

# Cryptocurrencies, Fintech, and All That: Monetary Economics in the 21st Century

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- In any given day, you might read about:
  1. Cryptocurrencies.
  2. Central bank digital currencies.
  3. The blockchain and other distributed ledgers.
  4. Tokenization.
  5. Smart contracts.
  6. Fintech.
  7. ...
- Furthermore, you can even encounter all these new developments in your daily life.



# Questions

- What do all of these new developments mean?
- How should we think about these new topics from the perspective of monetary economics?
  1. Positive economics.
  2. Policy advising (national and global).
- Of course, a fair treatment of these topics will require (at least!) a whole semester. Thus, I will be highly selective in my discussion.
- Notice: different (although not unrelated!) from perspectives in computer science, microeconomics, law, and business.

- **Cryptocurrencies: A Crash Course in Digital Monetary Economics**, Australian Economic Review, vol. 51, no. 4, pp. 514-526.
- **Can Currency Competition Work?**, Journal of Monetary Economics, vol. 106, pp. 1-15.
- **Central Bank Digital Currency: Central Banking For All?**, NBER WP 26753.
- **Central Bank Digital Currency: When Price and Bank Stability Collide**, NBER WP 28237.

# Structure of the talk

1. I will first briefly review why money is the memory of society.
2. I will use that framework to think about private cryptocurrencies (with a coda on blockchain).
3. I will analyze central bank digital currencies.
4. I will offer some concluding remarks.

**Money is memory**

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# Why do we use money?

- Money is one of the most remarkable inventions of humankind.
- It solves a fundamental challenge of any society that relies on the division of labor: the “double coincidence of wants” problem.
- A simple example:
  1. Every fall semester, at Penn, I teach “Global Economic History.”
  2. Students want to take my class.
  3. But the students do not produce anything I want.
  4. For example, I want to buy a bottle of milk (and possibly, on another day than the day of my lecture).
  5. Hence, barter is not a realistic solution except in a few exceptional cases.
- In other words, trade is subject to frictions. These frictions are “essential.”



# How can we get around trading frictions?

1. We can assign goods in society through a central planner. Works in small groups (e.g., a family, a small hunter-gatherer band), but this system cannot be scaled up due to informational problems.
  - Experience of the Soviet Union (and, no, AI will never fix this problem).
2. We can conduct all transactions simultaneously in a centralized market à la Arrow-Debreu.
  - This trading arrangement is fruitful for answering many questions of interest in economics, but it is not realistic: logistic costs would be too high.
  - Problem of enforceability.
3. We can keep a ledger where each member of society would write their production (or received transfers) as positive balances and her consumption (or negative transfers) as negative balances. My experience of a spring break trip when I was in college.
  - Again, the problem of scalability.
  - But there is an intuition here we might be able to exploit.



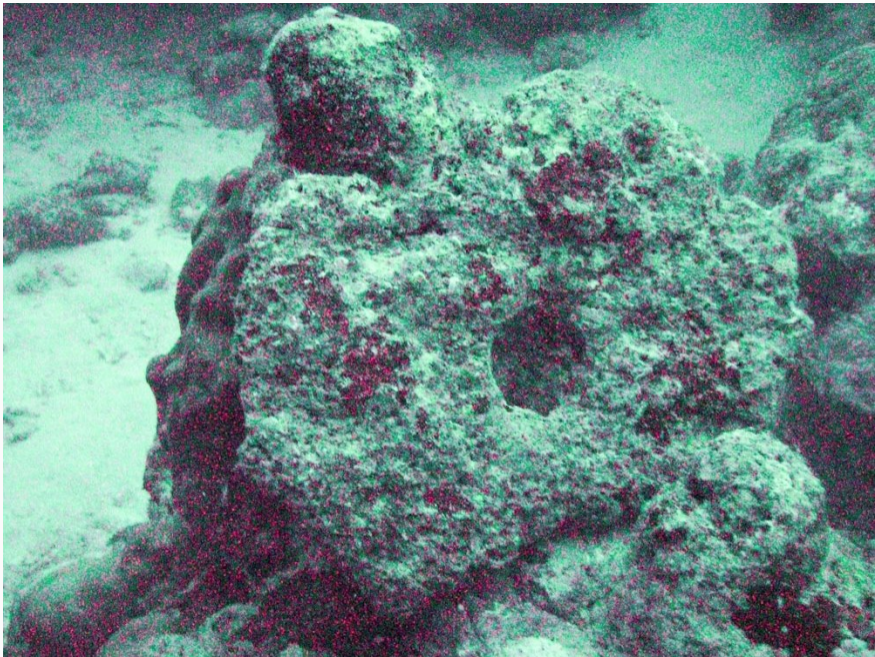
© Alamy Stock Photo

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16			16
9			9
11			11
304			304
1980			1980
11			11
16			16
1			1
2			2
<u>1050</u>			<u>1050</u>

