# Best Before? Expiring Central Bank Digital Currency and Loss Recovery[1]


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[1]Views expressed do not necessarily reflect official positions of the Bank of Canada.

# Personal research agenda

## Central Bank Digital Currency

- Garratt and Van Oordt, 2021. Privacy as a Public Good: A Case for Electronic Cash. *Journal of Political Economy* 129(7), 2157-2180.
- Kahn, Van Oordt and Zhu, 2021. Best Before? Expiring CBDC and Loss Recovery. *Bank of Canada Staff Working Paper* 2021-67.
- Kahn and Van Oordt, 2022. The Demand for Programmable Payments. *Tinbergen Institute Discussion Paper* 2022-076.

## Private Digital Currency

- Bolt and Van Oordt, 2020. On the Value of Virtual Currencies. *Journal of Money, Credit and Banking* 52(4), 835-862.
- Garratt and Van Oordt, 2020. Why Fixed Costs Matter for Proof-of-Work Based Cryptocurrencies. *Bank of Canada Staff Working Paper 2020-27.*
- Garratt and Van Oordt, 2022. Entrepreneurial Incentives and the Role of Initial Coin Offerings. *Journal of Economic Dynamics & Control* 104171.
- Van Oordt, 2022. The Emerging Autonomy-Stability Choice for Stablecoins. *Book Chapter in Holzmann & Restoy.*
- Van Oordt, 2023. Manipulation in Crypto Funding Markets. *Work in Progress.*

# Overview of economic research on CBDC

As central banks explore issuing digital cash substitutes...

- Bank of Canada (2020); Group of Seven Central Banks (2020); European Central Bank (2021); Kosse and Mattei (2022)

...the focus is increasingly shifting from **whether to issue**...

- Andolfatto (2021); Barrdear and Kumhof (2022); Brunnermeier and Niepelt (2019); Chiu et al. (forthcoming); Fernández-Villaverde et al. (2021); Keister and Sanches (forthcoming); Williamson (2022)

...towards **design aspects** of CBDC

- **Security** (Kahn et al., 2020)
- **Interest** (Barrdear and Kumhof, 2022; Jiang and Zhu, 2021)
- **Privacy** (Garratt and Van Oordt, 2021; Lee and Garratt, 2021)
- **Programmability** (Kahn and Van Oordt, 2022)
- **Multiple features** (Abramova et al., 2022; Bijlsma et al., 2021; Huynh et al., 2020; Li, forthcoming)
- **Personal loss recovery through an expiry date**: This paper
  - Note: expiry date not to stimulate spending (Andolfatto, 2020)

# Introduction

An important advantage of physical cash: Payments can be made without power or network connectivity.

- Developing countries
- Remote locations
- Cyberattacks or technological failures
- Natural disasters
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Central banks aim for similar offline capability in CBDCs.

- About 73% of Austrian survey respondents with interest in the digital euro consider offline payment functionality "important" or "very important" (Abramova et al., 2022).

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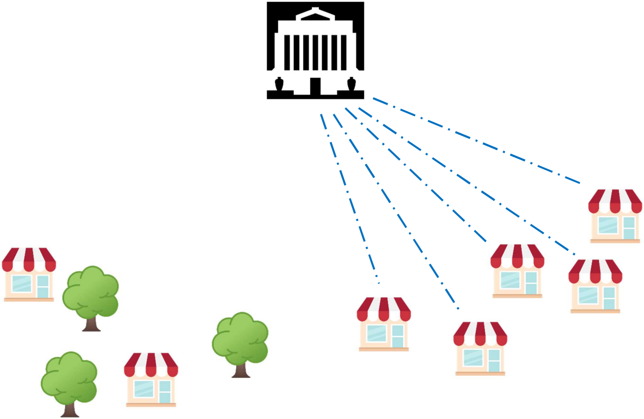
Offline functionality argues for device-based storage.

# Facilitating offline payments and double-spending

Ruling out double-spending requires

1. storing balances uniquely in (tamper-resistant) device, and
2. separation of funds that can be spend with that device

# Facilitating offline payments and double-spending



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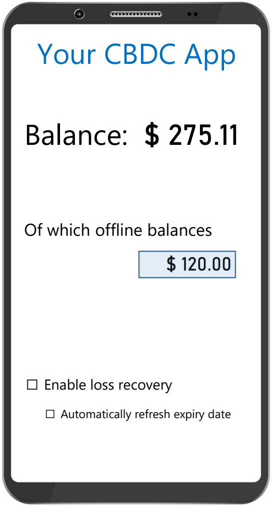
**This paper:** Can we reduce the cost of digital cash losses?

- Yes, we can do so with an expiry date.
- Automatically reimburse consumers expired offline balances
- Interesting economic trade-offs.

