Stable Coins and Central Bank Digital Currency

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Abstract

Stable coins are cryptocurrencies whose value is pegged to one or more government-issued currencies such as the US dollar. Like other cryptocurrencies they have the ability to transfer value person-to-person, quickly and at low cost anywhere in the world. With a stable value and potentially with wider acceptance they may overcome the issues that have hindered the adoption of cryptocurrencies. There has been substantial interest in and issuance of stable coins recently, and for good reason. If they become widely used, there will likely be major implications in a number of areas starting with banking and monetary policy, and potentially with regards to Central Bank Digital Currency (CBDC). CBDCs have been studied by many central banks in recent years and there have been a number of limited trials. Up to now, it has been assumed that CBDC means central bank-issued digital currency. However stable coins, if regulated, may provide an ideal on-ramp to a CBDC implementation. The advantages of regulated stable coins over a government-issued digital currency in a country such as the United States include scaling considerations, implementation time and risk, as well as political considerations. So perhaps rather than assuming CBCD means central bank-issued digital currency, we should also consider central bank-authorized digital currency.

Stable Coins

Stable coins are digital assets (aka "cryptocurrencies") whose value is pegged to an existing government-issued ("fiat") currency. The issuer of the stable coin agrees to redeem any stable coins presented to them for the equivalent amount of local currency. This allows users to move value, denominated in local currency, between digital asset exchanges and personal wallets. It also lets users trade these stable coins for digital assets on exchanges that support only cryptocurrencies, and in turn redeem cryptocurrencies on crypto-only exchanges for these stable coins.

Most stable coins are backed by assets denominated in the currency to which the coin is pegged, frequently held in cash or highly liquid cash equivalents. A couple more thinly-traded stable coins are backed by cryptocurrency assets and maintain their pegs algorithmically. Most stable coins issued to date have been pegged to the US dollar.

Although the use of stable coins up to the present has been primarily for trading on crypto-only exchanges, the ability to transfer stable coins between wallets potentially opens up substantial new uses. For example, a user could transfer stable coins to the wallet of a merchant on checkout, similar to the use of a credit or debit card. The difference would be that the merchant would receive the full amount immediately, unlike a payment with a credit or debit card. Or a user in the United States could send stable coins from their wallet to that of another user in the US or even a user in another country, immediately at low or no cost.

Stable Coin Growth

Stable coin issuance has grown dramatically in the past year or so. In 2018 alone a number of US dollar-pegged, asset-backed stable coins have been issued including TrueUSD (TUSD), USD Coin (USDC), Paxos Standard Token (PAX), Gemini Dollar (GUSD), and StableUSD (USDS). All but TUSD were issued since September 2018. In June 2019 Facebook also announced a planned stable coin. And in September 2019 Binance announced issuance of BUSD, an NYFDS approved stable coin.
See Appendix A for a list of stable coins.

Stable coin issuers and exchanges as banks

Traditional Banks

Banks take deposits from customers and use the proceeds to invest in assets and make loans to other customers. In most countries they are highly regulated including the types and riskiness of the assets they can hold, as well as how much they can lend out versus the portion of deposits they must keep in reserve (the reserve ratio). Banks perform several functions in the economy including allocation of capital from savers to the most potentially profitable assets and borrowers. They also implement the government's monetary policy through their transmission of interest rates, as well as potentially through the amounts of loans available due to the reserve ratio.

But bank transfers are relatively slow and costly for most users. Consider transactions in the current banking system;

- debit and credit cards (expensive for merchants and takes days to receive funds),
- domestic ACH (a day or two, less expensive than cards),
- checks (days),
- wires (expensive),
- international transfers (expensive and slow)

Compare these to a method that has the ability to transfer value person-to-person or person-to-business anywhere almost immediately at very low cost.

Stable coin issuers and exchanges

Stable coin issuance allows the issuers, especially exchanges, to effectively be banks, or more broadly to be financial services companies with advantages over banks. Like banks, coin issuers take deposits in the form of users purchasing their stable coins. The issuers currently do not pay interest (though they could). Most stable coin issuers assure users that their stable coins are backed 100% by assets. But in many cases those assets need not be cash. In those cases issuers can use the cash to purchase assets that generate income, provided that they have sufficient liquid assets to meet redemption requirements. They will surely notice that as usage increases, net redemptions are actually negative. Many cryptocurrency exchanges currently limit withdrawal amounts per period, which would greatly aid in managing reserves.

In some ways, it means that the required minimum reserve ratio for stable coin issuers is 0%[1]. So they have advantages over banks of not paying interest on "deposits" for stable coins and in not having

[1] If a stable coin issuer used proceeds to purchase a bond from a company that in turn used the bond sale proceeds to purchase stable coins, recursive replays of this scenario could increase leverage and the monetary supply limitlessly. Consider Exchange A purchasing $1M stable coins from the issuer. The issuer uses that $1M to

required cash reserves. And they don't have the physical, labor, or regulatory overhead that banks have.

Given the potential profitability, more companies including exchanges are likely to issue stable coins. And exchanges may pool and lend fiat and stable coin balances. Both are relatively straightforward. The main challenge may be to stay on the right side of the regulators in whatever jurisdiction(s) they are in, and to implement the controls that enable them to do so. The same is true for stable coin issuers.

