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.

Economic research agenda on CBDC

As central banks explore issuing digital cash substitutes...

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

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

- Barrdear and Kumhof (forthcoming); Brunnermeier and Niepelt (2019); Andolfatto (2020); Chiu et al. (2019); Fernández-Villaverde et al. (2021); Keister and Sanches (forthcoming); Williamson (forthcoming)

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

- **Security** (Kahn et al., 2020)
- **Interest** (Barrdear and Kumhof, forthcoming; Jiang and Zhu, 2021)
- **Privacy** (Garratt and Van Oordt, 2021; Lee and Garratt, 2021)
- **Programmability** (Kahn and Van Oordt, 2021)
- **Multiple features** (Li, 2021; Huynh et al., 2020; Bijlsma et al., 2021)
- **Expiry date and personal loss recovery**: This paper
  - Note: 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
- Geopolitical conflicts

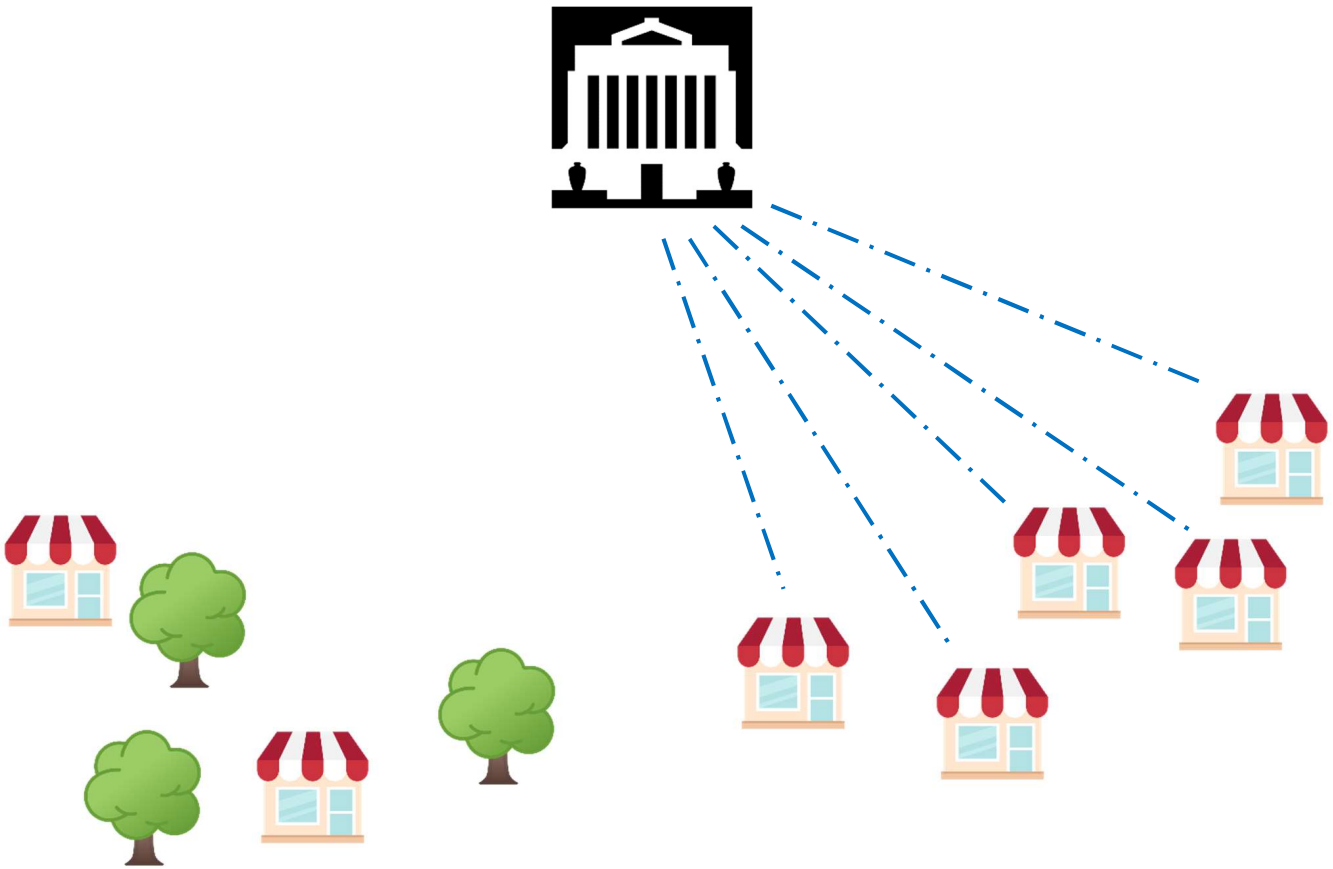
Central banks aim for similar offline capability in electronic cash substitute. Argues for device-based storage.

