\tau x^m}_{\text{seigniorage from monitored}} + \underbrace{(1-\rho)\tau x^m}_{\text{sales tax rev.}},$$

where $\tau = \frac{u^{'}(x^m)}{\zeta u^{'}(x^n)} - 1$ by $u^{'}(x^m) = \frac{\mu_c(1+\tau)}{\beta}$ and $u^{'}(x^n) = \frac{\mu_c}{\beta}$

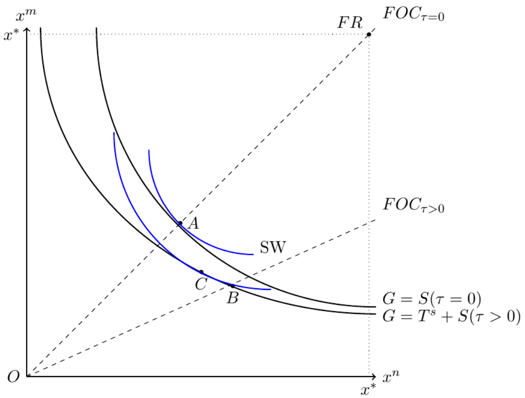
WELFARE COMPARISON

In the economy without CBI

Proposition

1. *In a* **cash-only** *economy without the CBI, the optimal policy mix is* $\tau = 0$ *and* $\mu_c = \hat{\mu}_c > 1$*, where* $\hat{\mu}_c$ *solves* $G = \left(\frac{\hat{\mu}_c - 1}{\beta}\right) f\left(\frac{\hat{\mu}_c}{\beta}\right)$.
2. *In a* **cash and CBDC** *economy without CBI, the optimal policy mix is* $\tau = 0$, $\zeta = 1$ *and* $\mu_c = \mu_d = \hat{\mu}_c > 1$.
3. *In a* **CBDC-only** *economy without CBI, the optimal policy mix is* $\tau = 0$, $\zeta = 1$ *and* $\mu_d = \hat{\mu}_c > 1$.

WELFARE COMPARISON



- Two types of inefficiency: distortion in the relative MU in transactions with and without tax evasion, and tax revenues losses
- The optimal policy mix, $\tau = 0$ and $\mu_c = \hat{\mu_c} > 1$, is consistent with the Ramsey's principle of optimal taxation
- At B, $\mu_d = \mu_c < \mu_d(1+\tau) \Rightarrow$ At A, $\mu_d = \mu_c = \hat{\mu}_c$ and $\tau = 0$

WELFARE COMPARISON

With Central Bank Independence

- The gov't and central bank budget constrains are

$$G = T^s = (1-\rho)\tau f\left(\frac{\zeta\mu_c(1+\tau)}{\beta}\right),$$

$$S = \rho\left(\frac{\mu_c - 1}{\beta}\right) f\left(\frac{\mu_c}{\beta}\right) + (1-\rho)\left(\frac{\zeta\mu_c - 1}{\beta}\right)(1+\tau) f\left(\frac{\zeta\mu_c(1+\tau)}{\beta}\right)$$

- The non-negative seigniorage condition is given by

$$\frac{G}{\beta} = \rho\{u^{'}(x^n) - \frac{1}{\beta}\}x^n + (1-\rho)x^m\{u^{'}(x^m) - \frac{1}{\beta}\}x^m$$

WELFARE COMPARISON

In the economy with CBI

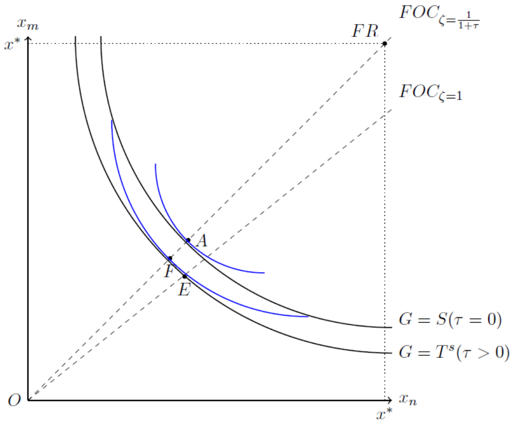
Proposition

4. *In a* **cash-only** *economy with CBI, the optimal monetary and fiscal policy mix is* $\boldsymbol{\mu_c = 1}$, *and* $\boldsymbol{\tau = \hat{\tau} > 0}$, *where* $\boldsymbol{\hat{\tau}}$ *solves* $\boldsymbol{G = (1-\rho)\hat{\tau} f(\frac{1+\hat{\tau}}{\beta})}$.

5. *In a* **cash and CBDC** *economy with CBI, if* G *and* ρ *is not so large, the optimal policy mix is* $\zeta = \frac{1}{1+\tau^*}$, $\mu_c = \mu_c^* > 1$, *and* $\tau = \tau^* > 0$, *where* μ_c^* *solves* $G = (\mu_c^* - 1) f\left(\frac{\mu_c^*}{\beta}\right)$ *and* τ^* *solves* $G = (1-\rho)\tau^* f(\frac{\mu_c^*}{\beta})$.

6. *In a* **CBDC-only** *economy with CBI, the optimal policy is* $\tau = \tau^\# < \tau^*$, $\zeta = 1$ *and* $\mu_d = 1 < \mu_c^*$, *where* $\tau^\#$ *solves* $G = \tau^\# f\left(\frac{1+\tau^\#}{\beta}\right)$.

WELFARE COMPARISON



- Paying a strictly positive interest on CBDC can move the equilibrium allocation from E to F at which welfare is higher
- At E, $\mu_d = \mu_c < \mu_d(1+\tau) \Rightarrow$ At F, $\mu_d < \mu_c = \mu_d(1+\tau)$ (Partially Pooling)

CONCLUDING REMARKS

- When the central bank is not independent, CBDC does not necessarily improve welfare more than cash does
- When the central bank is independent, CBDC improves welfare
  - CBDC can mitigate the inefficiency that the sales tax can generates: misalignment in the marginal rate of substitution in transactions with and without tax evasion
- Tax evasion in the economy with CBI can rationalize the introduction of CBDC with a positive interest rate for higher welfare
- Eliminating cash does not necessarily improve welfare further, compared with the cash and CBDC economy