## A better ledger

- Usually, we do not need all the information in the ledger.
- If we are willing to accept “finality,” we only need to keep the current balance in the ledger.
  - It can be implemented as a “balance of gifts.”
  - Or in terms of tokens.
  - *Rai stones*, the traditional money employed on Yap Island.
  - Some underwater!
- Advantage of tokens: you can run a decentralized system without a central bookkeeper. Informationally much more efficient.
- In other words: money is the memory of society! (Kocherlakota, 1998).





## A working definition of money

1. Because of the division of labor, we need to trade among us.
2. Trade through barter is unfeasible, in particular intertemporal trade.
3. Societies work around this problem by having a decentralized net-balance ledger system expressed in tokens.
4. We call these tokens “money.”

### **A working definition**

Money is an informationally efficient recordkeeping mechanism to allow for decentralized trading under essential frictions.

## A few implications

- In this definition, money is a medium of exchange and store of value (both are, actually, the same: intra vs. intertemporal trade), but not necessarily a unit of account (*Livre Turnois*).
- Different assets have different degrees of “moneyness.”
- Money is created every time we engage in a decentralized ledger.
- Whoever says money, says trade frictions: we cannot assume, by default, that welfare theorems are going to hold or that we will have unique equilibria.



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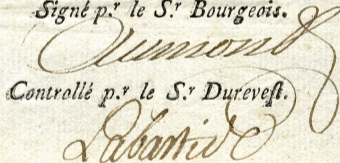
Cent livres Tournois:

**L**A BANQUE promet payer au Porteur à vüe Cent livres Tournois en Especes d'Argent, valeur reçüe. A Paris le premier Janvier mil sept cens vingt.

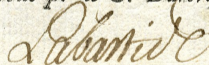
Vu p.<sup>r</sup> le S.<sup>r</sup> Fenelon.



Signé p.<sup>r</sup> le S.<sup>r</sup> Bourgeois.



Contrôlé p.<sup>r</sup> le S.<sup>r</sup> Durevest.



Coupon Bond

10000

10000



THE UNITED STATES OF AMERICA

26925E

4 1/4% TREASURY BOND OF 1975-85 Dated April 5, 1980 Due May 15, 1985 Redeemable on and after May 15, 1975