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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Consequence: Loss of device implies loss of funds...
(analogy to cash)

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

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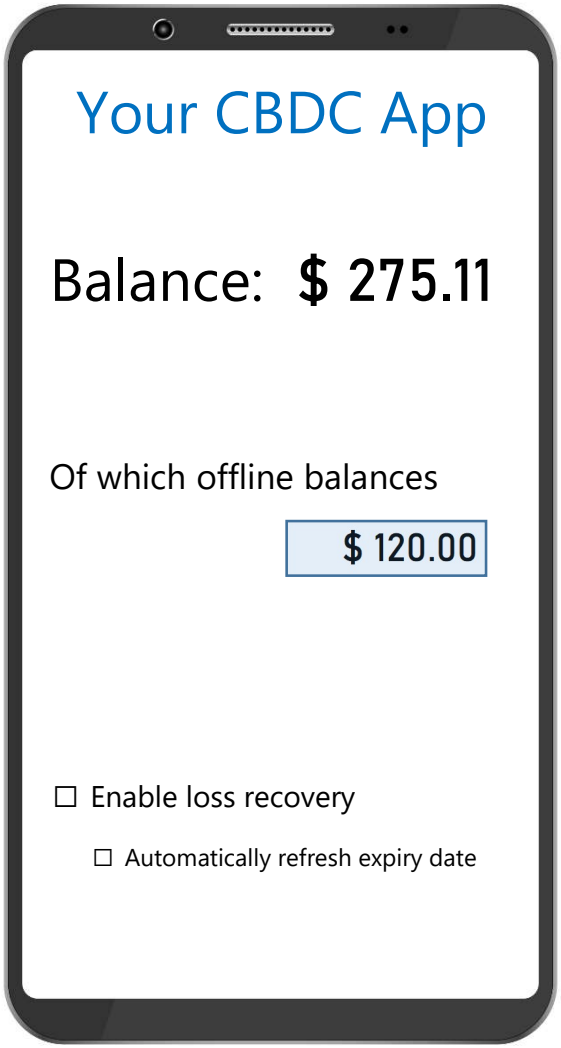
This paper: Can we reduce the cost of digital cash losses?

