Central Bank Digital Currency: When Price and Bank Stability Collide

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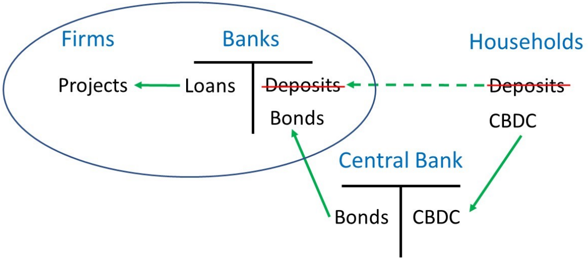
Central Bank Digital Currency or CBDC

- **In this paper:** A **CBDC** is an (interest bearing) account held by households at the central bank or **CB** (Barrdear-Kumhof, 2016)
- Likely to be introduced by many central banks within a few years.
- **Disintermediation Threat:** if HH hold CBDC rather than deposits, banks cannot fund firms ...
  1. ... unless CBDC is limited in scope and attractiveness (Fed) or
  2. ... unless HH re-invest CBDC at banks (Duffie) or ...
  3. ... Central Bank re-funds banks or projects (Brunnermeier-Niepelt).

  This issue arises due to introducing a CBDC.
- **Here:** third option / Consolidate CB+firm+banks+gov into CB



The CBDC Trilemma

In our model: Only HH, CB, projects. CB is financial intermediary.

Key Mechanism

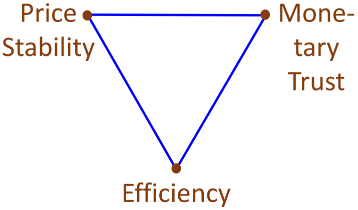
- Nominal Diamond-Dybvig (1983) model for a CB and its CBDC.
- Central bank can always deliver on its nominal obligations.
- But: CB runs can happen: “spending run” on available goods.

Three competing objectives:

1. Traditional CB objective: commitment to **Price Stability**
2. Social optimum, optimal risk sharing: **Efficiency**
3. Absence of runs, financial stability: **Monetary Trust**

Key Result: **CBDC Trilemma**

Of the three objectives,
the central bank
can only achieve two.



Literature

- Academic:
  - Diamond and Dybvig (1983): Banking theory, deposit insurance, and bank regulation.
  - Allen and Gale (1998): system-wide run may alter price level.
  - Skeie (2008): nominal banking, keeping real resources fixed.
  - Freixas-Martin-Skeie (2011): nominal banking. Aggregate and interbank shocks. CB response: interbank rate, liquidity provision.
  - Allen-Carletti-Gale (2014): nominal banking with CB adjusting price level and nom int rates in response to aggr liquidity shocks.
  - Keister and Sanches (2019): Should central banks issue CBDC?
  - Williamson (2021): CBDC in a new monetarist model.
  - Brunnermeier and Niepelt (2019), Niepelt (2021): Pass-through.
  - Andolfatto (2021): CBDC competing with deposits.
- Policy:
  - Barrdear and Kumhof (2016): The macroeconomics of CBDCs.
  - Bordo and Levin (2017): CBDC and the future of monetary policy.
  - Adrian and Mancini-Griffoli (2019): The rise of digital money.

The model: the real portion is Diamond-Dybvid, 1983

- time $t = 0, 1, 2$.
- Continuum $[0, 1]$ of agents:
  - $t = 0$: symmetric, endowed with one unit of a real good
  - $t = 1$: types reveal: "impatient" λ, "patient" $1 - \lambda$.
    Impatient agents: have to consume in $t = 1$.
  - $u(\cdot)$ strictly increasing, concave, RRA greater than one,
    $-x \cdot u''(x)/u'(x) > 1$.
- Real Technology:
  - long term: $1 \rightarrow 1 \rightarrow R$
  - storage $t = 1 \rightarrow t = 2$, available to all: $1 \rightarrow 1$
- **Optimal solution**:

$$\max \lambda u(x_1) + (1 - \lambda) u(x_2) \quad \text{s.t. } \lambda x_1 + (1 - \lambda) \frac{x_2}{R} = 1$$

  Unique solution, where $u'(x_1^*) = R u'(x_2^*)$
- With that: $x_1^* > 1$. (Diamond and Dybvig, 1983)

The model: the nominal portion introduces CBDC.

