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# Accounts, Tokens and E-money


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LSE Conference on Technology in Finance, Law and Regulation
May 16, 2019

## Payments arrangements as record-keeping systems

Two types of arrangements distinguished by identification requirements:

- **Account-based:** is the *individual* the owner of the account
- **Token-based:** is the *object* real or counterfeit

Helps understand the risk and efficiency tradeoffs:

- What is the cost of identifying and individual/object in a transaction?
- Who has access to the records? For safety and privacy issues
- Who bears cost of protection against malfeasance?
- Who bears liability in event of malfeasance?

# Relevance of the account v. token distinction

## For traditional payments:

- Not a perfect distinction (e.g. Swiss Bank Accounts)
- Still useful: institutional norms are built around this distinction
  - Difference in responsibility of bank for protecting holder of bank note and holder of bank account
  - Price v. Neal 1762, drawee pays forged bill at his peril

## For digital currencies:

- New technologies blur the distinctions
- But institutional norms still active
- So better understanding is crucial for establishing new norms and crafting policy response

# Should the Central Bank Issue E-money?

# E-money: should central banks issue a *new* form of e-money?

Central banks offer some payments media: high value payments systems (restricted access) and cash (universal access)

- **Have the new technologies like DLT and mobile computing changed the risk and efficiency tradeoff in the public provision of centralized and decentralized payments media?**

# Tradeoffs: costs, risks and privacy

Account-based systems track **individuals**

- Cost structure: issuer verifies identities, monitors behaviour and handles collateral. Liability usually lies on the issuer/operator
- Users relinquish some degree of anonymity

Token-based systems track the history of **objects**

- Verification of cash is bilateral; Bitcoin is distributed
- Cost structure: issuer cares about the cost of counterfeiting tokens more than the cost of verification of transactions

# Central bank e-money schemes

1. Account-based scheme: universal accounts at the central bank
2. Token-based schemes
   - Decentralized verification: like the FedCoin proposal
   - Centralized verification: transactions verified by the central bank
   - Delegated schemes: via custodians and intermediaries, like narrow banks

# Central bank e-money: account-based scheme

- Proposal: universal account at the central bank
- Requires: i) account opening; ii) processing of transactions; and iii) management of relationships with the public
- Central banks do not have the comparative advantage in any of these functions
  - Would compete directly with commercial bank deposits
  - Would require dealing frequently with the public

# Central bank e-money: token with decentralized verification

- Proposal: develop/choose tech to issue, store and transfer tokens using a decentralized ledger of tokens
- Requires: i) decentralized token verification tech; ii) underwrite safety of the system
- Example: CADcoin, Fedcoin
- Challenges:
  - Why use decentralized verification when we already have a trusted central party?

# Central bank e-money: token with centralized verification

- Proposal: develop/choose tech to issue, store and transfer tokens using a centralized ledger of tokens
- Requires: i) token verification tech; ii) underwrite safety of the system
- Example: ‘digital cash’ sacrificing some anonymity, speed or safety
- Challenges:
  - Can we develop or choose the appropriate technology?
  - Counterfeiting risk (cyber) in digital is potentially catastrophic

# Central bank e-money: delegated token scheme

- Proposal: delegate management of tokens to special set of institutions. Like “deposited currency schemes” or narrow banks
- Requires: i) institution supervision; ii) technology to prevent individuals from holding central bank tokens directly
- Accounts would necessarily emerge: need to identify owners of tokens
- Challenges:
  - Would current intermediaries have incentives to distribute tokens?
  - For institutions tokens could be inferior to reserves

# Conclusions

- New technologies have not changed the tradeoff for the universal provision of **central bank accounts**
  - System would be expensive
  - Directly compete with commercial banks
- New technologies have potentially improved the tradeoff for the issuance of **digital tokens**
  - Likely increase in the contestability of payments platforms
  - Questions remain on counterfeiting risks (cyber)

# Eggs in One Basket: Security and Convenience of Digital Currencies

# Accounts v. Tokens: relevance for the design of a CBDC

- An ecosystem with public and private solutions is likely to emerge
  - What are the risks of anonymous accounts?
  - How are risks shared between users and suppliers?
  - Are there externalities that should be addressed?
- Should specific security protocols be mandated?
  - For example: length of passwords, how frequently they should be changed, address reuse, two-factor authentication, etc.
- Should liability rules be re-examined?

# Ultimate Issue: choosing level of aggregation

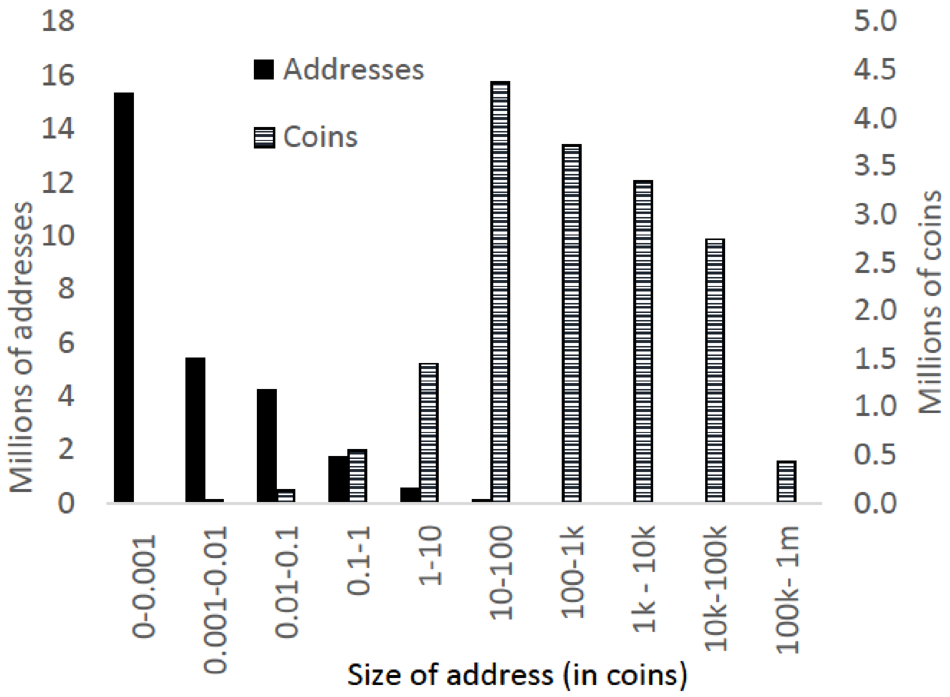
- Tokens are like "mini-accounts," each segregated from the next
- For convenience customers prefer some aggregation into accounts ("wallets" or "purses")
- Fundamental tradeoff for customer: convenience vs safety