- 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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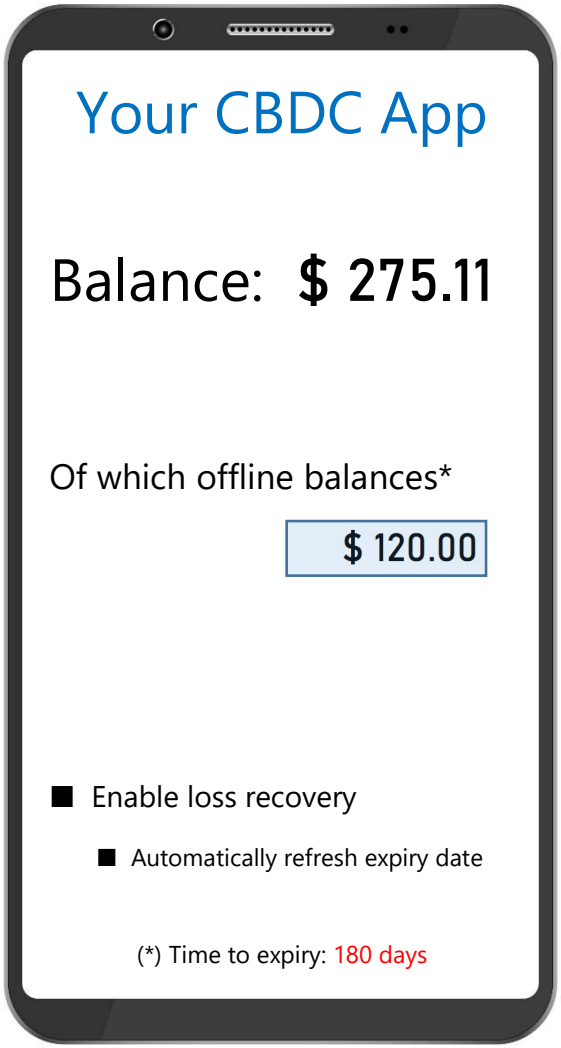

Expiry date and loss recovery

Ok. Expired cash gets reimbursed.

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But who "lost" the cash?

We consider two information structures:

- **"Higher privacy"**
  - Syncing payor's device 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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But who "lost" the cash?

We consider two information structures:

- **"Higher privacy"**
  - Syncing payor's device 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 wants 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

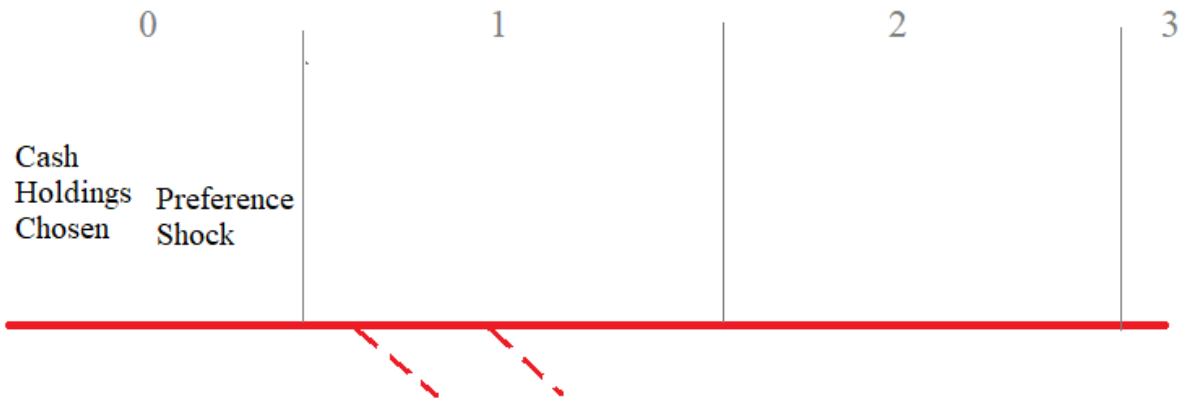
Goal: Illustrate trade-offs related to the expiry date