FOR VALUE RECEIVED

PROMISES TO PAY TO THE BEARER THE SUM OF

TEN THOUSAND DOLLARS

ON MAY 15, 1985, AND TO PAY INTEREST ON THE PRINCIPAL SUM FROM THE DATE HEREOF, AT THE RATE OF FOUR AND ONE-QUARTER PERCENT PER ANNUM, PAYABLE ON A SEMIANNUAL BASIS ON NOVEMBER 15, 1980, AND THEREAFTER ON MAY 15 AND NOVEMBER 15 IN EACH YEAR UNTIL THE PRINCIPAL HEREOF SHALL BE PAYABLE, UPON PRESENTATION AND SURRENDER OF THE INTEREST COUPONS HERETO ATTACHED AS THEY SEVERALLY MATURE, AT THE TREASURY DEPARTMENT, WASHINGTON, D. C., OR, AT THE HOLDER'S OPTION, AT ANY AGENCY OR AGENCIES IN THE UNITED STATES WHICH THE SECRETARY OF THE TREASURY MAY FROM TIME TO TIME DESIGNATE FOR THE PURPOSE, THIS BOND IS ONE OF A SERIES OF BONDS OF THE UNITED STATES, AUTHORIZED BY THE SECOND LIBERTY BOND ACT, AS AMENDED, ISSUED PURSUANT TO AND SUBJECT TO THE TERMS AND CONDITIONS OF TREASURY DEPARTMENT CIRCULAR NO. 3040, DATED APRIL 4, 1980, AND DESIGNATED 4 1/4 PERCENT TREASURY BONDS OF 1975-85. ALL OR ANY OF THE BONDS OF SAID SERIES MAY BE REDEEMED, AT THE OPTION OF THE UNITED STATES, ON AND AFTER MAY 15, 1975, AT PAR AND ACCRUED INTEREST, OR ANY INTEREST DUE OR DUE, ON FOUR MONTHS' NOTICE OF REDEMPTION GIVEN IN SUCH MANNER AS THE SECRETARY OF THE TREASURY SHALL PRESCRIBE. IN CASE OF PARTIAL REDEMPTION THE BONDS TO BE REDEEMED WILL BE DETERMINED BY SUCH METHOD AS MAY BE PRESCRIBED BY THE SECRETARY OF THE TREASURY. FROM THE DATE OF REDEMPTION OR MATURITY IN ANY SUCH NOTICE, INTEREST ON THE BONDS CALLED FOR REDEMPTION SHALL CEASE. THE INCOME PROCEEDS FROM THIS BOND IS SUBJECT TO ALL TAXES IMPOSED UNDER THE INTERNAL REVENUE CODE OF 1954. THIS BOND IS SUBJECT TO ESTATE, INHERITANCE, GIFT OR OTHER EXCISE TAXES, WHETHER FEDERAL OR STATE, BUT IS EXEMPT FROM ALL TAXATION NOW OR HEREAFTER IMPOSED ON THE PRINCIPAL OR INTEREST HEREOF BY ANY STATE, OR ANY OF THE TERRITORIES OF THE UNITED STATES, OR BY ANY LOCAL TAXING AUTHORITY. THIS BOND, UPON THE DEATH OF THE OWNER, WILL BE REDEEMED AT THE OPTION OF THE DULY CONSTITUTED REPRESENTATIVES OF THE DECEASED OWNER'S ESTATE, AT PAR AND ACCRUED INTEREST, IF IT CONSTITUTES PART OF SUCH ESTATE AND THE PROCEEDS ARE TO BE APPLIED TO THE PAYMENT OF



# GOL

CAMPEONATO DE LIGA  
1984/85

R. MADRID

35

DELANTERO  
**SANTILLANA**

Carlos Alonso González  
Nació en Santillana del  
Mar (Cantabria)  
el 23/8/52

HISTORIAL DEPORTIVO  
Racing, Real Madrid.

**\*EDITORIAL MAGA\***

# How do we organize this recordkeeping mechanism?

- Just a few questions:
  1. Who should issue the tokens?
  2. What is the form of the tokens?
    - In particular, should the token be intrinsically worthless or incorporate some value (such as a precious metal)?
    - In what denominations?
    - How do we make it durable, and easy to store and transport?
    - How do we warranty that it is readily recognized and not a forgery?
  3. Who receives the initial endowment of tokens?
  4. How many tokens are socially optimal?
  5. And when should we issue them?

## Public vs. private monies

- Notice that nothing that I have said so far requires money to be issued by a government.
- In fact, money started as being “private”: commodity monies.
- Coinage was only taken over by the government later in the development of money.
- Current government money is nothing more than consols with zero nominal coupon.
- Saves on the use of commodities, allows for control of inflation, and the creation of liquidity when needed.
- This observation motivates the fiscal theory of the price level and why there is a Laffer curve of seignorage.
- “Legal tender” does not mean much (“Swiss dinar”).

