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The Orkney Slew and Central Bank Digital Currencies

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Abstract

This Article on central bank digital currencies is motivated by a parable, *The Orkney Slew*, which is set in an archipelago. Based on the parable, we point out a significant economic market failure that exists in cross-border payments realm. The analysis then focuses on real-world examples and the national security concerns—including for Anti-Money Laundering/Combatting the Financing of Terrorism (AML/CFT) and the continued efficacy of U.S. sanctions—associated with the rapidly evolving digital payments landscape.

Many central banks around the world are now cooperatively experimenting with cross-border interoperability of digital currencies. These efforts are driven by the idea of building a global network—an infrastructure—to improve global supply chains and large value cross-border payments as well as to mitigate national security concerns. While we do *not* believe that such an infrastructure is necessary at this moment, we do argue that cross-border experimentation is necessary.

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Introduction

The advent of cryptocurrencies—particularly stablecoins, which are digital tokens that can circulate as private money—has ignited a debate on the government's role in providing a sovereign alternative. This sovereign alternative is oftentimes referred to as a "central bank digital currency." Dozens of governments and central banks are now deciding whether to create one and, if so, how to design and operationalize it.

We seek to advance the debate on central bank digital currencies by presenting insights from a parable, *The Orkney Slew*, which is set in the archipelago of Monasis. In Part I, we begin by reproducing a translation of the parable, which is contained in a unique document found uncatalogued in the Yale University's Beinecke Rare Book and Manuscript Library. We then propose possible interpretations of the parable, which contains references to different colors of the same item—a "grank"—that is used for cross-island trade and "magic" that can transform those colors.

In Part II, we advance the interpretive analysis of cross-border market failures by describing an episode from U.S. history when cross-border transactions between states suffered from similar frictions. Specifically, prior to the National Bank Act of 1863, trade across state lines was expensive and inefficient largely because the money used by traders consisted of private bank notes issued by banks all over the country. These private bank notes did not trade at par, but rather at discounts. As a result, it was hard to move capital around the country. By creating a uniform national currency, the National Bank Act significantly reduced financial frictions and facilitated trade and economic growth.

We then discuss lessons for today's policymakers in Part III. These lessons include (a) the significant market failure that currently exists in cross-border international trade; (b) the role of interoperability and international standard setting in resolving that market failure; (c) the national security implications associated with the rapidly evolving payments landscape, including for AML/CFT and the continued efficacy of U.S. sanctions; (d) the importance of viewing this task as building infrastructure; and (e) the necessity of experimentation in the policy process. Of note, the national security concerns are even more pressing now considering the sanctions imposed on Russia following its invasion of Ukraine in February 2022, including the expulsion of Russian banks from SWIFT. The global financial and payments system is very likely to undergo significant changes in the coming years as a result.

To be clear, we are *not* advocating for countries to adopt central bank digital currencies at this moment. There might be significant technological and operational problems that defeat their feasibility and which may have their own unintended consequences. We do, however, believe that central banks should cooperatively

experiment in order to learn whether interoperable digital currencies could be developed to address the issues cited in this Article.

Part I. The Orkney Slew

The document containing *The Orkney Slew* was translated by Professor Harbison Neuman. Or, rather, it was decrypted since the language it is written in is unknown. The footnotes in the document are indicated as those of Professor Neuman. The Beinecke librarians are unable to date the manuscript and could find no record of its provenance.[1]

The Orkney Slew

In the vast archipelago of Monasis, people live on different islands. Groups of islands are ruled by different sovereigns. Each island is different in that the people on each island produce granks of different colors, but residents of each island have a taste for other colors of granks than their own to consume. So, there must be trade between islands. Granks of one color must be used to buy the preferred color of grank for the residents of that island. Trade is complicated because the residents of an island may not want the specific color that is offered for their granks. They could accept them anyway and then use that color grank to exchange for the color they want, if they can find the preferred color. This would require costly search for the island with the preferred color which would accept the color the searcher had. Cross island trading is costly and inefficient.

The trading problem could be overcome if there was a centralized market for all islands where representatives of each island could meet to trade. But this could only happen for islands of each country, ruled by that sovereign. Unfortunately, this at best would only partially solve the problem because there may not be a sufficient range of

[1] Translator's Note: The document is written in an unknown language with thirty-six letters and some ideographs. The title was translated based on learning the phonetics from the main text. The ideographs appear to be names of the countries or sovereigns. Since these could not be translated, we simply refer to them as "sovereigns."

colors in any one country's market. Moreover, each sovereign conducts a grank policy whereby the sovereign can exchange one color grank for another but only using the colors of the islands under his domain. Each sovereign follows an optimal grank policy, although it can only be second best. It is not first-best because there is a limited range of colors produced by the islands under each sovereign's rule.

The sovereigns feel important—and they are important—because they can set the optimal grank policy. Still, they have jitters. They must guard against grank inflation on their island. How could that happen? No one knows for sure, but it has happened in the distant past.

Then there is an invention whereby the color of a grank can be changed via a global form of *magic* available to all islanders.[2] But it is available to each sovereign in a slightly different form and, for each sovereign, there is a limited range of colors that can be changed. This magic could completely solve the trade problem, but a sovereign must approve the use of this magic on his island. Further, the sovereigns as a group would have to agree on how the magic would be used across islands.

The sovereigns fear this invention because it completely diminishes their power, or so they think. However, a sovereign could regulate the new form of magic by only allowing it to work on the granks in the possession of the sovereign. Individual residents would not be allowed to use the magic on their granks and cannot use it across islands. This would safeguard the sovereign's power which is necessary to conduct optimal grank policy. But should sovereigns use this magic and how would

[2] Professor Neuman: The translation of the word "magic" is for ease of reading. A possibly more accurate translation would be "awesome new invention" or "paradigm changing invention."

> this new power interact with possible grank inflation? No one knows. Thus, sovereigns are reluctant to use the magic even when they have banned the individual use of it reserving it for themselves. What problem is it solving some of them asked?
>
> Some sovereigns decide to study the new magic and some run experiments by allowing residents on one or two of their islands to use the magic. Ideally, the sovereigns would all meet and adopt a consistent cross-island policy for magic use across islands. For unknown reasons, this does not happen. And gradually, the sovereign and the residents realize that the sovereigns cannot control the magic.
>
> In the end . . .

The manuscript breaks off here. The page is ripped and no other pages have been found by the Beinecke librarians.[3]

What is the origin of the *Orkney Slew*? It is not clear what "Orkney Slew" refers to. There are the Orkney islands off the northeastern coast of Scotland, an archipelago that includes many Neolithic sites. There is a "slew" of islands. But the document is not 5,000 years old. There is the Orkneyinga saga, also called the History of the Earls of Orkney, which is a medieval narrative—written around 1200—of the history of the Orkney and Shetland islands.[4] There is some doubt about the historical accuracy of the sagas and the extent to which they have been exaggerated. In any case, the Orkneyinga saga is written in Icelandic, whereas the above manuscript is in an unknown language.[5]

In addition, the origin of the term "grank" is not known. In modern parlance, the term grank refers to the ranking of the rarity of a species. It is used as a tool in determining conservation needs. In American slang, a "grank" refers to something that it is

[3] At this point, we would like to explicitly state that this parable is obviously a work of fiction. The Yale librarians would probably be amused (and then annoyed) if contacted.

[4] ORKNEYINGA SAGA: THE HISTORY OF THE EARLS OF ORKNEY (1981), translated by Hermann Páisson & Paul Edwards.

[5] There are other Old Norse languages, but they too do not resemble the language in the document, according to the translator. *See* E.V. Gordon (author) & A.R. Taylor (editor), AN INTRODUCTION TO OLD NORSE (1981).

extreme or out of the ordinary—for example, "Jack's car is such a grank." It can also be a last name. There is also a rapper named "Unruly Grank."[6] But none of this seems to have anything to do with the use of the term in the parable.

Despite these mysteries, the parable appears to make the following points: First, there is heterogeneity across islands so that there are potential gains from trade, but these gains are not being realized. Second, and consequently, the issues raised relate to cross-border trade. Third, technology changes. Fourth, although there could be enormous gains from trade, the sovereigns seem incapable or unable to bring this about. Lastly, the problem is a market failure. There are network externalities that cannot be realized because the sovereigns appear to be incapable of coordinating. Yet we do not know how the parable ends because of the missing part of the document.

* * *

The author (or authors) of the parable was (or were) likely thinking along the same wavelength as Lucas (1980), who presented a model in which goods come in many colors.[7] In Lucas's model, the different colors also motivate trade.[8] In the parable, granks are a form of money and also a consumption good. Islanders from different islands exchange goods for goods, but only if there is a coincidence of wants: A buyer of red granks, for example, must be offering a color that the seller desires. Aside from the inefficiency of cross-island trade, the lack of generally acceptable money is another inefficiency. The "magic" seems like a sort of rainbow grank, which could be used as a form of money. But, as the parable relates, it is not a complete rainbow but differs for each sovereign.

Lucas's paper is over forty years old. We know more about money now—namely, money has to satisfy the No-Questions-Asked ("NQA") principle. Introductory economics teaches us that money has three important properties: It must be a store of value, a unit of account, and a medium of exchange. But these properties are not satisfied just because it is assumed that the object will be used as a "medium of exchange." For that to happen, the object must satisfy the NQA principle.[9] Said in a different way, money is supposed to be *information-insensitive*; money is special

[6] *See, e.g.*, https://www.youtube.com/watch?v=tXRVML9YLjc.

[7] Robert E. Lucas, Jr., *Equilibrium in a Pure Currency Economy*, 18 ECONOMIC INQUIRY 203 (1980).

[8] Lucas uses a cash-in-advance constraint, meaning that consumers buy goods only with fiat money. There is no privately produced money in the economy and there are no microfoundations given for the cash-in-advance constraint.

[9] Gary G. Gorton & Jeffery Y. Zhang, *Taming Wildcat Stablecoins*, 90 UNIVERSITY OF CHICAGO LAW REVIEW (forthcoming).

because its price is not supposed to change. The price adjustments that occur because of changes in supply and demand—like the price adjustments for bananas—do not apply to money. A one-dollar bill will always transact for one dollar without question. This is the NQA principle.