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: $t = 0$



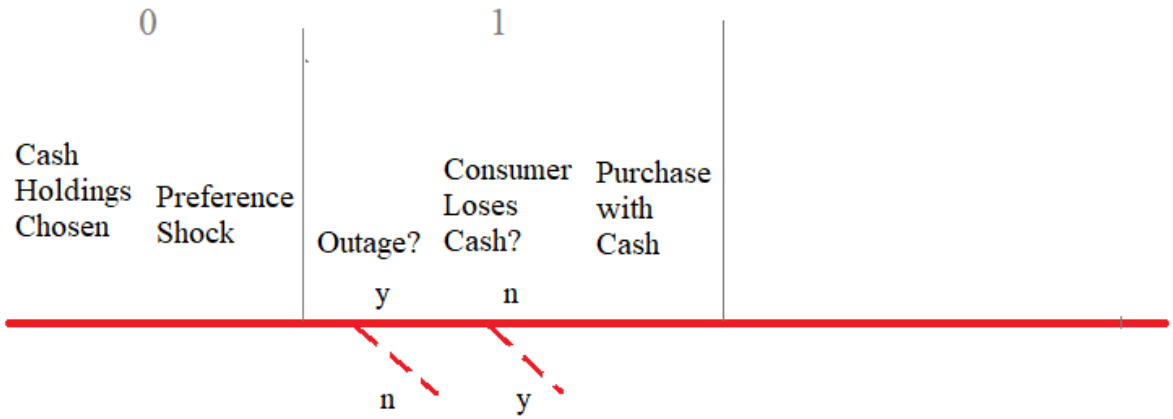
At $t = 0$, the consumer decides how much cash to hold

- 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: $t = 1$



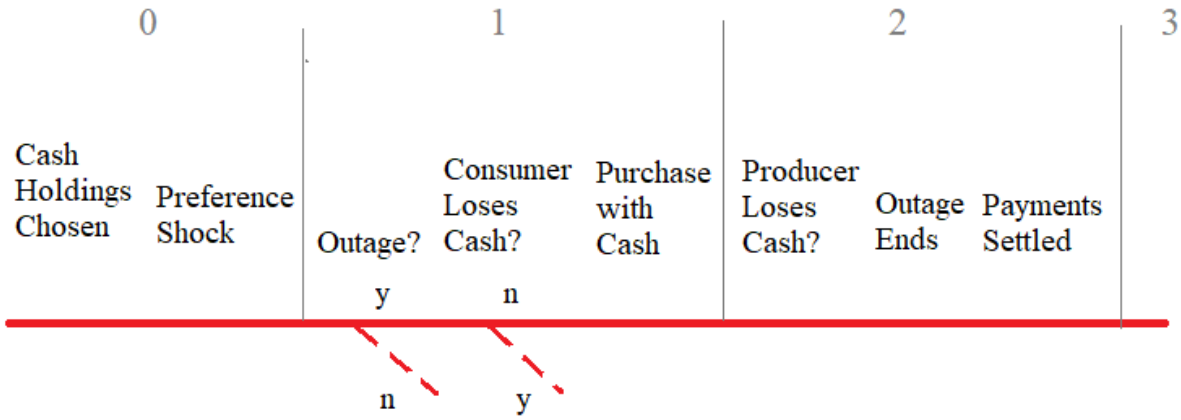
Two independent random shocks realized

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

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 $t = 2$:

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

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

Model Summary

If paid with offline payments, competitive producers charge a premium, to compensate for potential losses; thus consumer's default payment instrument is online.

Consumers hold offline money as a precaution, to facilitate trade during outages. Holdings limited by

- Chance of loss
- Inconvenience or opportunity cost of sequestering on the device (modeled as interest rate differential)

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 ability to consume 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 the second unit

Social welfare:

- Reducing likelihood of losing cash would increase welfare, because increases buyer willingness to hold cash, and thus increases offline trade.

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

Acceptance:
Cash expires in period 2 before the producer can deposit cash

- 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:
Producers know outage will end before expiry date, so willing to accept cash.

Cash holdings:
Consumers 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:

- Strictly improves whenever equilibrium cash holdings are higher
- With high privacy this is generally the case

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 producer loses cash)

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...