## Pellofas from La Seu d'Urgell and Peramola





البنك المركزي العراقي

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ع ٥٩  
٠٨٧٠٦٧٦

عن البنك المركزي العراقي

خمسة وعشرون ديناراً

ورق نقدي صادر بموجب القانون

المخازن

٢٠١٤



# Cryptocurrencies

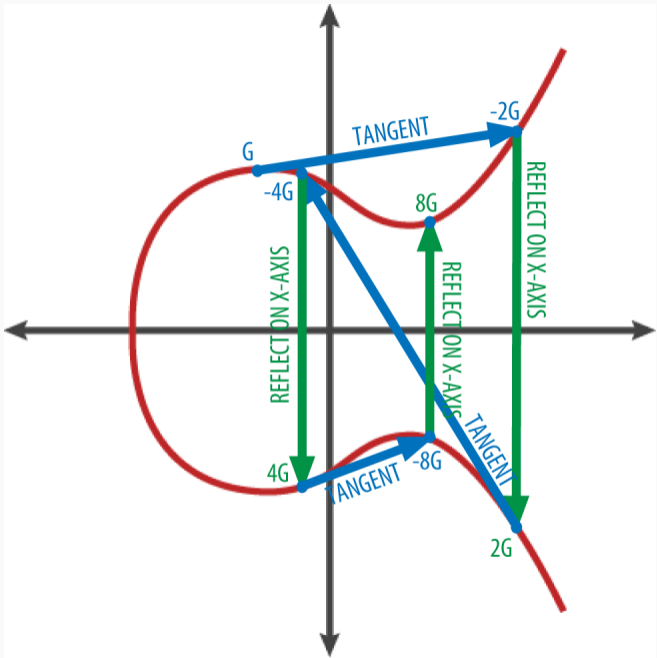
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- Historically, technology has been a key determinant of how we organize money.
- Somewhat surprisingly, interaction between technology and money takes a back seat in most textbook expositions of money:
  1. Invention of writing.
  2. Minting: hammered coinage, milled coinage, industrial coinage.
  3. Invention of paper.



## Technological change and money, II

- The arrival of cryptocurrencies is, therefore, one more step in the interaction between technological change and money:
  1. Computer networks have changed the logistics of distribution of private monies (separation from banks)
  2. Cryptography techniques prevent over-issuing, the double-spend problem, and counterfeiting.
  3. Possibility to automatically implement contingent contracts.
- As of October 29, 2020, we have 21 crypto-currencies with market caps over \$1 billion.
- The largest, *Bitcoin*, has a market cap of \$ 250 billion (a bit more than Toyota).
- *Bitcoin* is fully fiduciary (even more so than public monies!).



# An intriguing phenomenon

- Active competition among privately-issued currencies.
- Not seen since the end of free banking (Scotland in 1844, the U.S. in 1863).
- Although free banking was a different institution: cryptocurrencies perhaps closer to commodity money that uses an intrinsically worthless standard.
- **F. A. Hayek (1999): The Denationalisation of Money.**
  1. Private markets can implement desirable outcomes, even in the field of money.
  2. Privately issued currencies can deliver price stability.



## When Lagos-Wright met Hayek





# Questions

- Will a system of private money deliver price stability?

## Questions and (tentative) answers

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- Are security risk significant? **Yes, Goldfinger attacks.**



## A short coda: the blockchain

- Nothing I have said before deals with the blockchain.
- But, in some sense, we have already worked out what the blockchain is: a distributed ledger.
- A fundamental problem of (nearly) all economic activities is the verification of conditions:
  1. Who is the owner of this building?
  2. Has a package being delivered?
  3. What do we have in a depot?
  4. What is the balance on my checking account?
  5. Have I paid my HOA this month?
  6. How many teaching credits do I have in my department?
- Related versions of this problem appear in the control of industrial processes (e.g., avionics), but we can skip them today.

# Consequences

- Difficulties in verifying conditions prevent (or make it too expensive) economic transactions.
- In fact, the systems of private law are designed (or should be designed) to facilitate verification (and its finality) and, therefore, maximize exchange and surplus.
- A common solution is to have centralized verification systems composed of three elements:
  1. A ledger.
  2. A bookkeeper.
  3. Rules (and meta-rules).
- Example: a land registry.



## Problems with centralized systems

1. Require trust in the bookkeeper.
2. They are expensive.
3. They are slow and suffer from latency delays.
4. Not very flexible.
5. They limit the adoption of new technologies.
6. Cases where they cannot be applied.

# Decentralized systems I

- Can we design decentralized verification systems?
- Potentially faster and more powerful (smart contracts, automatic regulation).
- In fact, we already use decentralized systems:
  1. Fiduciary money.
  2. Email (SMTP).
- Continuum of centralization vs. decentralization, with plenty of mixed systems.
- Blockchain is a decentralized system with verification by consensus.