Definition

A **central bank policy** is a triple $(M, y(\cdot), i(\cdot))$, where M is units of CBDC money per agent, $y : [0,1] \rightarrow [0,1]$ is the central bank's liquidation policy for every observed fraction n of spending agents, and $i : [0,1] \rightarrow [-1,\infty)$ is the nominal interest rate policy.

$t = 0$:
- Agents sell goods to CB for M CBDC units in $t = 1$.
- CB: invests all received real goods in projects.

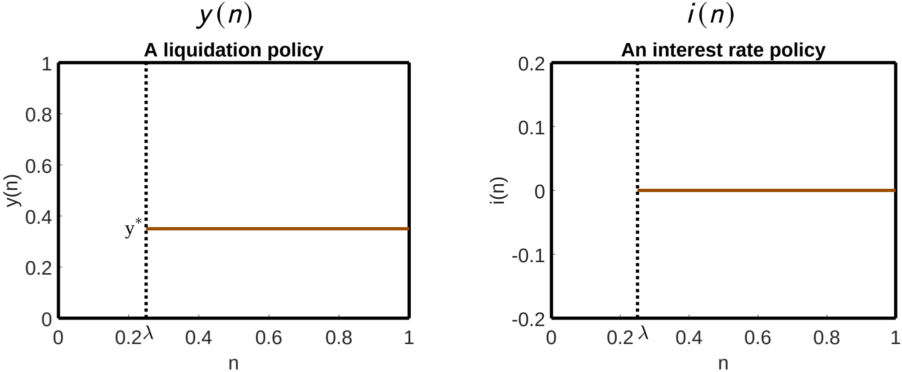
$t = 1$:
- Agents learn type. Impatient agents **spend** M. Patient agents may. Total fraction: $\lambda \leq n \leq 1$.
- CB **observes agg. spending fraction** n.
- CB liquidates fraction $y = y(n) \in [0,1]$ of projects.
- CB sells goods y. Market clearing price P_1.

$t = 2$:
- Remaining agents **spend** $(1 + i(n))M$.
- CB sells remaining project payoffs $R(1 - y)$
- Market clearing price P_2.

Note: "**spend**" not "**withdraw**" (into what? No physical cash).

A (boring) example for a central bank policy

A **central bank policy** is a triple $(M, y(\cdot), i(\cdot))$:



Set M so that $P_1 = 1$ clears the market, if $n = \lambda$ agents spend in $t = 1$.

Equilibrium

Definition

Given a central bank policy $(M, y(\cdot), i(\cdot))$, an **equilibrium** (n, P_1, P_2) is aggregate spending behavior $n \in [0, 1]$, and price levels P_1 and P_2 such that:

1. The individ. consumer's spending decisions are optimal, given aggregate spending n, the central bank's policy $(M, y(\cdot), i(\cdot))$, the price level sequence (P_1, P_2).
2. Given the aggregate spending realization n, the central bank liquidates $y(n)$ and sets the nominal interest rate $i(n)$
3. Given the realization $(n, y(n), i(n))$ and M, the price levels (P_1, P_2) clear the goods market in each period;

Market Clearing

$$\begin{aligned} nM &= P_1 y(n) \\ (1-n)(1+i(n))M &= P_2 R(1-y(n)), \end{aligned}$$

$\Rightarrow n, y(n), i(n)$ pin down the price levels P_1, P_2.

$$P_1(n) = \frac{nM}{y(n)} \quad \text{and} \quad P_2(n) = \frac{(1-n)(1+i(n))M}{R(1-y(n))}$$

Note: $P_2(n)$ can be "anything" per $i(n)$, but $i(n)$ does not affect $P_1(n)$.
Real allocation: only depends on n via $y(n)$:

$$x_1(n) = \frac{M}{P_1} = \frac{y(n)}{n} \quad \text{and} \quad x_2(n) = \frac{(1+i(n))M}{P_2} = \frac{1-y(n)}{1-n}R$$

Given n, patient agents spend in $t=1$, iff $x_1(n) \geq x_2(n)$.