# Idea in a nutshell



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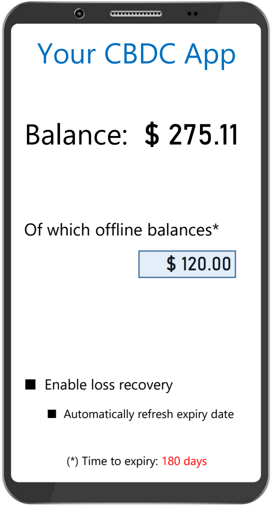

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We consider two information structures:

- **"Higher privacy"**
  - Syncing payor's device with unspent cash does not reveal whether and where payor spent offline balances
  - Onus is on payees to deposit balances before expiry date

# Expiry date and loss recovery

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We consider two information structures:

- **"Higher privacy"**
  - Syncing payor's device with unspent cash does not reveal whether and where payor spent offline balances
  - Onus is on payees to deposit balances before expiry date
- **"Lower privacy"**
  - Syncing device reveals whether and where payor spent offline balances.
  - Payee still needs to deposit balances before expiry date
  - If payor's device reveals offline balances were used to pay a payee without being deposited, then that payee is reimbursed

# Summary of results

- Loss recovery with expiry date could have a substantial positive impact on demand for offline balances and welfare.
- Less costly to set a longer than optimal expiry date than to set an expiry date that is too short.
- More information-sharing between consumers and the central bank can improve loss recovery but has an ambiguous impact on social welfare.

# Outline

- Small model (understand trade-offs)
- Infinite horizon model (idea of quantitative impact)
- Conclusion

# Small model

**Goal:** Illustrate trade-offs related to the expiry date

*Cash*: a money balance that can be used for offline payments

- Stored-value in a payment card or smartphone chip

Cash "insures" consumption during outages, but is subject to losses.

# Timeline: $t = 0$

At $t = 0$, the consumer decides how much cash to hold

- Online balances pay interest $i$, cash does not

A preference shock is realized

- Consumer either want to consume one or two units at $t = 1$

# Timeline: $t = 1$

Two independent random shocks realized

- An outage disrupting the connectivity for payments may occur
- Consumer may lose cash (probability $\delta$)

Consumers buy goods from producers

- If no outage, both online balances and cash can be spent
- If outage, only cash can be spent and consumption will bounded by cash holdings

# Timeline: $t = 2, 3$

At $t = 2$:

- Outage ends if there is one
- Producer may lose offline cash with probability $\eta$
- Withdraw/deposit cash and online payments arrive

At $t = 3$, everybody enjoys counting their money

# Social welfare

**How to account for lost cash?**

- Lost cash is a windfall profit for the central bank
- Reimbursing lost cash is costly to the central bank
- Net welfare effect of reimbursed cash is zero in the aggregate

In equilibrium, social welfare equals expected number of units consumed per consumer

# Results: No expiry date

**Consumers' cash holdings**

Hold cash to purchase 1 or 2 units if the benefit exceeds the cost.

- Benefit comes from "insuring" consumption during an outage
- Cost includes foregone interest and cost of cash losses: $i + \delta$

Constraint for carrying enough cash to purchase a second unit is more demanding

- Only with probability one-half consumers are interested in consuming 2 units

**Social welfare:**

- The more cash consumers carry in equilibrium, the better

# Results: Cash expires quickly (shelf life: 1 period)

**Acceptance:**

Cash expires before the producer can deposit cash in period 2

- Central bank would automatically reimburse the consumer

Producers reject cash

**Cash holdings:**

- None

**Social welfare:**

- No transactions occur during outages...
- Reduced to the level in a no-cash environment

# Results: Cash expires slowly (shelf life: 2 periods)

**Acceptance:**
All offers as if there is no expiration date.

**Cash holdings:**
May hold more cash because the cost of cash losses is reduced

- Consumers are reimbursed for lost cash with some delay
- Cost of carrying cash is

$$i + \delta(1 - \beta^2)$$

**Social welfare:**

- Improves whenever equilibrium cash holdings are higher

# Welfare and Low privacy

After an outage, would consumers be willing to reconnect?

- Consumers who spent all offline cash do not reconnect
- Consumers who have unspent cash reconnect iff $i \geq \eta$ (interest foregone vs windfall if seller loses)

Two situations:

- If $i < \eta$, increase in cost of precautionary cash holdings... *Reduction in social welfare*
- If $i \geq \eta$, some producers charge lower "cash" prices because of reimbursement for cash losses: *May improve social welfare*

# Infinite Horizon Model

Small model helps to better understand economic trade-offs

How about the quantitative impact?

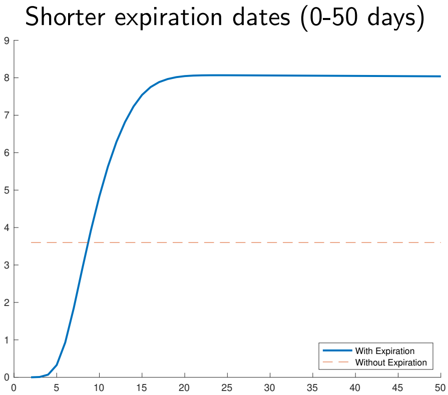
Calibration of more complex model to get a rough idea...