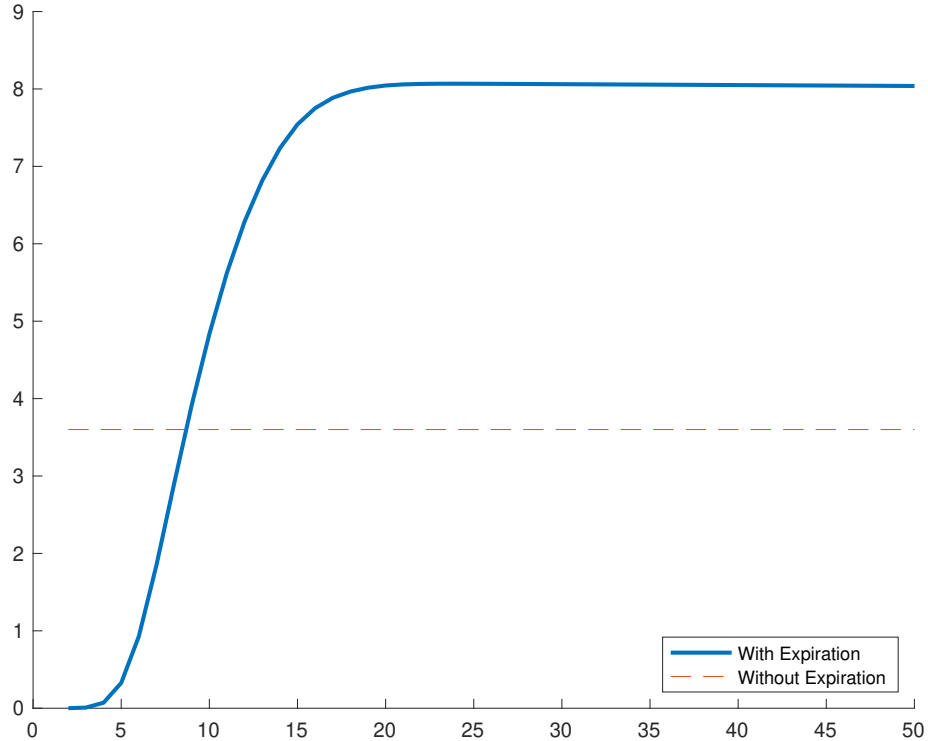
Parameters and calibration

Parameter	**Daily value**	**(annualized)**
Discount factor (β)	0.99990	0.96
Risk aversion (σ in $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$)	0.70	
Loss probability consumer (δ)	0.0004858	0.162
Loss probability producer (η)	0.0004858	0.162
Outage probability (λ)	0.00061	0.20
– Length: Poisson distribution	9.555	0.0262

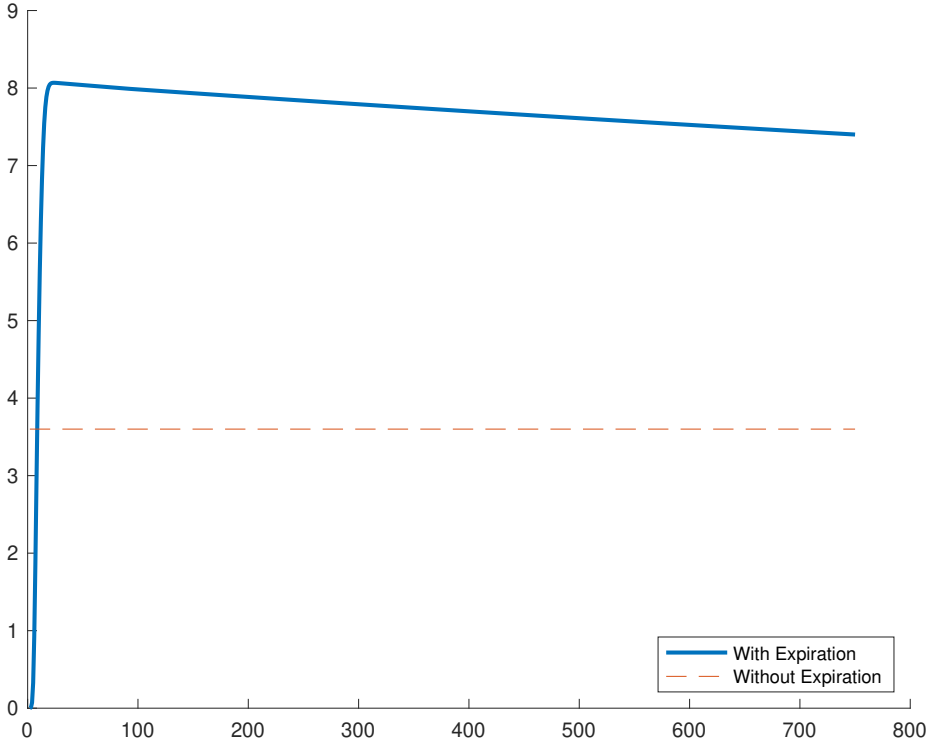
Conduct online survey: 16.2% (8.4%) people lost or damaged their cards (phones) in the previous year