The NQA principle captures the idea that it is difficult to engage in transactions or store value when the price of a claim fluctuates and parties are differentially informed about the value of the claim. This has been a problem for centuries. Even the value of gold coins was difficult to ascertain because they were shaved or sweated (*i.e.*, shaken to remove gold dust). In contrast, because money is supposed to be *information-insensitive*, its price is not supposed to change.[10] Privately produced money recognizes this problem and is also designed to be information-insensitive, such that no party to a transaction wants to engage in due diligence about the money because it is too expensive. And all parties to the transaction know this, which is why the money is accepted at par.

[10] These ideas have been formalized in the economics literature. *See* Gary Gorton & George Pennacchi, Financial Intermediaries and Liquidity Creation, 45 JOURNAL OF FINANCE 49 (1990); Bengt Holmström, *Understanding the Role of Debt in the Financial System*, BANK FOR INTERNATIONAL SETTLEMENTS WORKING PAPER No. 479 (Jan. 14, 2015), https://www.bis.org/publ/work479.htm; Tri Vi Dang, Gary Gorton & Bengt Holmström, *The Information View of Financial Crises*, 12 ANNUAL REVIEW OF FINANCIAL ECONOMICS 39 (2020).

Part II. The U.S. National Banking System

Imagine that the islands represent American states. How would the U.S. economy fare if there were barriers to cross-state trade? What would happen if those barriers were reduced? The U.S. National Banking Era is instructive in demonstrating how a significant reduction in those barriers can facilitate trade and economic growth.

Prior to the National Bank Act of 1863, cross-state trade was expensive and inefficient largely because the money used consisted of private bank notes issued by banks all over the country.[11] These private bank notes did not trade at par, but rather at discounts, because they did not satisfy the NQA principle. The discounts increased the further the note circulated away from the issuing bank. For example, a note issued by a bank in Tennessee might circulate at a 20 percent discount in Philadelphia. Because of this variation, it was hard to move capital around in the economy. Economic historians have looked at the inefficiencies by observing the average weekly rate of discount, as seen in Table 1,[12] which shows large differences across locations.

During the National Banking Era, there was a significant narrowing of interregional discount rates as a national capital market formed.[13] Indeed, the National Bank Act introduced a uniform currency for the first time in American history: national bank notes. National bank notes had to be backed with U.S. Treasury bonds. Jaremski (2014) shows the under the Act, 729 new banks were established between 1863 and 1866 and these new banks concentrated in what would become the nation's manufacturing belt, which led to capital deepening in the manufacturing sector.[14] Relatedly, Xu and Yang (2021) also find that counties with access to the new national banks experienced significant manufacturing growth.[15] These changes are attributed, by the authors, to the uniform currency and entry into banking.

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[11] Starting in 1837, some states changed the way that they granted bank charters. These states allowed free banking—that is, anyone could open a bank. However, there were rules. Banks had to back their note issuance one-for-one with state bonds that were deposited with the state treasurers (the banks received the coupons from these bonds). *See* Gorton & Zhang, *supra* note __.

[12] R. M. Breckenridge, *Discount Rates in the United States*, 13 POLITICAL SCIENCE QUARTERLY 119 (1898). The data are from 43 cities, arranged according to the geographical divisions in which they lie.

[13] *See* Lance E. Davis, *The Investment Market, 1870-1914: The Evolution of a National Market*, 25 JOURNAL OF ECONOMIC HISTORY 355 (1965); John A. James, *The Development of the National Money Market, 1893-1911*, 36 JOURNAL OF ECONOMIC HISTORY 878 (1976).

[14] Matthew Jaremski, *National Banking's Role in U.S. Industrialization, 1850–1900*, 74 JOURNAL OF ECONOMIC HISTORY 109 (2014).

[15] *See* Chenzi Xu & He Yang, *Monetizing the Economy: National Banks and Local Economic Development*, Stanford GSB Working Paper (Feb. 2021), https://chenzi-xu.com/docs/nationalbanks_xu_yang.pdf.

Table 1: The Average Weekly Rate of Discount, 1893–97

	Percentage			*Percentage*	
New England			*Middle States*		
Boston	3.832		Cincinnati	5.012	
Hartford	4.602		Chicago	5.742	
Providence	4.982		Pittsburgh	5.838	
Portland	6.000		St. Louis	5.903	
			Milwaukee	6.276	
Average		4.854	Indianapolis	6.369	
			Cleveland	6.376	
Eastern States			Detroit	6.415	
New York	4.412		St. Paul	6.607	
Baltimore	4.567		Minneapolis	6.903	
Philadelphia	4.642		Kansas City	6.911	
Buffalo	6.007		St. Joseph	6.969	
			Duluth	7.253	
Average		4.907			
			Average		6.352
Southern States					
New Orleans	5.853		*Western States*		
Richmond	6.000		Omaha	7.980	
Memphis	6.103		Denver	10.000	
Nashville	6.673				
Louisville	6.826		Average		8.990
Charleston	7.026				
Galveston	7.311		*Pacific States*		
Mobile	7.957		San Francisco	6.216	
Savannah	7.992		Los Angeles	7.057	
Atlanta	8.000		Portland	8.000	
Birmingham	8.000		Salt Lake City	8.000	
Houston	8.000		Tacoma	9.273	
Little Rock	8.015		Seattle	9.969	
Dallas	8.342				
			Average		8.583
Average		7.293			

Of course, it was not only the introduction of a uniform currency which facilitated economic growth in the postbellum period. Financial infrastructure had to be built. As part of the financial infrastructure, the correspondent banking system developed further and became effective in transferring funds from West to East.[16] Banks were not as common in the South and West as they were in the East and North. (The funds were concentrated in the New York money market.) The South was not only rural, but

[16] *See* John A. James, MONEY AND CAPITAL MARKETS IN POSTBELLUM AMERICA (1978).

many of its banks had also been destroyed during the Civil War.[17] The loss of financial institutions had devastating long-run effects.[18] Further, as American historian Alfred Chandler has argued, the national capital market depended on the development of centralized national networks of rail transportation, telegraphic communications, and wholesale distribution.[19] Altogether, one way to summarize the situation of postbellum American financial markets is to say that state institutions were not "interoperable." That is, they did not exist, or could not connect, in such a way as to allocate capital efficiently. Infrastructure had to be built. Over time, as it was built, discount rate differentials across geographies declined.[20]

The inefficiencies faced by the U.S. banking system prior to the introduction of uniform currency and expansion of financial infrastructure illustrate fundamental challenges that arise when banking institutions are not "interoperable." As we discuss in the next Part, central bank digital currencies may suffer from similar interoperability constraints. Importantly, central bank digital currencies, which would be issued by different countries, would not be a uniform currency for the global economy because each would be denominated in the country's national currency. Exchange rates would still fluctuate. Any global system of central bank digital currencies would therefore have to be interoperable—for example, the blockchains on which the different central bank digital currencies resided would have to be able to securely exchange data. Below, we discuss that interoperability. In the limit, perfect interoperability could be thought of as a uniform currency. To be sure, we do not propose a single currency for the world, but we do suggest that history is instructive about the benefits of reducing trade frictions.

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[17] *See* John A. James, *Financial Underdevelopment in the Postbellum South,* 11 JOURNAL OF INTERDISCIPLINARY HISTORY *443* (1981).

[18] *See* Chenzi Xu, *Reshaping Global Trade: The Immediate and Long-Run Effects of Bank Failures,* Stanford GSB Working Paper (Feb. 2021), https://chenzi-xu.com/docs/reshaping_global_trade_Xu.pdf.

[19] Alfred D. Chandler, THE VISIBLE HAND: THE MANAGERIAL REVOLUTION IN AMERICAN BUSINESS (1977).

[20] Looking at today's financial markets, Cheng and Torregrossa (2021) provide a legal and policy perspective on the Federal Reserve's role as a "network hub" that continues to connect the U.S. financial system's various forms of money, allowing them to interoperate. *See* Jess Cheng & Joseph Torregrossa, *What is Money? A Lawyer's Perspective on U.S. Payment System Evolution and Dollars in the Digital Age* (July 12, 2021), https://ssrn.com/abstract=3885031.

Part III. Central Bank Digital Currencies

What if we interpret the parable's islands as countries? Does the parable speak to current issues? Today, despite significant technological innovations, cross-border trade between countries is costly and inefficient, like in the parable. Large value payments go through the correspondent banking network, which can take days to settle. According to the Committee on Payments and Market Infrastructure, "[cross border payments are] slow, expensive, unreliable and unavailable in some countries."[21] In addition, according to Sir Jon Cunliffe (Bank of England deputy governor for financial stability and Chair of the Committee on Payments and Market Infrastructures):

> [D]espite . . . technological advances it can still take as long as 10 days to transfer money to different jurisdictions. And that transaction can cost up to 10 percent of the value of the transfer. A payment from the UK to some countries has to go through four currencies and as many as five banks. Cross-border payment systems still use message formats developed 100 years ago for the telex machine. . . Global financial transfers were well over $20tn in 2019 and are expected to hit $30tn by 2022. Improving the cost, speed and reliability of payments would remove frictions that prevent many small businesses reaching out to customers beyond their borders. Six out of 10 cross-border business-to-business payments require some kind of manual intervention, each taking at least 15 to 20 minutes.[22]

In a report to the G20, the BIS, IMF, and World Bank (2021) wrote:

> Cross-border payments suffer from long transaction delays and can be particularly costly due to the involvement of a high number of intermediaries across different time zones along the correspondent banking process. In addition, cross-border payments suffer from low traceability and lack transparency, causing frictions regarding AML/CFT checks. Also, the decline of cross-border banking relationships for the past decade might leave some jurisdictions with inadequate access to the global financial system . . . Finally, the traditional correspondent banking model . . . does not offer sufficient

[21] BIS, *CPMI Report Identifies Steps to Enhance Cross-Border Payments,* Report (Jul. 13, 2020), https://www.bis.org/press/p200713.htm.

[22] Sir Jon Cunliffe, *Cross-Border Payment Systems Have Been Neglected for Too Long*, FINANCIAL TIMES (Jul. 13, 2020).