Behold, the fool saith, "Put not all thine eggs in the one basket" … but the wise man saith, "Put all your eggs in the one basket and — WATCH THAT BASKET."

Mark Twain *Pudd'nhead Wilson* (1894)

# Empirical Evidence: Account Sizes in Bitcoin

- Bitcoin stores balances in addresses which can contain multiple coins
- Most coins are held in addresses with 10-100 coins or $50,000 to $500,000 USD
- Four addresses hold 100k coins or more, each worth >US$500M



# Empirical Evidence: Risk of Theft in Digital Currencies

- Famous hacks and breaches of wallets (exchanges)
  - MtGox in 2014, lost 750,000 bitcoins, 7% of all bitcoins in circulation (US$473m)
  - Coincheck in 2018 lost 500 million NEM tokens (US$530m)
- Losses are very common: in 2018 US$950m worth of digital currencies where stolen
- 2019: Binance (one of the largest exchanges) lost US$40m, Bithumb US$13m, …

# Framework

## Good guys

- Customers
  - divide wealth among accounts
  - withdraw with some frequency
  - exercise some level of care in withdrawing
- Banks (i.e. wallets)
  - maintain customer accounts
  - require passwords for access
  - establish safety protocols

## Bad Guys

- Hackers
  - focus on banks
  - deterred by complexity of password
- Thieves
  - focus on customers' withdrawals ("man-in-the-middle" attacks)
  - deterred by customer care and protocol complexity

# Hacking and Equilibrium Password Length

First type of risk: hackers attempt to obtain funds directly from bank by brute force

- $N$ accounts with average balance $s$. Each hacking attempt against a bank costs $h$
- Password length is $q$. Payoff of hacking an account is $s$ with probability $N2^{-q}$
- In equilibrium deterrence requires:

$$q \geq \log_2 ( sN / h )$$

- The bigger the bank, the longer the passwords are necessary.

- With Bitcoin market cap (US$1e11), cheap electricity and the best computing equipment (16Th/sec), $q^*$=93. In Bitcoin $q$=256!

# Probability of Theft is Endogenous to Customer Care

If hacking were the only concern, customers should consolidated wealth in a single account under a long password, however:

- Probability of theft depends on care taken by customer ($e_c$) and protocols established by bank ($e_b$):

$$\pi(e_b, e_c)$$

- Cost to customer also depends on care and protocols (e.g. two-factor authentication):

$$c(e_b, e_c)$$

# Moral Hazard Problem: first best

Bank/principal and customer/agent: customer level of care not observable by bank, but protocol terms are observable by customer

- Optimal arrangement minimizes:

$$L\,\pi(e_b, e_c) + e_b + c(e_b, e_c)$$

- If feasible, customer can be induced to take efficient level of care

$$L\,|\pi_c| = c_c$$

- Bank sets efficient protocols (accounting for costs the protocol imposes on customers)

# Moral Hazard Problem: second best

If costs cannot be imposed on customer (e.g. regulatory limitations)

Say losses are divided $L = L^b + L^c$

- Customer will reduces care:

$$L^c \, |\pi_c| = c_c$$

- Reaction by bank can be:
  - increase stringency of protocols (substitution for customer care) *or*
  - decrease stringency of protocols (to induce increased customer care)

# Password Aggregation Programs

- Reduce cost to customer by holding passwords in a common location, backed by a master password
- In effect consolidate separate accounts into a single account

Interrelation of probability of theft

- Theft when accessing one account leads to theft in all accounts (thus theft at frequently-used accounts imposes disproportionate risk on an infrequently-used account)

# Password Aggregation Programs: implications

- If customer bears entirety of cost of theft, his choice regarding password aggregation programs is efficient
- If he bears less than full cost, he may choose to use password aggregation despite its social costs
- Then banks will have incentive to engage in costly adjustments to block password aggregation

# Policy Interventions

- Externalities suggest a role for policy interventions like mandating certain protocols but these depend on the particular setup
- Requires a more detailed examination of liability rules  and how banks (wallets) are competing

# Conclusions

# Conclusions

- Plenty of work is needed before deciding to issue central bank digital currency (examine its implications, choose a design)
- Even without it, policy makers (consumer protection, privacy agencies) might want to examine the issues of security in private digital currencies

Thanks!

# CBDC Conference and Policy Roundtable, October 16-18, 2019

- Policy Roundtable for Central Bankers: October 16, 2019
- Conference on the Economics of CBDC: October 17-18, 2019