Cash holdings as a function of the time to expiration

Shorter expiration dates (0-50 days)



Longer expiration dates (0-750 days)



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.

Thank you

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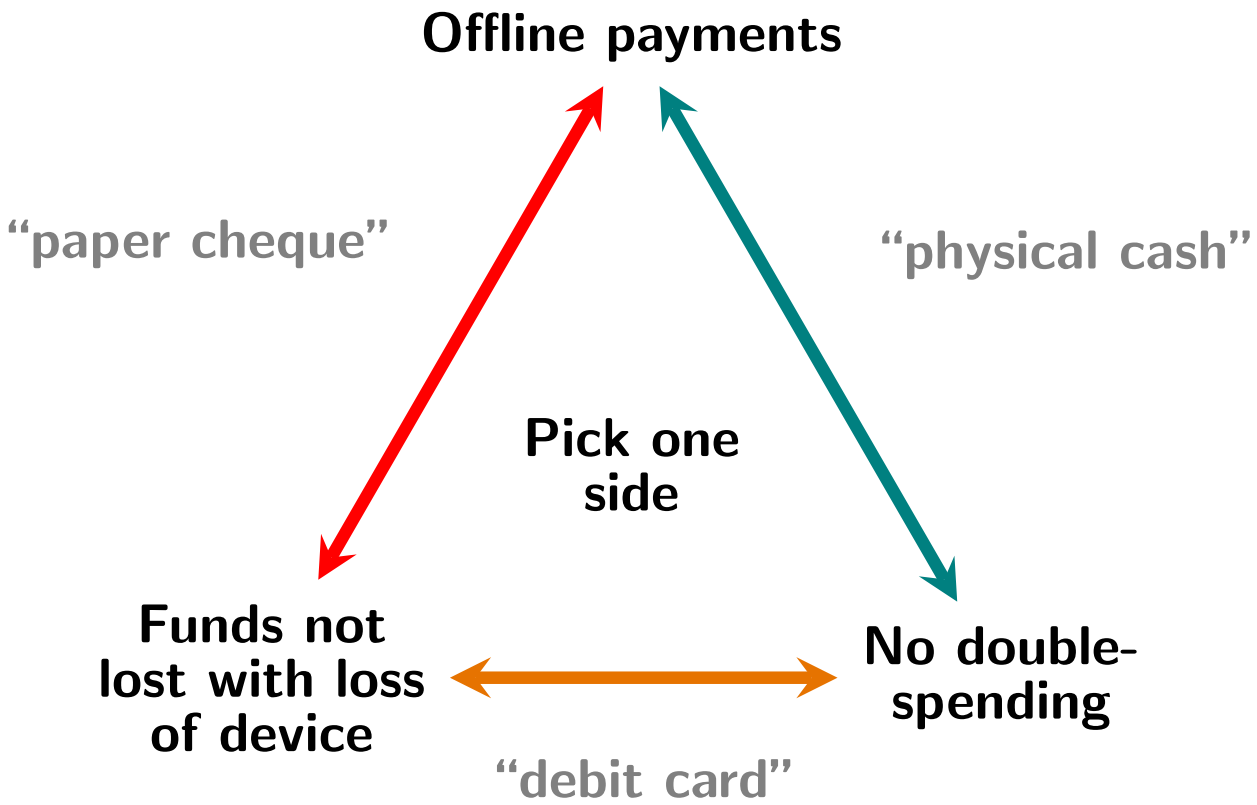
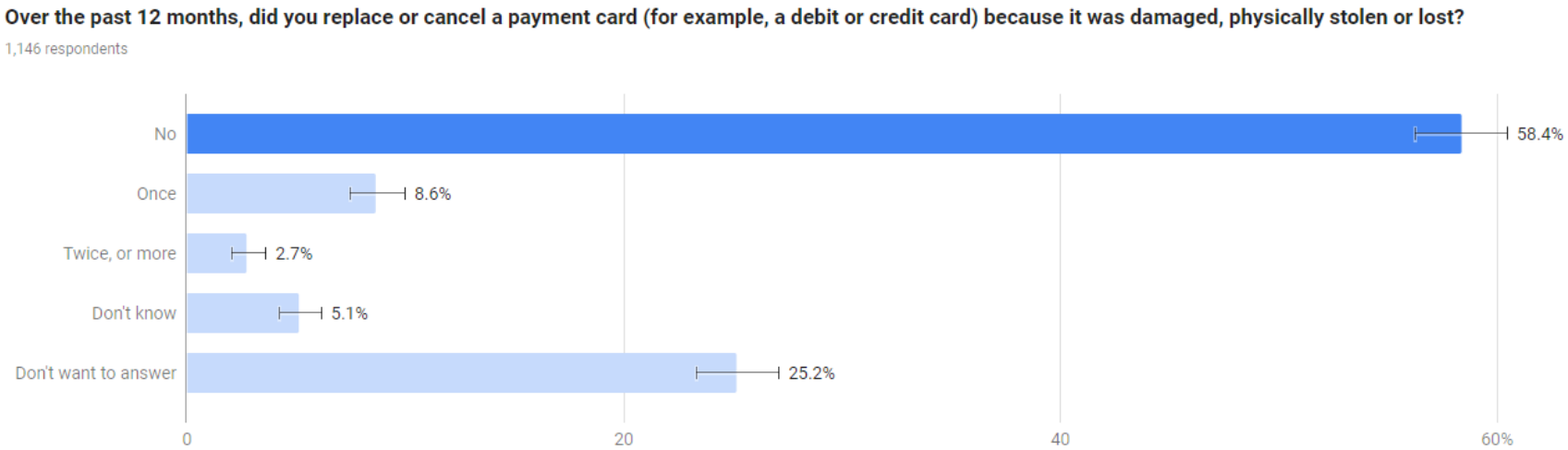
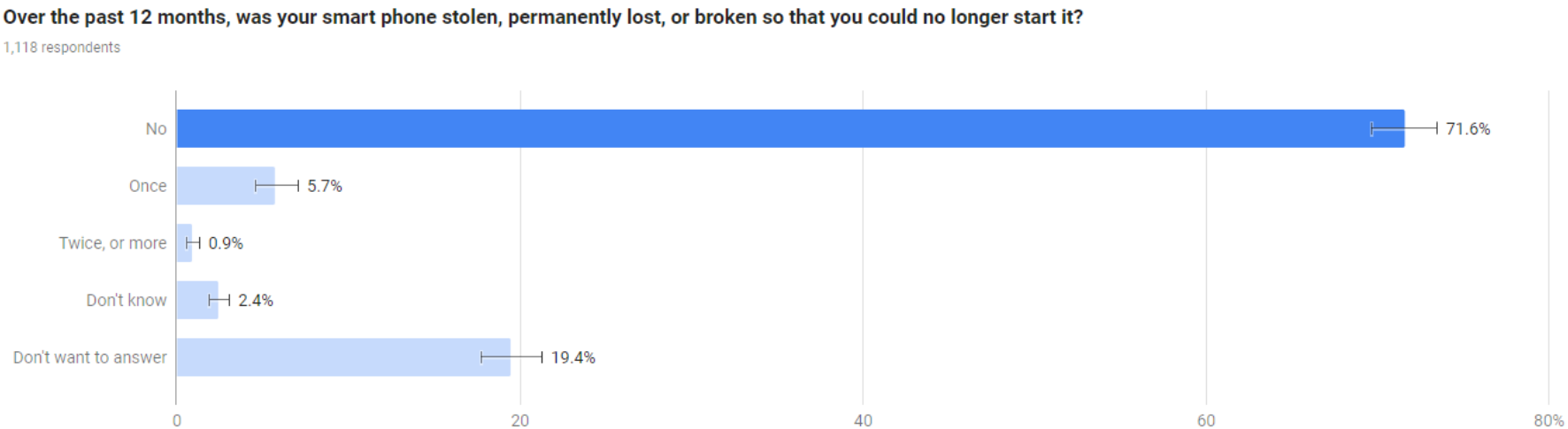
Offline payment trilemma