> interoperability and standardisation to smoothen cross-border transactions. These frictions result in numerous risks and operational complexities to manage.[23]

Suffice it to say, cross-border payment systems are in desperate need for an upgrade, one that could bring about a tremendous increase in economic efficiency and could mitigate national security concerns in an increasingly uncertain world.

A. Market Failure in Cross-Border Payments

These criticisms of the cross-border payment system are widespread because there is a *market failure* in this space. There are unrealized positive network externalities, particularly by companies that have a global supply chain. As a result, central banks around the world have started to experiment with technological innovation akin to the magic described in the parable. According to the BIS, as of 2020, over 50 countries were conducting some form of investigatory work on central bank digital currencies, be it an initial scoping investigation, prototype development or testing, or the issuance of a full-fledged central bank digital currency.[24] In addition, 25 countries are in an advanced prototype or issue stage of development.[25] In the United States, the Federal Reserve says it will release a whitepaper on the costs and benefits of issuing a central bank digital currency later this year.

Certainly, central bank digital currencies bear investigating because of the network externalities that require some degree of interoperability between the central bank digital currencies of different countries. Strong cooperation will be needed to determine how the technological and legal aspects can be harmonized to overcome cross-border inefficiencies.[26]

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[23] BIS, IMF & World Bank, *Central Bank Digital Currencies for Cross-Border Payments*, Joint Report to the G20 (Jul. 9, 2021), https://www.bis.org/publ/othp38.htm.

[24] Codruta Boar & Andreas Wehrli, *Ready, Steady, Go? – Results of the Third BIS Survey on Central Bank Digital Currency*, BIS Papers No. 114 (Jan. 2021), https://www.bis.org/publ/bppdf/bispap114.pdf.

[25] *Id.*

[26] To be sure, further technological advances are needed to ensure that blockchains are more scalable (*i.e.*, faster) and interoperable (*i.e.*, blockchains can interact more easily). These advances are happening now. *See, e.g.*, Rafael Belchior, André Vasconcelos, Sérgio Guerreiro & Miguel Correia, *A Survey on Blockchain Interoperability: Past, Present, and Future Trends*, 54 ACM Computing Surveys 1 (2020); Peng Li, Toshiaki Miyayaki & Wanlei Zhou, *Secure Balance Planning of Off-blockchain Payment Channel Networks* (2022); Changting Lin, Nin Ma, Xun Wang & Jianhai Chen, *Rapido: Scaling Blockchain with Multi-path Payment Channels*, 406 NEUROCOMPUTING 322 (2020).

In certain jurisdictions, the adoption of a central bank digital currency is as controversial as the use of magic in the archipelago of Monasis. Members of the Board of Governors of the Federal Reserve System have laid out the reasons for their skepticism about central bank digital currencies in public remarks. In his speech, *Parachute Pants and Central Bank Money*, Vice Chair for Supervision Randal K. Quarles notes:

> Yet, proponents of a Federal Reserve CBDC believe that it would solve a number of significant problems. They suggest, for example, that a Federal Reserve CBDC may be necessary to defend the critical role the U.S. dollar plays in the global economy. Others say that a CBDC would overcome longstanding economic inequalities in American society. As we begin our Fed analysis of these issues, I will have to be convinced that a CBDC is a particularly good tool to address either of these issues, about which I am skeptical, and I will especially have to be convinced that the potential benefits of developing a Federal Reserve CBDC outweigh the potential risks.[27]

Similarly, in his speech, *CBDC: A Solution in Search of a Problem?* Governor Christopher J. Waller argues that a central bank digital currency would not solve any market failure associated with the payment system.[28] His criticisms are partly correct. For instance, establishing a central bank digital currency would not solve problems associated with financial inequality or vastly improve domestic retail payments. But there *is* a market failure, a very significant one in fact in cross-border payments. There are positive global network externalities that cannot be realized unless central banks coordinate to make their different digital currencies interoperable, as discussed below.

Other policymakers promote the virtues of private money like stablecoins for improving cross-border transactions.[29] The problems associated with privately produced stablecoins have been explored at length by the academic literature.[30] In

[27] Randal K. Quarles, Speech at the 113th Annual Utah Bankers Association Convention, Sun Valley, Idaho (Jun. 28, 2021), https://www.federalreserve.gov/newsevents/speech/quarles20210628a.htm.

[28] Christopher J. Waller, Speech at the American Enterprise Institute, Washington, D.C. (Aug. 5, 2021), https://www.federalreserve.gov/newsevents/speech/waller20210805a.htm.

[29] Quarles, *supra* note 22.

[30] *See, e.g.*, Gorton & Zhang, *supra* note __; Arthur E. Wilmarth, Jr., *It's Time to Regulate Stablecoins as Deposits and Require Their Issuers to Be FDIC-Insured Banks*, 41 Banking & Financial Services Policy Report 1 (2022); Howell E. Jackson & Morgan Ricks, *Locating Stablecoins within the Regulatory Perimeter*, Harvard Law School Forum on Corporate Governance (2021); Timothy G. Massad, *Regulating*

short, stablecoin issuers are subject to runs as their coins do not have credible backing.[31] Stablecoins are therefore a subpar (literally) medium of exchange.

The U.S. historical experience does not suggest that experimenting with private money will turn out to be successful. Specifically, the National Bank Act of 1863 required newly chartered national banks to back their national bank notes with Treasuries. That helped national bank notes achieve NQA, something that state bank notes could not achieve. However, because Treasuries had a convenience yield,[32] they were precious. National banks did not want to use all of their Treasuries to back notes, which led to an under-issuance of notes. The under-issuance of notes led to the creation of demand deposits,[33] which were subject to runs for decades. In short, regulating private money (bank notes) led to the creation of a shadow banking sector (demand deposits), akin to squeezing a balloon. The experiment of regulating private money failed.

The Financial Stability Board (FSB) report that is often cited in discussions of cross-border payments is wholly consistent with the position that international coordination is desirable with respect to the development of central bank digital currencies. Indeed, the FSB recommends international coordination as one potential path forward, as shown in the subsequent graphic (see "Building Block 19" in the report). Generally, the FSB report recognizes the market failure described above: "Faster, cheaper, more transparent and more inclusive cross-border payment services, including remittances, while maintaining their safety and security, would have widespread benefits for citizens and economies worldwide, supporting economic growth, international trade, global development and financial inclusion."[34] Specific recommendations include developing a common cross-border payments vision and targets; implementing international guidance and principles; aligning regulatory, supervisory, and oversight

Stablecoins Isn't Just About Avoiding Systemic Risk, Brookings Report (2021); Dan Awrey, *Bad Money*, 106 Cornell Law Review 1 (2020). *See also* Alexandros Vardoulakis et al., *Lessons from the History of the U.S. Regulatory Perimeter*, FEDS Notes (2021) (noting that the growth of stablecoins presents a challenge to today's bank regulatory perimeter).

[31] Look no further than the recent volatility in cryptocurrency markets. Stablecoins have been frequently knocked off their pegs. *See* Scott Chipolina, *Investors pull $7bn from Tether as stablecoin jitters intensify*, FINANCIAL TIMES (May 17, 2022), https://www.ft.com/content/db9c3f32-cd91-4149-9788-95b2046bea10.

[32] A convenience yield is a return which is all, or in part, nonpecuniary. For instance, individuals carry cash around even though it does not pay interest, because it has a convenience yield.

[33] Demand deposits are private money held in accounts at commercial banks, and owners of such accounts can redeem their deposits for cash at will. For example, when someone withdraws cash from an ATM operated by Wells Fargo, that person is taking money from a demand deposit account at Wells Fargo.

[34] FSB, *Enhancing Cross-Border Payments: Stage 3 Roadmap*, Report (Oct. 13, 2020), https://www.fsb.org/wp-content/uploads/P131020-1.pdf.

frameworks for cross-border payments; applying AML/CFT rules consistently and comprehensively; reviewing the interaction between data frameworks and cross-border payments; and *factoring an international dimension into the design of central bank digital currencies*. To be sure, one of the FSB's suggestions is to explore the use of stablecoin arrangements for cross-border payments, and while doing so runs into the problem described in Gorton and Zhang (2021), it is not inconsistent with cooperatively *experimenting* with cross-border interoperability of different central bank digital currencies.

B. Interoperability, Standards, and QWERTY

To avoid the inefficiencies that merchants face when transmitting large payments across the correspondent banking network, cross-border payment mechanisms have to be *interoperable*. There are several kinds of interoperability. One definition of interoperability in our context refers to the ability to securely exchange data from one blockchain to another blockchain—even though the blockchains are of different types—and to link blockchains to the current payment systems. Blockchain or distributed ledger interoperability is a complex and complicated challenge to tackle.[35] The National Interoperability Framework Observatory ("NIFO"), endorsed by the European Commission, observes that there are interoperability layers: technical interoperability, semantic interoperability, organizational interoperability, legal interoperability, integrated public service governance, and interoperability governance.[36] Interoperability with legacy systems is also a trouble spot. In light of these challenges, it would seem appropriate for central banks to experiment with developing a central bank digital currency, ideally with a healthy dose of collaboration so that the resulting system will eventually be interoperable.

Consider a couple of examples to see the costs of a system that is not interoperable. Two historical examples illustrate this dynamic. First, what happens when car bumpers aren't the same height? In that case, car collisions do not end up bumper-to-bumper, resulting in greater damages.[37] Another example is the standardization of

[35] *See* Rafael Belchior, André Vasconcelos, Sérgio Guerreiro & Miguel Correia, *A Survey on Blockchain Interoperability: Past, Present and Future Trends*, Working Paper (2021), https://arxiv.org/pdf/2005.14282.pdf; Stefan Schulte, Marten Sigwart, Philipp Frauenthaler & Michael Borkowski, *Towards Blockchain Interoperability*, BUSINESS PROCESS MANAGEMENT (2019).

[36] *See* National Interoperability Framework Observatory, https://joinup.ec.europa.eu/collection/nifo-national-interoperability-framework-observatory/3-interoperability-layers#3.6.