ἀρμενίων καὶ μαθηρὸς οὐ μέλιτος καὶ προτρομὴν πολέμου ἡμεῖς ἔχοντες  
χρῶν· κατὰ τοὺς μισοὺς τὰς ἀπὸ τῆς σαλατινῆς ἀπὸ τῆς  
μετὰ τὴν ἰστορίαν τῆς πόλεως κινήσαντες· πολέμου μου κατέσχεον



Ἰσίδωρος δὲ καὶ πάντας ἀπέριξ καὶ ἐχειρῶσατο· καὶ δούλους αἰοῖσέ τ' ἐργάσατο· τὴν μὲν ὥψιμε

# The Byzantine Generals Problem

- Proposed by **Lamport, Shostak, and Pease (1982)**:
  1. Several divisions of the Byzantine army camped around a city.
  2. Each division commanded by a different general.
  3. The generals must agree on an attack plan (for instance, attack in the morning or in the afternoon).
  4. The generals can only communicate through messengers.
  5. At least one of the generals might be a traitor.
- We look for a mechanism:
  1. Ensures loyal generals agree on a common plan.
  2. Avoids adopting a bad plan because of traitorous generals.

## Some bad news and some good news

- Problem does not have a solution if at least  $1/3$  of generals are traitors.
- The **Fischer-Lynch-Paterson** (FLP) theorem: impossibility result for asynchronous deterministic consensus if at least one general is a traitor (randomized consensus algorithms can circumvent the FLP impossibility theorem).
- Is there hope? Yes: we can have mechanisms that “nearly always” work.
- The blockchain, proposed by **Satoshi Nakamoto** in 2008 building on **Haber and Stornetta (1991)** and **Bayer, Haber, and Stornetta (1992)**, is one of them.
- Distributed ledger with consensus and proofs-of-work.
- Advantages and disadvantages.

# Central bank digital currency

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## A central bank open to all?

- The arrival of private cryptocurrencies has suggested the possibility that central banks issue their own digital currencies (CBDCs).
- Many proponents of a CBDC go well beyond a basic central bank-issued electronic money.

### **Barrdear and Kumhof, 2016, p.7**

By CBDC, we refer to a central bank granting universal, electronic, 24x7, national-currency-denominated and interest-bearing access to its balance sheet.

### **Bordo and Levin, 2017**

“an account-based CBDC could be implemented via accounts held directly at the central bank” [p. 7] or “CBDC could be provided to the public via specially designated accounts at supervised commercial banks, which would hold the corresponding amount of funds in segregated reserve accounts at the central bank” [p. 8].

## Our question

Should central banks open their deposit and lending facilities to *all* firms and private citizens?

- This question is separate from assessing the merits of electronic public money, but it is really the one at the core of our discussion.
- **Tobin (1987)**: “deposited currency” (and implemented in the past!).
- Related with the motivation behind postal saving systems and government-owned commercial banks.
- Why now? Changes in technology may justify changes in the architecture of a financial system.
- Nearly all of the analysis carries over to this “deposited currency” environment.
- Already relevant for policy: 2018 Swiss sovereign-money initiative (*Vollgeld*)



# How can I address this question?

- I will briefly review the historical experience.
- I will summarize the results coming from a version of the **Diamond and Dybvig (1983)** model augmented with a central bank that allows for deposits by consumers.
  1. Basic equivalence result: central banks can deliver the right amount of maturity transformation.
  2. Conditions on commercial and central bank runs.
- I also have a nominal economy in a companion paper, but I will skip it today.

## All of this has happened before...

- Historically, many central banks allowed deposits by and extended loans to firms and private citizens.
- Well-known examples: Bank of England, First and Second Banks of the United States.
- The Bank War between Andrew Jackson and Nicholas Biddle was linked directly to the operations of the Second Bank of the United States with firms and merchants.
- Sometimes, the central banks were dominant players in the commercial banking sector.
- In 1900, the Bank of Spain (*Banco de España*), with 58 branches across the nation, held 68% of total financial assets and 75% of all checking accounts in the Spanish financial sector.
- Sharp distinction between a central bank operating only with primary depository institutions and commercial banks dealing with the public at large is mainly a post-WWII development.