Three competing objectives of the Central Bank

The central bank picks a policy $(M, y(\cdot), i(\cdot))$ to achieve three objectives:

1. **Price stability**: assure stable prices for all/ most n.
   - Key focus: Get $P_1(n)$ to be close to some target $\bar{P}_1$ for all/ most n.
   - Interpretation: Think of $\bar{P}_1 = P_0 * (1 + \pi^T)$ for some un-modelled price level P_0 and some inflation target π^T between $t = 0$ and $t = 1$.
   - Paper also: Achieve some inflation target between period 1 and 2.
2. **Efficiency**: optimal risk-sharing. Achieve the socially optimal real allocation x_1^* arising from the Diamond-Dybvig portion.
3. **Monetary trust** and stability: no equilibria with $n > \lambda$.

Objective 2: **Efficiency**

The social optimum (x_1^*, x_2^*) is an equilibrium, if $y(\lambda) = y^* = \lambda x_1^*$.

Objective 3: **Monetary Trust**

A Run on the Central Bank is a Spending Run:

Definition

A **run** occurs if $n > \lambda$: patient agents also spend in $t = 1$.

Definition

Monetary Trust: a central bank policy, so that a run cannot occur in equilibrium.

In a run, money looses its 'store of value' function.

- Patient agents purchase goods now and hoard them.
- Trust in the monetary system evaporates, monetary instability.
- Compare to:
  - temporary pandemic stockouts.
  - hyperinflations.
  - currency crises.
- But: different from a systemic bank run, where HH turn deposits into cash without spending it.

No run

t=0

t=1

t=2

Run

t=0

t=1


Towel
MORE CUSHION
SCENTED KITCHEN

t=2


20
Kitchen roll
Toilet rolls
Washing up liquid

Implementing **Efficiency** and **Monetary Trust**

Lemma

The central bank policy $(M, y(\cdot), i(\cdot))$ *implements optimal risk sharing* (x_1^*, x_2^*) *in dominant strategies if the central bank*

1. *sets* $y(\lambda) = y^*$ *for any* $n = \lambda$.
2. *sets a liquidation policy that implies* $x_1(n) < x_2(n)$ *for all* $n > \lambda$.

This is achieved with a **run-deterring policy**

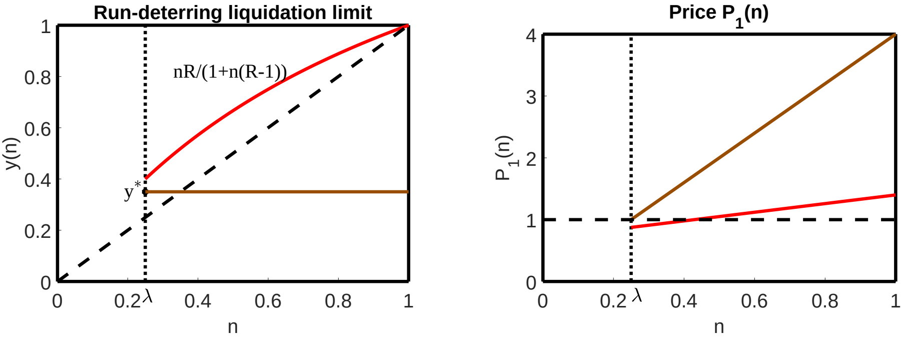
$$y(n) < \bar{y}(n) = \frac{nR}{(1 + n(R-1))}.$$

Corollary (**Trilemma 1**: **no Price Stability**)

Run-deterring policies imply

$$P_1(n) > \frac{M}{R}(1 + n(R-1)), \qquad \text{for all } n \in (\lambda, 1]. \tag{1}$$

Run-Deterring Policies and Price Implications



- For $y(n) \equiv y^*$: $\mathrm{P}_1(\mathrm{n}) = n\frac{M}{y^*}$.
- For $y(n) = \bar{y}(n)$: $\mathrm{P}_1(\mathrm{n}) = \frac{M}{R}(1 + n(R-1))$.
- These two policies violate the **Price Stability** objective for $P_1(n)$.
- This arises "off equilibrium". "Threat" of high inflation for $n > \lambda$.
- Commitment / credibility vs sub-game perfection / time consistency: if $n \neq \lambda$ arises, will a price-stability oriented central bank follow through on that threat?
- What about $P_2(n)$? It depends on $i(n)$. Nothing else does.