[37] *See* Amy Schatz, *Uneven Vehicle Bumper Heights Result in Expensive Repair Bills*, WALL STREET JOURNAL (Sep. 13, 2004), https://www.wsj.com/articles/SB109502700872015734 ("The researchers are calling on the National Highway Traffic Safety Administration to revise the bumper rule to require

shipping containers. The International Standards Organization started setting standard sizes for shipping containers in 1961.[38] Without standardization, there would be significantly greater inefficiencies in shipping as some containers would be larger (or smaller), thereby wasting room on ships.

Next, we describe an example that involves cross-border trade because that is the main rationale for a establishing a central bank digital currency. Specifically, consider the Convention on the Contract for the International Carriage of Goods by Road, commonly known as the CMR Convention. It is a United Nations convention signed in May 1956. The CMR Convention provides the legal framework facilitating the international transfer of goods over road. The CMR is important because it includes a successive carriage provision, which says that the first carrier of the goods is liable until the delivery of the goods at their destination. This provision prevented first carriers from blaming foreign carriers if goods arrived damaged.[39] The CMR governs the accompanying documentation of transported consignments, the principles of liability of the carrier, and the procedure for applying damages claims. Without the CMR Convention, carriers would have to know the national regulations of all countries involved in a shipment. And matters of liability would be governed by different sets of national regulations.[40]

The CMR has grew out of an effort to address challenges faced by national railroad networks as they were rapidly expanding in the mid-1800s in Europe. At that time, railroad expansions and internationalization faced challenges because the gauges (*i.e.*, spacing of rails on railway tracks) and railroad materials were not standardized between countries. As a result, railroads were unsafe and it was also difficult to transport goods across borders. (Because railroads and materials were not compatible from country to country, goods had to switch railroads and wagons each time they entered a new country.[41]) This led to the first international code for transportation of goods by rail: This code was first created in the Berne Agreement on the Transport of

bumpers on sport-utility vehicles to line up better with bumpers on cars. Bumpers generally only save a vehicle from serious damage if they are at roughly the same height on each vehicle, so their energy-absorbing bars line up. That is why the government requires car bumpers to be between 16 inches and 20 inches from the ground. But there is no similar requirement for SUVs.").

[38] Barnaby Lewis, *Boxing Clever – How Standardization Built a Global Economy*, ISO (Sep. 11, 2017), https://www.iso.org/news/ref2215.html.

[39] Michiel Spanjaart, *The Successive Carrier: A Relic from the Past*, 21 UNIFORM LAW REVIEW 522 (2016).

[40] Johan Schelin, *CMR Convention in a Law and Economics Perspective*, 21 UNIFORM LAW REVIEW 21 434 (2016).

[41] *Id.*

Goods by Rail/Berne Convention of 1890,[42] and is today regarded as instructive as an example of international cooperation on standards.

* * *

Blockchain is in the process of revolutionizing shipping and its many supply chain participants.[43] This development does not receive as much publicity as Bitcoin and crypto exchanges, but this is the arena where real change is happening. A leading example is shipping. Some of the largest shippers in the world such as Maersk, Hyundai Merchant Marine, and Maritime Silk Road Platform have come together to explore the upsides of this new technology.[44] In the spirit of the CMR, the Digital Container Shipping Association is in the process of setting standards and API (application specific interface) definitions.[45]

Similar efforts abound. Table 2 shows a sample of cross-border supply chain projects. Though many of these activities do not appear in newspapers, they have significant implications for the real economy. Table 2 highlights two points: First, the locus of activity with blockchain applications is cross-border. Second, these initiatives correspond to building infrastructure.

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[42] *Id.*

[43] *See, e.g.*, Yanling Chang, Eleftherios Iakovou & Weidong Shi, *Blockchain in Global Supply Chains and Cross Border Trade: A Critical Synthesis of the State-of-the-Art, Challenges and Opportunities*, 58 INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH 2082 (2020); Ivan Chistiakov, Yash Madhwal & Yury Yanovich, *Logging Multi-Component Supply Chain Production in Blockchain*, ICCMB (2021); Shuchih Ernest Chang, Yi-Chian Chen & Ming-Fang Lu, *Supply Chain Re-Engineering Using Blockchain Technology: A Case of Smart Contract-Based Tracking Process*, 144 TECHNOLOGICAL FORECASTING & SOCIAL CHANGE 1 (2019). *Cf.* Matteo Crosignani, Macro Macchiavelli & Andre F. Silva, *Pirates without Borders: The Propagation of Cyberattacks through Firms' Supply Chains*, Federal Reserve Bank of New York Staff Report No. 937 (Jul. 2021), https://www.newyorkfed.org/medialibrary/media/research/staff_reports/sr937.pdf.

[44] *Maersk and IBM Introduce TradeLens Blockchain Shipping Solution*, PRNewswire (Aug. 9, 2018) https://newsroom.ibm.com/2018-08-09-Maersk-and-IBM-Introduce-TradeLens-Blockchain-Shipping-Solution.

[45] *See* DCSA (accessed Sep. 9, 2021), https://dcsa.org/. Cross-border blockchain includes work on digital versions of the documents covered by CMR. In particular, there is work on digital bills of lading. A bill of lading is a document issued by a carrier to acknowledge receipt of cargo for a shipment. A bill of lading describes the type, quantity, and destination of the goods being shipped. *See* Mark L. Shope, *The Bill of Lading on the Blockchain: An Analysis of its Compatibility with International Rules on Commercial Transactions*, 22 MINNESOTA JOURNAL OF LAW, SCIENCE & TECHNOLOGY 163 (2021); Naomi Chetrit, Mayrav Danor, Angelic Shavit, Boaz Yona & Dov Greenbaum, *Not Just for Illicit Trade in Contraband Anymore: Using Blockchain to Solve a Millennial-Long Problem with Bills of Lading*, 22 VIRGINIA JOURNAL OF LAW & TECHNOLOGY 56 (2018). Baris Soyer & Andrew Tettenborn, eds., NEW TECHNOLOGIES, ARTIFICIAL INTELLIGENCE AND SHIPPING LAW IN THE 21ST CENTURY (2019).

Table 2: Global Supply Chains That Use Blockchain

Name of Blockchain Initiative	Primary Companies Involved	Sector	Blockchain Platform	Status	Does the blockchain platform have their own coins/tokens?	Can the coins/tokens be used off-chain?
TradeLens	Maersk, IBM	Transportation	IBM Blockchain Platform (based on the Linux Foundation's Hyperledger Fabric)	Launched (2018)	Yes — IBM's Fabric Token SDK.	Unclear — seems like Fabric Token SDK is compatible with IBM's Fabric Smart Client, which supports off-chain transactions.
Autonomous services selection system and distributed transportation database(s)	UPS	Transportation	UPS's own blockchain	Applied for patent (2018)	No — proposed ledger system may use coins such as Bitcoin or Ether.	N/A
N/A	Anheuser-Busch InBev (AB InBev), SettleMint, Fujitsu	Beverage	SettleMint's blockchain technology (SettleMint allows clients to choose from either Ethereum, Hyperledger Fabric, or Corda as the underlying blockchain protocol — unclear which one AB InBev chose).	Pilot (2020)	Unclear — unknown which blockchain protocol AB InBev chose. If AB InBev chose Ethereum, SettleMint uses a JWT Token for authentication.	N/A — SettleMint itself seems to be compatible with companies' off-chain systems. JWT Token appears to only be for authentication.

Trado	Unilever, Sainsbury's, Provenance	Beverage	Provenance's public blockchain network	Pilot (2017)	Yes — Hash (Provenance's native token).	Unclear — whitepaper does not say.
IBM Food Trust	Walmart, IBM, Nestle, Dole, Unilever	Food	IBM Blockchain Platform	Pilots (2017) Launched (2018)	Yes — IBM's Fabric Token SDK.	Unclear — seems like Fabric Token SDK is compatible with IBM's Fabric Smart Client, which supports off-chain transactions.
Tracr	De Beers, BCG Digital Ventures	Jewelry	Ethereum	Pilot (2018)	Yes — Ether (ETH), but unclear if Tracr uses it.	Yes.
TrustChain	IBM, Rio Tinto Diamonds, Leach Garner, Asahi Refinery, Helzberg, the Richline Group	Jewelry	IBM Blockchain Platform	Proof of Concept (2018)	Yes — IBM's Fabric Token SDK.	Unclear — seems like Fabric Token SDK is compatible with IBM's Fabric Smart Client, which supports off-chain transactions.
N/A	Ford, IBM	Automotive	IBM Blockchain Platform	Pilot (2019)	Yes — IBM's Fabric Token SDK.	Unclear — seems like Fabric Token SDK is compatible with IBM's Fabric Smart Client, which supports off-chain transactions.
PartChain	BMW	Automotive	The Linux Foundation's Hyperledger Fabric	Pilot (2019) Launched (2020)	Yes — Hyperledger's FabToken allows users to tokenize assets.	No — transactions seem to be limited within Hyperledger Fabric.

N/A	Tesla, CargoSmart, COSCO Shipping, Shanghai International Port Group	Automotive	The Linux Foundation's Hyperledger Fabric	Pilot (2020)	Yes — Hyperledger's FabToken allows users to tokenize assets.	No — transactions seem to be limited within Hyperledger Fabric.
KitChain	Pfizer, Biogen	Pharmaceuticals	LedgerDomain Selvedge (based on the Linux Foundation's Hyperledger Fabric)	Proof of concept (2019)	Yes — Hyperledger's FabToken allows users to tokenize assets. Unclear if LedgerDomain has its own additional token.	No — FabToken transactions seem to be limited within Hyperledger Fabric.

Next, we note that setting the right standards is necessary to maximize gains in cross-border transactions. By "standards," we mean a set of technical and legal specifications that participants in the network agree to abide by. Such standards agreements can come about in different ways, some through a process of negotiation, or passive acceptance of a single dominant agent, or mandated by the government or governments.[46]

The importance of setting standards was made in a famous article by Paul David (1985), *Clio and the Economics of QWERTY*—with QWERTY referring to the topmost row of letters on a typewriter keyboard.[47] It turns out that this is not the optimal arrangement of letters if the goal is to maximize speed of typing for the same energy input. David tells the story of how QWERTY came to be adopted and concludes thusly:

> Despite the presence of the sort of externalities that standard static [economic] analysis tells us would interfere with the achievement of the socially optimal degree of system compatibility, competition . . . drove the industry prematurely into standardization *on the wrong system*.