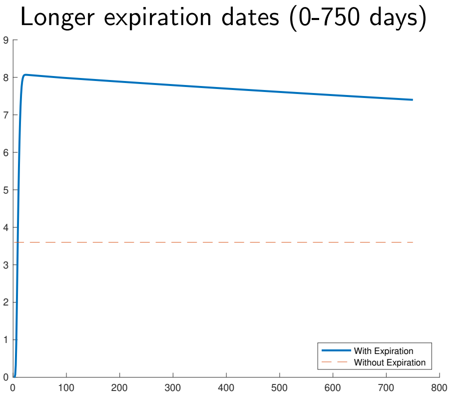
# Parameters and calibration

| Parameter | Daily value | (annualized) |
|---|---|---|
| Discount factor ($\beta$) | 0.99990 | 0.96 |
| Risk aversion ($\sigma$ in $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$) | 0.70 | |
| Loss probability consumer ($\delta$) | 0.0004858 | 0.162 |
| Loss probability producer ($\eta$) | 0.0004858 | 0.162 |
| Outage probability ($\lambda$) | 0.00061 | 0.20 |
| – Length: Poisson distribution | 9.555 | 0.0262 |

Conduct online survey: 16.2% (8.4%) people lost or damaged their cards (phones) in the previous year

# Cash holdings as a function of the time to expiration



# Concluding remarks

- Loss recovery based on introducing an expiry date could have a substantial positive impact on consumer demand for offline digital currency balances.
- The cost of setting a longer than optimal expiry date is small; setting an expiry date that is too short has a large negative impact.
- More information sharing between consumers and the central bank can improve loss recovery but has an ambiguous impact on social welfare.

Vielen Dank!

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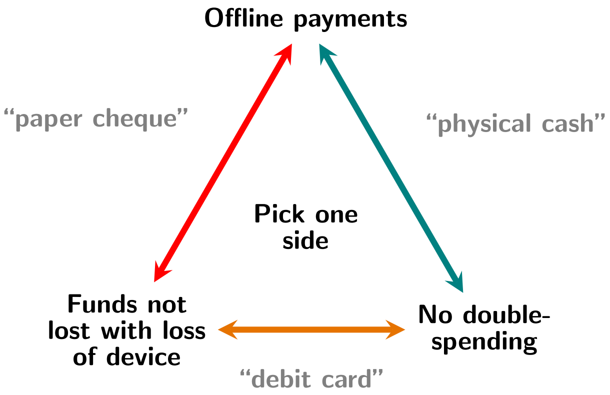
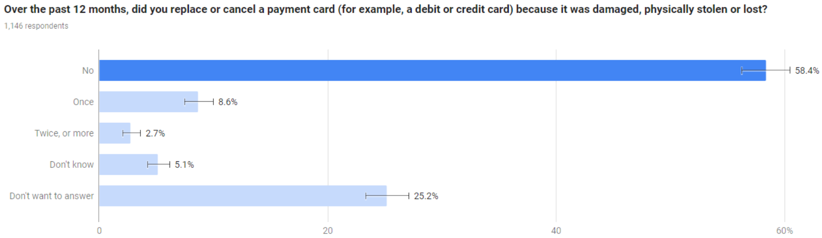
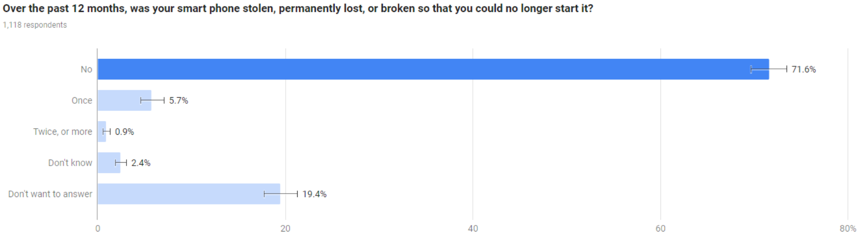
# Offline payment trilemma



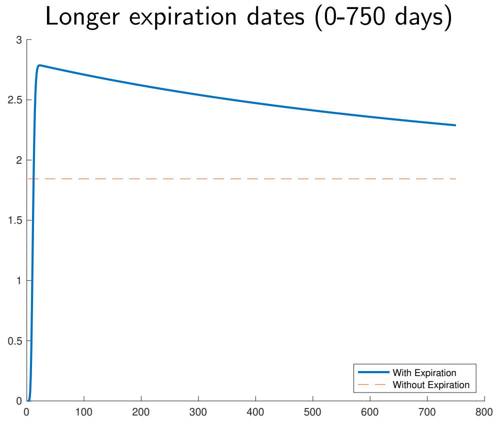
# Some survey evidence in the US

(probability of losing balance during a year: on card $\pm 16\%$, on phone $\pm 8\%$)



# Cash holdings with low discount factor ($\beta = 0.76$)



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