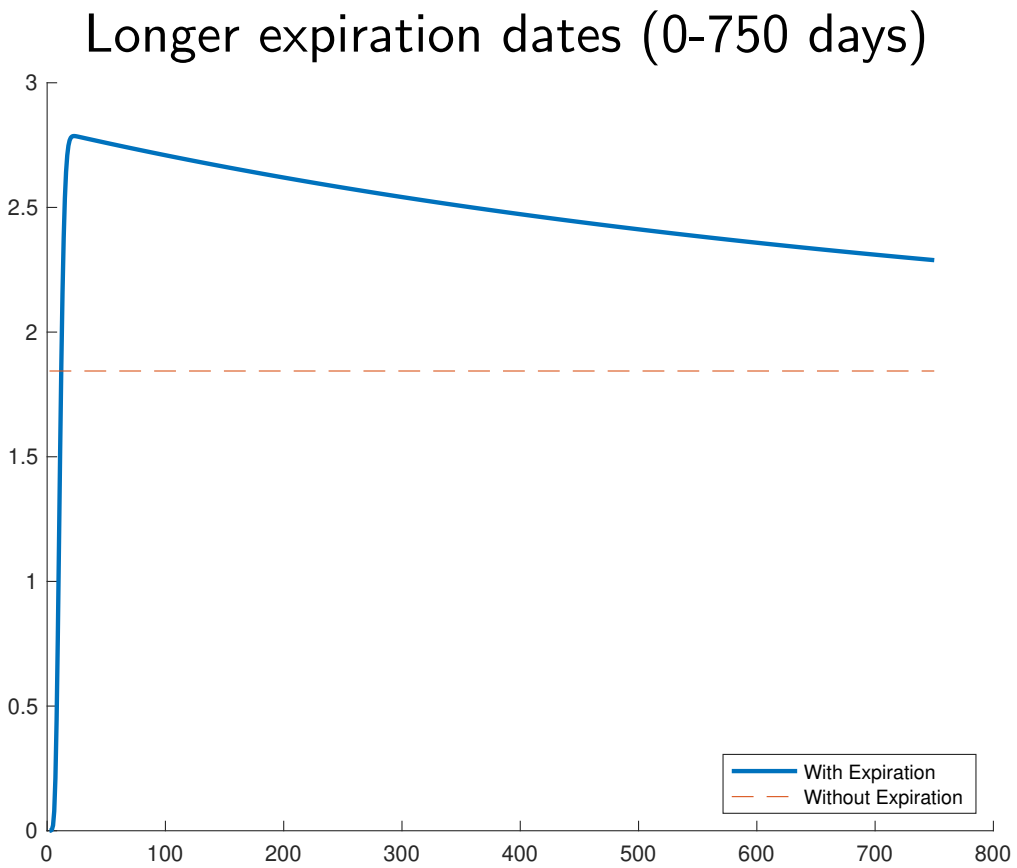
Some survey evidence in the US

(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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