To avoid pitfalls in setting suboptimal standards, the design of central bank digital currencies requires that central banks work collaboratively in their development. It is for this reason that many central banks are collaborating on experimental projects on the use of digital currencies for cross-border payments. Most of these experiments are focused on wholesale payments—the large volume transactions which are most important for global supply chains. Again, interoperability extends beyond the technical needs for two blockchains to interact, it includes standardization in the business and legal spheres.

Ongoing collaborations focus on these interoperability challenges. Table 3 below lists the collaborative central bank projects. For example, the central banks of Canada and Singapore are collecting under Project Jasper-Ubin, while the European Central Bank and the Bank of Japan are working together under Project Stella. Of course, none of the countries in Table 3 have announced that they are issuing a digital currency, but

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[46] Paul A. David & Shane Greenstein, *The Economics of Compatibility Standards: An Introduction to Recent Research*, 1 ECONOMICS OF INNOVATION AND NEW TECHNOLOGY 3 (1990). The authors classify standard adoption into four types: Unsponsored standards are those that have no identified originator but are nevertheless adopted. Sponsored standards come from some sponsoring group of users or suppliers. Then there are standards written by a voluntary standards-writing organization like the International Standards Organization. Finally, mandated standards are promulgated by the government.

[47] Paul A. David, 75 AMERICAN ECONOMIC REVIEW PAPERS AND PROCEEDINGS, 332 (1985).

some of those in Table 4 have already launched a CBDC. For instance, Sweden has a pilot program for its E-krona and China has a pilot program for its e-CNY.[48]

[48] The Federal Reserve does not appear in either table. The Atlantic Council states: "Of the four largest central banks in the world (the Federal Reserve, the European Central Bank, the Bank of Japan, and the Bank of England), the Federal Reserve is the only one to not commit to a digital currency test project." Central Bank Digital Currency Tracker (Jul. 22, 2021), https://www.atlanticcouncil.org/news/press-releases/atlantic-council-releases-new-state-of-the-art-central-bank-digital-currency-tracker/.

Table 3: Central Bank Joint CBDC Projects

Name	Country	Description
Project Jasper-Ubin	Singapore & Canada	Monetary Authority of Singapore (MAS) and the Bank of Canada (BOC) linked up their respective experimental wholesale CBDC networks, Ubin and Jasper, in 2019 to demonstrate how wholesale CBDC could efficiently eliminate the settlement risk inherent in cross-border, cross-currency transactions, by synchronizing payment actions without the need for a trusted third party or a common platform.
Project Jura	France & Switzerland	Project Jura, conducted by the Bank of France, the Swiss National Bank and the BIS Innovation Hub, together with a private sector consortium, explores cross-border settlement with two wholesale CBDCs and a digital security on a DLT platform. It will involve the exchange of a French digital security and euro wholesale CBDC and the exchange of euro wholesale CBDC against Swiss franc wholesale CBDC.
Project Inthanon-LionRock	Thailand & Hong Kong	Project Inthanon-LionRock is a joint initiative by the Bank of Thailand (BOT) and the Hong Kong Monetary Authority (HKMA).
Project mCBDC Bridge	China & United Arab Emirates	The mCBDC Bridge project is run by the BIS Innovation Hub in collaboration with the HKMA, BOT, Digital Currency Institute of the People's Bank of China and the Central Bank of the United Arab Emirates.
Project Dunbar	Singapore	Project Dunbar is an initiative by the BIS Innovation Hub Singapore Centre in collaboration with MAS and plans to work with central banks, financial institutions and technology partners.
Project Aber	Saudi Arabia & United Arab Emirates	The project is led by the Saudi Central Bank41 and the Central Bank of the United Arab Emirates. Commercial banks (three Saudi and three UAE) were selected to participate in the development of the currency.
Project Helvetia	Switzerland	Project Helvetia, an experiment between the Bank for International Settlements Innovation Hub Swiss Centre, the Swiss National Bank (SNB) and the financial market infrastructure operator SIX, successfully shows the feasibility of integrating tokenized assets and central bank money.
Project Stella	Europe & Japan	Project Stella is a joint research project of the European Central Bank (ECB) and the Bank of Japan (BOJ). The project is in its fourth phase of experimental work and conceptual studies exploring the opportunities and challenges of DLT.
No Name as of Yet	Canada, England, Japan, Europe, Sweden, & Switzerland	Collaboration between the Bank of Canada, the Bank of England, the Bank of Japan, the European Central Bank, the Sveriges Riksbank and the Swiss National Bank, together with the Bank for International Settlements (BIS).

No Name as of Yet	France & Singapore	Collaboration between Banque de France and Monetary Authority of Singapore. Pilot project announced 2020 and to be completed fall 2021. Pilot simulates cross-border and cross-currency transactions. Wholesale CBDC.
No Name as of Yet	France & Tunisia	Collaboration between Banque de France and Banque Centrale de Tunisie. Pilot project launched March 2020. Pilot investigates how wholesale CBDC can facilitate cross-border transactions. Wholesale CBDC.

Table 4: Central Bank CBDC Pilot or Launched Projects

Name	Country	Status	Description
Sand Dollar	The Bahamas	Launched — October 2020	Digital representation of Bahamian dollar issued by Central Bank of The Bahamas. First CBDC in the world to officially launch. Retail CBDC.
DCash	Eastern Caribbean	Launched in four member states (Saint Kitts and Nevis; Antigua and Barbuda; Saint Lucia; Grenada) — March 2021 Pilot in remaining four member states (Anguilla; Montserrat; Dominica; Saint Vincent and the Grenadines) — started 2019	Created from a collaboration between Bitt (fintech company) and Eastern Caribbean Central Bank. First digital cash issued by a currency union central bank. Retail CBDC.
E-krona	Sweden	Pilot involving commercial banks — April 2021	Collaboration between Central Bank of Sweden (Riksbank), Handelsbanken (Swedish bank) and TietoEVRY (Finnish IT company). Pilot tests e-krona with external systems (how well participants' current systems will work with e-krona's system). Retail CBDC.
LBCOIN	Lithuania	Pilot — issued July 2020	Issued by Bank of Lithuania. World's first blockchain-based digital collector coin. Consists of six digital tokens for every physical collector coin (i.e., when Bank of Lithuania issued 4,000 LBCOINS, they issued 24,000 digital tokens and 4,000 silver collector coins). Retail CBDC.
E-hryvnia	Ukraine	Pilot — signed deal in January 2021 to develop CBDC	National Bank of Ukraine is working with Stellar Development Foundation (nonprofit aimed at growing Stellar network) to develop this CBDC. This project will begin in August 2021. Previously in 2019, National Bank of Ukraine ran a two-month pilot of e-hryvnia. Unclear if retail/wholesale.

e-CNY	China	Pilot — started April 2020	Issued by the People's Bank of China. First CBDC piloted by a major economy. Pilot program originally began in four cities but has since expanded to 28 cities in China. Serves as both wholesale and retail CBDC.
N/A	South Korea	Pilot — announced May 2021	Bank of Korea is partnering with Ground X (blockchain subsidiary of Korean-based internet company Kakao) to develop a CBDC. Pilot will run from August to December 2021. Retail CBDC.
N/A	Jamaica	Pilot — launched May 2021	Issued by Bank of Jamaica. Expected to be issued nationally by early 2022. Retail CBDC.
Khokha	South Africa	Pilot — announced 2020	Issued by South African Reserve Bank. Wholesale CBDC.
N/A	France	Pilot — launched March 2020	Issued by Banque de France. One pilot ended in December 2020. This pilot was a collaboration between IZNES, SETL, CACEIS, CITIGROUP, GROUPAMA AM, OFI AM and DXC. Most recent pilot was in June 2021 and its purpose was to issue a government bond. Wholesale CBDC.
e-Peso	Uruguay	Pilot — launched November 2017	Issued by Central Bank of Uruguay. First large-scale CBDC pilot launched by a country. Retail CBDC.

C. National Security Concerns

The development of a central bank digital currency also has far-reaching implications for *national security*. For example, who is allowed to maintain and oversee the data on international (financial) transactions? Could other countries' digital currencies replace the U.S. dollar's role as the world's reserve currency? We discuss the implications of central bank digital currencies on anti-money laundering, combatting terrorism, and sanctions, along with their longer-term implications for dollar dominance.

1. Anti-Money Laundering

Anti-money laundering ("AML") refers to a global set of laws and policies intended to stop criminal and terrorist money laundering.[49] Currently, the international standard setter for AML and Combatting Terrorism Financing ("CTF") is the Financial Action Task Force created in July 1989 by the G7. AML regulations vary by country, but in general the regulations require that financial institutions implement the following:

- Know your customer ("KYC") policies through which financial institutions properly verify customers identification and legitimacy.
- Requirements that that all transactions above a threshold are noted and a regulatory report is filed.
- Processes for filing suspicious activity notifications and reports.
- Policies ensuring compliance with sanctions that various international bodies and countries have put on.

Note that KYC regulations require that identities be known, whereas blockchain pushes the idea of anonymity. How will the two be reconciled? One pilot proof of concept was conducted by the European System of Central Banks ("ESCB"), consisting of the central banks of the European Union. The ESCB project was not cross-border in nature, but it identified one possible avenue to address the anonymity-identification tradeoff. The ESCB experiment assumed that (1) the central bank digital currency is cash-like; (2) the digital currency is a two-tier system with intermediaries at the center; (3) only the central bank can issue the digital currency; and (4) there is an AML authority that does the AML/CTF monitoring for large value transactions. With these assumptions, the ESCB showed that it is possible to create a central bank digital currency that allows user some privacy for low value transactions but requires higher value transactions to be subject mandatory AML/CTF monitoring. Here's their summary:

[49] For an overview, *see* THE PALGRAVE HANDBOOK OF CRIMINAL AND TERRORISM FINANCING LAW (2018).