George Fred<sup>l</sup> Handell Esq<sup>r</sup> Dr

Cr

1720	Jan 27	397	To William Banister	81	50	✓	June 25	208	By Royal Stock of S <sup>c</sup>	150	✓	
	Oct 19	438	To Edward Hull	840	100	✓	Nov 7	112	By Edward Bullock	100	✓	
	May 5	37	To William Hollway	614	150	✓				250	✓	
					100	✓	1721	July 13	281	By Capt <sup>l</sup> Francis Vickers	696	300
					250	✓		Nov 11	44	By Stephen Dantus	74	100
1725	Apr 23	120	To John Woods	318	50	✓		23	446	By John Vetter	590	300
	23	167	To John Vetter	569	50	✓					700	✓
					100	✓						
	Dec 30	196	To Christopher Whitmore	796	50	✓						
			To Ballan's A/c		550	✓						
					700	✓						

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Cr

1725	Feb 22	577	To Anne Linton	227	50	✓			By Ballan's A/c	500	✓	
	Feb 2	849	To John Taylor	240	300	✓						
					550	✓	1726	Apr 27	1055	By James Woodale	725	700
						✓					1250	✓
	July 10	516	To Henry Carington	336	50	✓						
	Oct 4	571	To Abraham Knap	233	500	✓						
	7	611	To Henry Carington	540	150	✓		Nov 28	62	By Philip Hollingworth	720	600
					1250	✓						
1727	Dec 12	129	To Robert Wooley	234	600	✓						

Samuel Handley of New York Dr

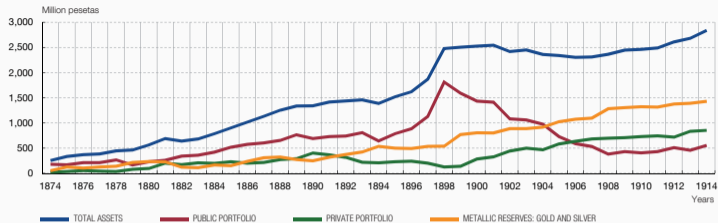
Cr

1727	Apr 3	770	To Charles Aspin	334	1000	✓	1727	Jan 27	514	By Edward Jernice	334	1000
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BANCO DE ESPAÑA: ASSETS, 1874-1914

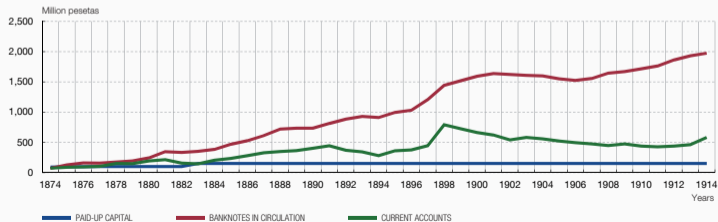
FIGURE 5.1



SOURCE: Banco de España, *Memorias anuales*.

BANCO DE ESPAÑA: LIABILITIES, 1874-1914

FIGURE 5.2



SOURCE: Banco de España, *Memorias anuales*.

## Replication of the Optimal Contract

The central bank replicates the socially optimal commercial bank contract.

## Optimal Maturity Supply

In equilibrium, the socially optimal contract is offered either by the commercial banks or the central bank or both. If both the central bank and the commercial bank have customers, then both banks are offering the optimal contract.

## A positive part...

- The proposition may seem obvious, but it captures an important point.
- One may be worried that offering deposit contracts with central banks will impair the maturity transformation function of the commercial banking sector, resulting in fewer investments in long-term projects.
- The proposition above shows that this will not be so if the central bank mimics the investment strategy of a commercial bank per relying on the investment bank sector.
- If the deposits in the central bank do not have any additional advantage, the competitive pressures of commercial banks will force to adopt the “right” investment strategy.

## ... and a sinister counterpart

- But, if the central bank enjoys an additional advantage over the commercial banks (e.g., fiscal backing), we should not expect the efficient amount of maturity transformation.
- Political-economic challenges.
- The cleanest way out appears to be letting the central bank abstain from offering deposit contracts.



## Conclusions

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# Monetary economics at the dawn of change

- We are at the start of a time of fast changes in how we implement transactions and record information in society.
- So far, much of the work involved with cryptocurrencies, the blockchain, and related technologies has been done by software developers and engineers.
- Monetary economics has much to say about these changes. We can bring to the table 300 years of monetary analysis.
- For instance, cryptocurrencies are, in my assessment and contrary to Hayek's conjecture, worse than a well-run government fiat money, but they can be better than a poorly-run government money.
- We might have much better monetary systems in 25 years.