Objective 1: **Price Stability**

Why price stability? 50+ years of extensive literature. Pick your poison.

- Traditional CB objective.
- Dual mandate. Maastricht treaty.
- Efficiency loss with higher inflation.
- (Fully) sticky prices in $t = 1$, fixed in $t = 0$: a constraint on CB.

Here: traditional CB objective of **Price Stability**. CB maximizes

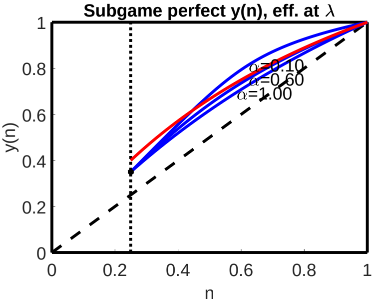
$$V(y, n, \bar{P}) = \alpha W(y, n) - (1 - \alpha)\left(\bar{P} - P_1(n)\right)^2 \tag{2}$$

where $0 \leq 1 - \alpha < 1$ is weight on price stability goal and $W(y, n)$ is expected consumer utility, given liquidation y and spending fraction n,

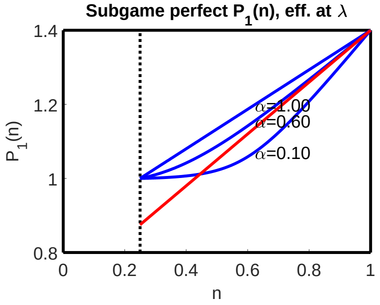
$$W(y, n) = n\, u\left(\frac{y}{n}\right) + (1 - n) u\left(\frac{R(1 - y)}{1 - n}\right) \tag{3}$$

- Consider time-consistent or subgame-perfect equilbria: CB sets optimal $y(n)$, given n.
- Let $P_1^* = M/x_1^*$ be the price level at efficient outcome, when $n = \lambda$.

Price Stability and Efficiency: $\bar{P} = P_1^*$.



Liquidation Policies

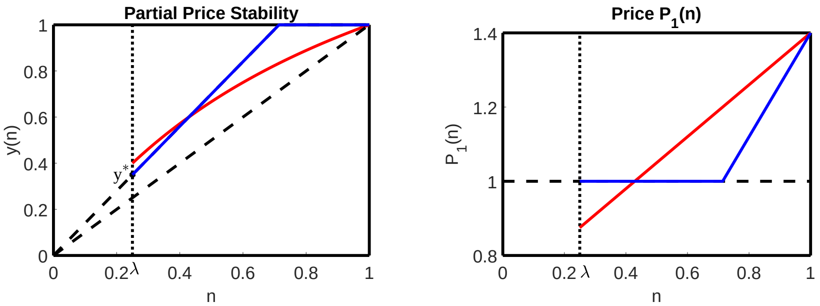


Prices

Figure: subgame-perfect liquidation policies $y_\alpha(n)$ and pricing implications.

- At $n = \lambda$: All levels α reach y^* (because $P_1(\alpha) = \bar{P}$)
- Forα near 1: run-deterring (for $n < 1$).
- For α near 0: subgame-perf liquidation policies give rise to runs.
- **Trilemma 2**: **no Monetary Trust**.

Price Stability and Efficiency, $\alpha \to 0$.

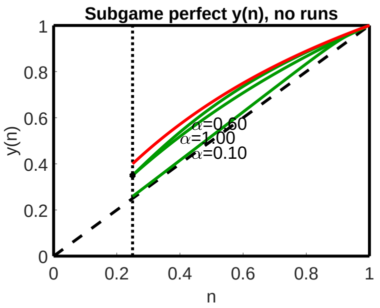


Liquidation Policies　　　　Prices

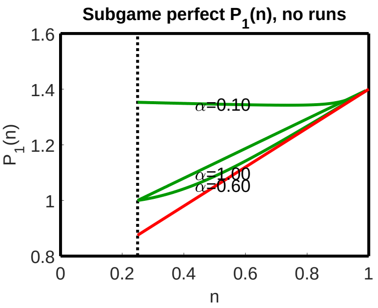
Figure: subgame-perfect partially price stable policies.