> [The ECSB's proof of concept] provides a digitalisation solution for AML/CFT compliance procedures whereby a user's identity and transaction history cannot be seen by the central bank or intermediaries other than that chosen by the user. The enforcement of limits on anonymous electronic transactions is automated, and additional checks are delegated to an AML authority. This is achieved using "anonymity vouchers", which allow users to anonymously transfer a limited amount of CBDC over a defined period of time.[50]

Specifically, the scheme operates by issuing anonymity vouchers to banks at regular intervals, which results in a deduction from the bank's reserve balance at the central bank in the amount of the digital currency units. If a user wants to transfer digital currency without the revealing the identity to the AML authority, then vouchers need to be "spent" in the ratio of one voucher per unit of digital currency. In this way, the amount of digital currency that can be transferred is limited. Anonymity vouchers are free of charge and not transferable. The AML authority issues vouchers at regular intervals.

The Bahamas launched a digital currency, the Sand Dollar, in late 2020. Their design has a three-tiered structure under which Tier I wallets require no due diligence and are limited to holding 500 dollars; Tier II wallets require the same standards as bank accounts and are capped at 8,000 dollars; finally, Tier III wallets are meant for institutions and have a one-million-dollar cap. This tiering structure is intended to deal with KYC rules.[51]

2. Sanctions

The challenges central bank digital currencies are likely to encounter in transferring sensitive financial data parallel existing concerns about the Society for Worldwide Interbank Financial Telecommunication ("SWIFT"), which is headquartered in Brussels, Belgium. SWIFT was established in May 1973 and has continuously expanded to include around 215 countries and 11,000 financial institutions.[52]

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[50] European Central Bank, *Exploring Anonymity in Central Bank Digital Currencies*, IN FOCUS (Dec. 2019), https://www.ecb.europa.eu/paym/intro/publications/pdf/ecb.mipinfocus191217.en.pdf.

[51] Central Bank of The Bahamas, C*onsumer-Centric Aspects of the Proposed Regulations for the Bahamian Digital Currency* (Mar. 26, 2021), https://www.centralbankbahamas.com/news/public-notices/consumer-centric-aspects-of-the-proposed-regulations-for-the-bahamian-digital-currency.

[52] SWIFT is a private joint-stock company, registered in Belgium, and owned by member institutions. All important financial institutions in the world are SWIFT members. The National Bank of Belgium plays an important role in overseeing SWIFT.

Today, SWIFT serves as the global financial infrastructure for payments. It is a platform for sending and receiving financial information cross-border in a very secure way. On August 21, 2021, for example, about 35 million SWIFT messages were sent. This involves assigning a SWIFT code to each financial institution. Banks communicate with each other via SWIFT messaging. For a financial institution or a country to be cut off from SWIFT means that the link to the rest of the world is severed—that is, no transfers between firms, governments, business would be able to occur. This would be a major blow to any government or financial institution.

The United States has tended to dominate SWIFT. Since the terrorist attacks of September 11, 2001, the U.S. Treasury financial security department and national intelligence agencies have accessed SWIFT data for use in counter-terrorism efforts.[53] U.S. leverage over SWIFT allows U.S. agencies to track global financial institutions and enables the United States to implement sanctions in the event of non-compliance with U.S. law. Banks who are blacklisted can be cut off from SWIFT, as can countries. For instance, the United States used SWIFT data to detect and freeze transactions of Iranian banks because of terrorist financing allegations.[54] In 2014, the United States threatened to exclude Russia. Recently, several Russian banks were removed from SWIFT following Russia's invasion of Ukraine in February 2022.[55] This action had a tremendous impact on the Russian ruble, which fell 26 percent versus the U.S dollar in the immediate aftermath of the SWIFT announcement.[56]

[53] SWIFT data was supposed to be confidential, but the U.S. agencies eventually were allowed to use it. *See* Juan Zarate, TREASURY'S WAR: THE UNLEASHING OF A NEW ERA OF FINANCIAL WARFARE (2013).

[54] *See* Mary Anastasia O'Grady, *El Salvador Runs a Bitcoin Scam*, WALL STREET JOURNAL (Sep. 12, 2021), https://www.wsj.com/articles/el-salvadors-bitcoin-scam-dollar-crypto-currency-monetary-policy-11631470517 ("Ever since Iran was denied access in 2012 to the Society for Worldwide Interbank Financial Telecommunication, a Brussels-based global banking network known as Swift, the axis of evil and its allies have intensified their search for a way to move illicit money electronically, outside the legal banking system.").

[55] *See* SWIFT, *An update to our message for the SWIFT Community*, https://www.swift.com/news-events/news/message-swift-community (Mar. 20, 2022). Though not all Russian banks were disconnected from SWIFT. See Philip Blenkinsop, *EU bars 7 Russian banks from SWIFT, but spares those in energy*, https://www.reuters.com/business/finance/eu-excludes-seven-russian-banks-swift-official-journal-2022-03-02/ (Mar. 2, 2022).

[56] Business Standard, *Ruble declines 26% after SWIFT sanctions against Russian banks*, https://www.business-standard.com/article/international/ruble-declines-26-after-swift-sanctions-against-russian-banks-122022800390_1.html (Feb. 28, 2022).

As a result, China is creating an alternative to SWIFT with the introduction of the Cross-Border Inter-Bank Payments System ("CIPS") in 2015.[57] In 2018, CIPS handled approximately US$3.7 trillion. SWIFT, meanwhile, facilitated the transfer of US$40 trillion in 2018 and US$77 trillion in 2019. This issue of cross-border data also has not escaped Russia's notice. According to the *American Banker*, July 23, 2019: "Russia and its BRICS [Brazil, Russia, India, China, and South Africa] partners are developing cross-border alternatives to U.S.-dominated payments systems such as Swift, driven by the rise in cross-border trade and a desire to find non-dollar alternatives to international payments systems vulnerable to sanctions by the U.S. government."[58] This is not merely a theoretical concern. After Russian banks were removed from SWIFT, the Russian government offered India's government the use of Russia's messaging system SPFS to pay for purchases of Russian military weapons and oil.[59]

According to the Australian Strategic Policy Institute, International Cyber Policy Center (2020):

> [China's central bank digital currency] intersects with China's ambitions to shape global technological and financial standards, for example, through the promotion of RMB internationalisation and fintech standards-setting along sites of the Belt and Road Initiative (BRI). In the long term, therefore, a successful [Chinese central bank digital currency] could greatly expand the party-state's ability to monitor and shape economic behaviour well beyond the borders of the People's Republic of China (PRC).
>
> To date, policymakers in the democratic world have taken a whack-a-mole approach to the security challenges presented by Chinese technologies, if they have taken action at all. Those actions—such as those pertaining to Huawei and 5G over several years and TikTok and WeChat more recently—have been taken long after the relevant brands

[57] China is also working with SWIFT by setting up a joint venture to test its digital currency. Reuters, *SWIFT Sets Up JV with China's Central Bank* (Feb. 4, 2021), https://www.reuters.com/article/china-swift-pboc/swift-sets-up-jv-with-chinas-central-bank-idUSL1N2KA0AK.

[58] *See* Robin Arnfield, *BRICS vs. Swift: Russia Spearheads Payments Plan to Guard Against U.S. Sanctions*, AMERICAN BANKER (Jul. 23, 2019), https://www.americanbanker.com/payments/news/brics-vs-swift-russia-spearheads-payments-plan-to-guard-against-us-sanctions.

[59] *See* Shruti Srivastava & Vrishti Beniwal, *Russia Offers SWIFT Alternative to India for Ruble Payments*, BLOOMBERG (Mar. 30, 2022), https://www.bloomberg.com/news/articles/2022-03-30/russia-proposes-swift-alternative-to-india-for-ruble-payments.

> and technologies have entered the global marketplace and established dominant positions, and they don't solve root problems. The potential for [a Chinese central bank digital currency] to be successful enough to have a disruptive impact on the global economic system might be far into the future, but it's important to consider what impact [they] could have on the global economy.

Thus, while all of these events may unfold in the span of decades as opposed to months, U.S. lawmakers and regulators would be wise to develop contingency plans now. Indeed, it would be too late if the United States acted once SWIFT were replaced.[60] Then the questions of standards and data accessibility suddenly become real.

3. Dollar Dominance

Could other countries' central bank digital currencies threaten the status of the U.S. dollar? The U.S. dollar plays a *dominant role* in international trade and finance. Approximately 60 percent of international reserves are held in dollar-denominated assets. Overwhelmingly, international trade is invoiced and settled in U.S. dollars.[61] Foreign banks raise large amounts of dollar-denominated deposits, around $10 trillion.[62] U.S. Treasury securities are held abroad in significant amounts, as shown in Table 5 below.[63] The U.S. return on external assets is higher than on external liabilities, allowing the country to run persistent trade deficits.[64] In other words, the United States makes money from the status of the dollar. These facts have been called

[60] SWIFT, however, is investigating blockchain; *see Progressing Technology Through Industry Initiatives*, https://www.swift.com/your-needs/data-and-technology/distributed-ledger-technology-dlt.

[61] *See* Linda S. Goldberg & Cédric Tille, *A Bargaining Theory of Trade Invoicing and Pricing*, NBER Working Papers 18985 (Apr. 2013), https://www.nber.org/papers/w18985; Gita Gopinath, *The International Price System*, NBER Working Paper 21646 (Oct. 2015), https://www.nber.org/papers/w21646.

[62] *See* Hyun Song Shin, *Global Banking Glut and Loan Risk Premium*, 60 IMF ECONOMIC REVIEW 155 (2012); Victoria Ivashina, David Scharfstein & Jeremy Stein, *Dollar Funding and the Lending Behavior of Global Banks*, 130 QUARTERLY JOURNAL OF ECONOMICS 1241 (2015).

[63] Federal Reserve Board of Governors, Flow of Funds, Table L210 Treasury Securities, June 10, 2021.

[64] Pierre-Olivier Gourinchas, Hélène Rey & Nicolas Govillot, *Exorbitant Privilege and Exorbitant Duty*, London Business School Working Paper (2017).

the "exorbitant privilege" that the country enjoys.[65] Essentially, the United States provides insurance to the rest of the world in exchange for an insurance premium.

Table 5: Ownership of U.S. Treasury Securities ($ Trillions)

End of Month	Total Publicly Held Debt	Foreign Holdings of Publicly Held Debt	Foreign Holdings as a Share of Total Publicly Held Debt
Dec. 2020	$21.6	$7.1	33%
Dec. 2019	$17.1	$6.7	39%
Dec. 2018	$16.1	$6.3	39%
Dec. 2017	$14.8	$6.2	42%
Dec. 2016	$14.4	$6.0	42%

The U.S. Treasury is a monopoly supplier of safe debt because of U.S. institutions: an independent central bank that has kept inflation low and stable; U.S. financial markets that are very deep for trading Treasuries; a fiscal policy that makes repaying at U.S. government debt at par very likely. Such institutions are hard to replicate. And in recent crises, some countries' sovereign debt lost its status as safe debt.

Thus, the threat of other countries' (digital) currencies dethroning the U.S. dollar is unlikely to materialize in the near term, but a challenge could materialize in the longer run. How could that happen? We have stressed that global supply chains would benefit greatly from central bank digital currencies.[66] But since there would have to be an FX transaction, one country's digital currency would have to be interoperable with other countries' digital currencies, which is why central banks are engaged in projects to learn how this could be conducted. At some distant point of time, it could

[65] *See* Ben S. Bernanke, *The Dollar's International Role: An "Exorbitant Privilege"?*, BROOKINGS (Jan. 7, 2016), https://www.brookings.edu/blog/ben-bernanke/2016/01/07/the-dollars-international-role-an-exorbitant-privilege-2/ ("In practice, however, the system afforded the greatest flexibility to the United States, which enjoyed substantial freedom to pursue its domestic policy objectives as well as the ability to run sustained balance-of-payments deficits. The latter, according to French finance minister Valéry Giscard d'Estaing, gave the United States an 'exorbitant privilege.'").

[66] In global supply chains, cash flow management is currently inefficient. It uses manual workflows and third-party actions, like accounting or customs. Consequently, traditional contracts cause delays. Tracking where goods are in the supply chain is also hard. Then there is the issuer of responsibility, which CMR partially solves.

be that other countries' digital currencies are very well-developed and become used in global supply chains, chipping away at the U.S. dollar's dominant position. Though all this would occur in the future, U.S. policymakers would be wise to not simply ignore these developments.

D. Building Infrastructure

Another lesson is to not think of creating central bank digital currencies as simply creating digital money. Realistically, it involves building *infrastructure*. Eventually all blockchains will be connected through an interoperable technology. That's the infrastructure.

Building infrastructure is a painstaking task. Once an infrastructure has been built, it seems like it was always there. Everyone takes email for granted now. People can send email from the United States to Bolivia in no time. The same goes for the internet. Few remember that the technological infrastructure which comprises today's internet had to be built over decades or that interoperability was a key engineering challenge that needed to be solved to enable its success.

The internet had its start in a famous 1945 essay, *As We May Think*, by Vannevar Bush.[67] Vannevar Bush was the Satoshi Nakamoto of his time. (Nakamoto is the pseudonym for a person or persons who developed bitcoin.) In the 1960s there were 10,000 computers, but there was no communication between them. How did they become interoperable? The precursors to what we now know as the internet was ARPANET, started in 1969 by the Defense Advanced Research Projects Agency ("DARPA"), a part of the department of defense. It was the first wide area packet switching network.[68] By the 1970s, there were over 300 networks, hundreds of gateways and thousands of hosts. The DARPA internet was formed in the 1970s to interconnect these islands. The subsequent development is well known.[69] Eventually, Tim Berners-Lee essentially invented the World Wide Web at CERN in 1990.[70] That was thirty years ago.

The worldwide web had a boost in the beginning from the military. Blockchain and digital currencies are in the early stages of development. Blockchains are not yet

[67] Published in *The Atlantic* magazine in July 1945.

[68] "Packet switching" in telecommunications refers to a method of grouping data in a way such that it can be transmitted over a digital network into packets.

[69] *See* Gerard O'Regan, WORLD OF COMPUTING: A PRIMER COMPANION FOR THE DIGITAL AGE (2018).

[70] *See* Tim Berners-Lee, WEAVING THE WEB: THE ORIGINAL DESIGN AND ULTIMATE DESTINY OF THE WORLD WIDE WEB (2000).

globally interoperable. But there is no military leadership, as there was in the beginning of the internet. And it seems that blockchains and digital currencies are more complicated. For example, in a decentralized blockchain transactions are irrevocable; they cannot be undone if a transacting party won't participate. Legal authorities cannot compel cooperation because the transaction party could be anonymous or in another jurisdiction. This means that existing laws will have to adapt.

E. The Lucas Critique and Policy Process

Gorton and Zhang (2021) discuss the policy options with respect to stablecoins and central bank digital currencies. But what about the policy *process*? How should policymakers evaluate policy options in the face of the Lucas (1976) Critique?[71] Two potential approaches are for policymakers to examine historical analogies or experiment in the present day to discover best practices and unintended consequences.

The Lucas Critique was articulated with respect to large econometric models. These models were estimated on historical data and then policy counterfactuals were performed, as if people would behave the same way under the new policy as they had historically. But, Lucas said, people are rational and will not behave the same way. The Lucas Critique is taught in every Ph.D. macroeconomics class, but it is promptly forgotten when it comes to real-world policymaking.

Consider the following hypothetical: The police department of a state hired a consulting firm to do cost-benefit analysis on whether the police department should buy radar guns. The consulting firm took some radar guns and tested them out by seeing how many speeders would be detected on state highways, and hypothetically gave tickets which some fraction would pay. The consulting firm concluded that the radar guns would much more than pay for themselves. After the police department bought all the radar guns, the department discovered that the radar guns did not pay for themselves, because people purchased radar detectors for their cars.

To discover these unintended consequences, one could use financial history to evaluate proposed policies.[72] This approach assumes that market economies have an inherent structure, unchanging definitive characteristics. As discussed in Gorton and Zhang

[71] Robert E. Lucas, Jr., *Econometric Policy Evaluation: A Critique*, 1 CARNEGIE-ROCHESTER CONFERENCE SERIES ON PUBLIC POLICY 19 (1976).

[72] *See* Gorton & Zhang, *supra* note ___. *See also* Gary Gorton, Toomas Laarits & Tyler Muir (2020), *Mobile Collateral versus Immobile Collateral*, JOURNAL OF MONEY, CREDIT AND BANKING (forthcoming).

(2021), one of these inherent characteristics is the demand for privately produced money.[73] Another method is to conduct extensive experiments—to run pilot programs. Central banks engaged in these pilot programs can learn the upsides of various digital currency designs as well as the unexpected limits. In short, there should be more experimentation.

[73] Another example of this historical approach is presented by Frost, Shin, and Wierts (2020), who focus on the Bank of Amsterdam (1609–1820). *See* Jon Frost, Hyun Song Shin & Peter Wierts (2020), *An Early Stablecoin? The Bank of Amsterdam and the Governance of Money*, BIS Working Paper No. 902 (Nov. 10, 2020), https://www.bis.org/publ/work902.htm. The authors write that "the economic concepts of stablecoins and of central bank solvency are not new. Indeed, the Bank of Amsterdam provides a rich source of experience on the working of money backed by assets, and the corrosive effect of excessive discretionary credit amid weak governance on the stability of this system." *Id.* at 36.

Conclusion

We do *not* argue that there must be a central bank digital currency right now, because there might be technological and operational problems that defeat its feasibility and which may have their own unintended consequences. We do believe, as do many central banks, in conducting experiments that can address the possible technological and operational problems, particularly interoperability.

We conclude by re-emphasizing a handful of points:

- Central bank digital currencies have potentially huge benefits for cross-border trade. Global supply chains are complicated. For example, building a Boeing airplane uses three million parts from multiple countries with multiple currencies.[74] The rationale for most central bank digital currencies is not the retail market, but in facilitating these types of large volume transactions. Indeed, central banks around the world share this view, as most of their experiments are cross-border in nature.
- Even if a central bank announced tomorrow that it would issue a digital currency, it would take years to make it interoperable with other countries' digital currencies. This interoperability is necessary for addressing the market failure associated with cross-border payments. There will have to be international standards.
- Setting international standards also has national security implications. Indeed, creating a framework includes deciding who owns or sees the information produced by interoperable digital currencies. Moreover, in the longer run, other countries' digital currencies might erode the U.S. dollar's dominant status, thereby undermining U.S. sanctions.
- Creating a digital currency is akin to building infrastructure. It is an arduous task.
- Experiments between central banks are helpful for learning about the costs and benefits of a proposed policy. This is an essential part of the policymaking process.

[74] *See* Laura Ross, *A Bird's Eye View of the Vast, Complex Boeing Supply Chain*, THOMAS INSIGHTS (Jul. 15, 2020), https://www.thomasnet.com/insights/boeing-supply-chain/ ("A single Boeing airplane is made of more than three million parts, which means the company's supply chain is a massive, global operation. More than 150,000 people are employed in more than 65 countries, not to mention the hundreds of thousands more working for Boeing suppliers across the globe.").