- We call this "Partial Price Stability".
- Also arises for: fully sticky prices, unless all is sold.
- **Trilemma 2**: **no Monetary Trust**.

Price Stability and Monetary Trust



Liquidation Policies

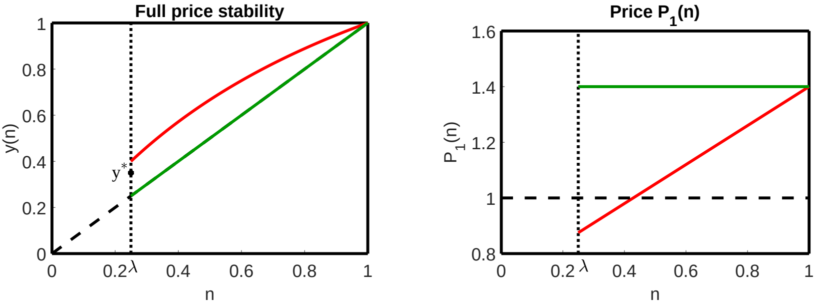


Prices $P_1(n)$

For run-deterring policies: need to raise the price stability target $\bar{P}$.

- Given α: Compute the smallest $\bar{P}(\alpha) \geq P_1^*$ so that the subgame-perfect liquidation policy is run-deterring following every subgame $n > \lambda$.
- **Trilemma 3**: **no Efficiency**.

Price Stability and Monetary Trust, $\alpha \to 0$



Liquidation Policies — Prices

Figure: Subgame-perfect fully price stable policies.

- We call this "Full Price Stability".
- Also arises for: fully sticky prices, unconditionally.
- Or: CB only invests in "storage", i.e. short-term govt bonds.
- Vollgeld, Narrow Banking, Chicago Plan.
- **Trilemma 3**: **no Efficiency**.

Why not change the money supply in $t = 1$?

- **Also allow** for state-contingent $M(n)$ in $t = 1$.
- Suppose $y(n) \equiv y^*$. To maintain price stability at some $\bar{P}$:

$$nM(n) = \bar{P}y^* = \lambda M(\lambda) \tag{4}$$

- Total money spent in $t = 1$ is constant. Money spent per agent decreases with n. CB commits itself to **reduce** quantity of money in response to demand shock and spending spree.
- Implementations:
  - State-contingent money supply.
  - Taxation of individual money holdings.
  - Suspension of spending: only some of the money can be used.
  - Change $i(n)$? Or OMOs, i.e. sell bonds? Won't do the trick: $i(n)$ does not impact real allocation.
- "Suspension of convertibility" becomes "**Suspension Of Spendability**" or **SOS**.
- No runs, stable prices! Problem solved?
- Doubtful. **SOS will undermine trust in monetary system.**
- With general $y(n)$: run issues as before. Agents only care about real allocation. Money is neutral.

Jacklin-inspired solution

- Jacklin (1987) has proposed to issue "equity" instead of deposits.
- Here: in period $t = 0$, do not provide agents with cash. Rather, provide them
  1. with a short-maturity bond, paying $D_1 = \bar{P} y^*$ in $t = 1$.
  2. with a long-maturity bond, paying $D_2 = \bar{P} R(1 - y^*)$ in $t = 2$.
- Agents trade bonds in period $t = 1$.
- Now, the liquidation policy $y(n) \equiv y^*$ will be efficient, financially stable and price stable!
- Trinity resolved? Runs always avoided?
- Not quite. Whether a "run" occurs or not, depends entirely on the real liquidation policy, in contrast to Jacklin.
- Not subgame perfect: given n, $y(n) = y^*$ is not optimal.
- For that and to get $P_1 \equiv \bar{P}$, introduce a discount window at the central bank, to obtain cash in $t = 1$ for the long-maturity bond.
- Promising approach! Match CBDC bonds to asset side!

Conclusions

In a nominal banking model for a central bank and its CBDC.

- The central bank can always deliver on its nominal obligations.
- But: "spending runs" can still happen.

We show the **CBDC Trilemma**

- Implement social optimum, no runs, **but** threaten inflation.
- Keep prices always stable: no runs, **but** inefficient ("Vollgeld").
- Keep prices mostly stable: efficiency, **but** runs may happen.