Appendix

Sources for Table 2

Name or Companies Involved	Sources
TradeLens	**Name/companies/sector/status:** https://www.tandfonline.com/doi/full/10.1080/00207543.2019.1651946 Section 3.1.2 **Blockchain platform:** https://www.tradelens.com/platform **Own coins/tokens?** https://www.coindesk.com/ibm-significant-code-contribution-hyperledger-red-hat-support **Off-chain?** https://www.ibm.com/blogs/blockchain/2021/06/making-fungible-tokens-and-nfts-safer-to-use-for-enterprises/
Autonomous services selection system and distributed transportation database(s)	**Name/blockchain platform/own coins/tokens?/off-chain?** link (patent application) Section [0040] — proposed ledger may use coins such as Bitcoin or Ether **Companies/sector/status:** https://www.tandfonline.com/doi/full/10.1080/00207543.2019.1651946 Section 3.2
N/A — Anheuser-Busch Inbev, SettleMint, Fujitsu	**Name/companies/sector/status:** https://ab-inbev.eu/news/from-barley-to-bar-ab-inbev-trials-blockchain-with-farmers-to-bring-supply-chain-transparency-all-the-way-to-beer-drinkers/ **Blockchain platform:** (SettleMint blockchain technology)

	https://www.foodbev.com/news/ab-inbev-trials-blockchain-to-track-and-trace-barley-supply-chain/ (SettleMint offers three blockchain protocol options) https://www.settlemint.com/blockchain-platform-features **Own coins/tokens?** (JWT Token for Ethereum) https://launchpad.settlemint.com/documentation/integration **Off-chain?** (SettleMint compatible with off-chain systems) https://www.settlemint.com/bridging-on-chain-off-chain-with-integration-studio/ (Off-chain not applicable for JWT Token) https://launchpad.settlemint.com/documentation/integration
IBM Food Trust	**Name:** https://www.hyperledger.org/learn/publications/walmart-case-study **Companies/sector:** https://www.tandfonline.com/doi/full/10.1080/00207543.2019.1651946 Section 3.3 **Blockchain platform:** https://www.prnewswire.com/news-releases/ibm-food-trust-delivers-traceability-quality-assurance-to-major-olive-oil-brands-with-blockchain-301169130.html **Status:** https://www.forbes.com/sites/astanley/2018/10/08/ready-to-rumble-ibm-launches-food-trust-blockchain-for-commercial-use/?sh=1241db027439 **Own coins/tokens?** https://www.coindesk.com/ibm-significant-code-contribution-hyperledger-red-hat-support **Off-chain?** https://www.ibm.com/blogs/blockchain/2021/06/making-fungible-tokens-and-nfts-safer-to-use-for-enterprises/
Trado	**Name/companies/sector:**

	https://www.logisticsbureau.com/whos-using-blockchain-in-2020-and-how/ https://www.cisl.cam.ac.uk/centres/centre-for-sustainable-finance/news/multi-sector-collaboration-between-blue-chips-start-ups-and-banks-delivers-new-model-to-improve-the-sustainability-of-global-supply-chains **Blockchain platform/status:** https://www.supplychaindive.com/news/unilever-blockchain-tea/513365/ https://www.edie.net/news/8/Blockchain-enabled-supply-chain-sustainability-scheme-hailed--successful--by-business-giants/ **Own coins/tokens?** https://provenance.io/#page-content-container https://www.businesswire.com/news/home/20210519005633/en/Provenance-Launches-New-Public-Decentralized-Blockchain-for-Financial-Services **Off-chain?** https://bfi.uchicago.edu/wp-content/uploads/Provenance-Whitepaper.pdf (p. 29-31)
Tracr	**Name/sector:** https://www.logisticsbureau.com/whos-using-blockchain-in-2020-and-how/ **Companies:** https://www.ledgerinsights.com/debeers-blockchain/ **Blockchain platform/status:** https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/923608/use-distributed-ledgers-verify-provenance-goods.pdf (p. 45-46) Tracr is not run on main Ethereum network, but likely on distributed ledger (DLT) system instead: https://thenextweb.com/news/de-beers-diamond-alrosa **Own coins/tokens?**

	https://ethereum.org/en/eth/ **Off-chain?** https://ethereum.org/en/eth/ Under "Uses for ETH grow every day"
TrustChain	**Name/companies/sector/status:** https://www.trustchainjewelry.com/ **Blockchain platform:** https://www.ibm.com/blogs/blockchain/2018/04/new-consortium-collaborates-to-put-jewelry-on-blockchain/ **Own coins/tokens?** https://www.coindesk.com/ibm-significant-code-contribution-hyperledger-red-hat-support **Off-chain?** https://www.ibm.com/blogs/blockchain/2021/06/making-fungible-tokens-and-nfts-safer-to-use-for-enterprises/
N/A — Ford, IBM	**Name/companies/sector/blockchain platform/status:** https://www.forbes.com/sites/rachelwolfson/2019/01/16/ford-motor-company-launches-blockchain-pilot-on-ibm-platform-to-ensure-ethical-sourcing-of-cobalt/?sh=1ac963a95a1d **Own coins/tokens?** https://www.coindesk.com/ibm-significant-code-contribution-hyperledger-red-hat-support **Off-chain?** https://www.ibm.com/blogs/blockchain/2021/06/making-fungible-tokens-and-nfts-safer-to-use-for-enterprises/
PartChain	**Name/companies/sector/status:** https://cointelegraph.com/news/bmws-blockchain-solution-for-supply-chains-to-roll-out-in-2020 **Blockchain platform:** https://tadviser.com/index.php/Product:PartChain_(blockchain_platform) **Own coins/tokens?** https://fabric-documentations.readthedocs.io/en/latest/token/FabToken.html

	Under "Using FabToken" and "What is FabToken" **Off-chain?** https://fabric-documentations.readthedocs.io/en/latest/token/FabToken.html Under "The token lifecycle"
N/A — Tesla, CargoSmart, COSCO Shipping, Shanghai International Port Group	**Name/companies/sector/status:** https://www.ledgerinsights.com/tesla-cargo-blockchain-shipping-pilot-cosco-shanghai-port-gsbn/ **Blockchain platform:** https://www.forbes.com/sites/biserdimitrov/2020/04/14/how-tesla-and-bmw-are-leading-a-supply-chain-renaissance-with-blockchain/ **Own coins/tokens?** https://fabric-documentations.readthedocs.io/en/latest/token/FabToken.html Under "Using FabToken" and "What is FabToken" **Off-chain?** https://fabric-documentations.readthedocs.io/en/latest/token/FabToken.html Under "The token lifecycle"
KitChain	**Name/companies/sector/status:** https://www.ledgerinsights.com/pharma-majors-pfizer-biogen-lead-blockchain-project-for-clinical-trial-supply-chain/ **Blockchain platform:** https://static1.squarespace.com/static/5b819b5b45776e48dcfb5df2/t/5d5336523effc200016ecf03/1565734487554/CSBWG-transforming-clinical-supply-1.8.pdf (p. 2) **Own coins/tokens?** https://fabric-documentations.readthedocs.io/en/latest/token/FabToken.html Under "Using FabToken" and "What is FabToken" **Off-chain?** https://fabric-documentations.readthedocs.io/en/latest/token/FabToken.html Under "The token lifecycle"

Sources for Table 3

Name	Country	Sources
Project Jasper-Ubin	Singapore & Canada	https://www.bis.org/publ/othp38.pdf (p.11) Whitepaper: link
Project Jura	France & Switzerland	https://www.bis.org/publ/othp38.pdf (p.11) https://www.bis.org/press/p210610a.htm
Project Inthanon-LionRock	Thailand & Hong Kong	https://www.bis.org/publ/othp38.pdf (p.11) Whitepaper: link
Project mCBDC Bridge	China & United Arab Emirates	https://www.bis.org/publ/othp38.pdf (p.11) Overview: link
Project Dunbar	Singapore	https://www.bis.org/publ/othp38.pdf (p.11) Overview: link
Project Aber	Saudi Arabia & United Arab Emirates	https://www.bis.org/publ/othp38.pdf (p.11) Whitepaper: link
Project Helvetia	Switzerland	https://www.bis.org/publ/othp35.pdf
Project Stella	Europe & Japan	https://www.bis.org/publ/othp38.pdf (p.24) Announcement: link

No Name as of Yet	Canada, England, Japan, Europe, Sweden, & Switzerland	https://www.bis.org/publ/othp38.pdf (p.11)
No Name as of Yet	France & Singapore	Overview: link https://www.banque-france.fr/en/communique-de-presse/banque-de-france-and-monetary-authority-singapore-break-new-ground-cbdc-experimentation-0
No Name as of Yet	France & Tunisia	Overview: link https://www.banque-france.fr/en/communique-de-presse/banque-de-france-cooperation-banque-centrale-de-tunisie-successfully-conducts-experiment-use-central

Sources for Table 4

Name	Country	Sources
Sand Dollar	The Bahamas	https://www.atlanticcouncil.org/cbdctracker/ https://www.sanddollar.bs/
DCash	Eastern Caribbean	https://www.atlanticcouncil.org/cbdctracker/ https://www.eccb-centralbank.org/news/view/bitt-partners-with-eccb-to-develop-worldas-first-central-bank-digital-currency-in-a-currency-union
E-krona	Sweden	https://www.atlanticcouncil.org/cbdctracker/ https://www.riksbank.se/en-gb/press-and-published/notices-and-press-releases/notices/2021/riksbank-begins-cooperation-with-external-participants-in-e-krona-pilot/ Handelsbanken: https://www.handelsbanken.com/en/ TietoEVRY: https://www.tietoevry.com/en/about-us/our-company/
LBCOIN	Lithuania	https://www.atlanticcouncil.org/cbdctracker/ https://www.lb.lt/en/news/bank-of-lithuania-issues-lbcoin-the-world-s-first-digital-collector-coin
E-hryvnia	Ukraine	https://www.atlanticcouncil.org/cbdctracker/ Stellar Development Foundation: https://www.stellar.org/foundation?locale=en National Bank of Ukraine report on the 2019 pilot:

		link
e-CNY	China	https://www.atlanticcouncil.org/cbdctracker/ Whitepaper: link
N/A	South Korea	https://www.atlanticcouncil.org/cbdctracker/ Ground X collaboration: https://www.coindesk.com/bank-of-korea-chooses-ground-x-as-supplier-for-cbdc-pilot
N/A	Jamaica	https://cbdctracker.org/currency/jamaica https://www.coindesk.com/jamaica-central-bank-pilot-cbdc-may
Khokha	South Africa	Overview: link Announcement: link
N/A	France	https://cbdctracker.org/currency/france-france_cbdc Government bond pilot: https://blockchain.news/news/french-central-bank-succeeds-cbdc-experiment-the-issuance-government-bond
e-Peso	Uruguay	https://cbdctracker.org/currency/uruguay-e-peso Launch: https://beincrypto.com/uruguays-e-peso-how-a-small-nation-built-the-worlds-first-cbdc/