Central Banks and Banking regulators responses

Prior to Facebook's development and announcement of the Libra stable coin, there was little direction from legislators or regulators. For the most part, stable coins were treated and regulated like any other cryptocurrencies. Cryptocurrencies have been accepted and even encouraged in some countries, such as Malta and Switzerland, and likewise in some US states such as Wyoming. At the same time they have been banned or discouraged in a number of other countries [1]. And they've been regulated more rigorously in some states such as New York.

The announcement of Libra however generated substantial government response. Witness the head of the US House of Representatives Financial Services Committee immediately calling for Facebook to pause development [2] , and the US Senate planning hearings [3] , both within a day of Facebook's Libra stable coin announcement . And the US Senate Banking Committee's letter [4] written a month before Libra was announced. Regulators in Europe, particularly in France, have also expressed opposition. The French Finance Minister said Libra posed risks and its development should be blocked [5]. The FSB and FATF have both indicated that it views global stable coins as a risk [6] [7]. And the G-20 has agreed to set strict regulations [8].

Stable coins as CBCD

Central Bank Digital Currencies

The ability of cryptocurrencies to securely transfer value between individuals anywhere without an intermediary has clearly been recognized as a threat to many banking services. Central banks have also recognized that there might be an opportunity to apply the technology to national currencies. And if properly applied, a secure ledger of all transactions could provide unprecedented control and insight into the money supply as well as multiple other benefits to governments. As detailed in Appendix B, a number of central banks have been quite active in research on economic topics related to digital currencies. Several limited trial projects have been run, and more are underway or planned.

It's with good reason that there has been growing interest in Central Bank Digital Currencies or CBDCs. The adoption of a secure, national cryptocurrency could provide a government with profound benefits on a number of levels.

- It could provide a central bank with increased efficiency, manageability, and transparency in monetary policy.
- It could provide banking regulators with superb insight and control.
- It could increase financial inclusion for countries with substantial unbanked populations

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lend to or buy a bond from Exchange B. Exchange B then uses those proceeds to buy $1M of stable coins from the issuer. The issuer then lends to Exchange C, who may also want stable coins, …

- It could provide strong KYC/AML for financial transactions.
- It could provide audit trails for controlled goods and substances.
- It could provide insight into the economy for policy makers and researchers
- It could be of interest to intelligence.
- It could be of benefit to taxing authorities, and payers, particularly for VAT/sales with immediate collection.
- It could provide efficient means of payments for benefits systems.

Central Bank Digital Currency Projects and Research

In the past year alone, the International Monetary Fund, the Bank for International Settlements and the World Economic Forum have each published reports on central banks' plans, research, and trials with national digital currencies [9] [10] [11]. The former details forms of "money", the pros and cons of CBDCS, potential designs, and potential effects on existing banks. One of the forms of money mentioned is cryptocurrencies, but other than a footnote, the examples cited are cryptocurrencies with volatile valuations. Said footnote mentions the difficulty maintaining a peg without asset backing, but doesn't consider asset backed stable coins further. The BIS paper summarizes the results of a survey of the world's central banks and their plans and attitudes towards CBDC. The BIS received responses from banks representing over 80% of the world's population and 90% of the world's output. Of the respondents, over 70% were involved or would soon be involved in CBCD research or plans. The survey did not mention stable coins. The World Economic Forum paper was a report summarizing research, speeches and whitepapers related to CBDCs by central banks and others. It includes all blockchain ("DLT") applications by governments, not only CBDCs.

In banking parlance, a cryptographically secured blockchain is usually referred to as Distributed Ledger Technology or DLT.

A number of central banks have conducted DLT tests or pilot programs for their domestic interbank settlement systems (sometimes referred to as Real-Time Gross Settlement or RTGS systems). Among these are the Monetary Authority of Singapore [12], the US Federal Reserve Bank of Boston [13], the Bank of Canada [14], the Bank of Thailand [15], Banco Central do Brazil [16], and the South African Reserve Bank [17]. Virtually all have found the system to work completely adequately and hold the promise of additional benefits.

Some of these central banks have continued with tests of securities settlement systems (aka Delivery vs. Payment or DvP systems) using DLT in conjunction with their stock exchange(s). These include the Bank of Canada [18] and the Monetary Authority of Singapore which included government bond reconciliation [19]. The German Bundesbank also conducted such as test as a standalone project rather than an extension of a interbank settlement pilot [20]. The Bank of Thailand is conducting a further pilot, Phase II of Project Inthanon, which will test reconciliation of central bank issued debt as well as data interchange using DLT. And in June 2019 the Swiss stock exchange asked its central bank to issue a CBDC to facilitate clearing [21].

A smaller number of central banks have tested cross-currency payment settlements using DLT. These include the Bank of Canada together with the Monetary Authority of Singapore [22], and the Bank of Japan together with the European Central Bank [23]. The Saudi Arabian Monetary Authority together with the United Arab Emirates Central Bank is also planning such a test [24]. A multi-currency clearing pilot test was also done by commercial bank, the Royal Bank of Scotland [25].

There have been a number of digital payment solutions implemented in various countries, though none are CBCD. The countries involved include Tunisia whose system was done by the country's postal service [26] , Senegal whose system was done by a commercial bank and does not appear to have traction [27], the UAE whose system is currently being implemented, and Ecuador whose central bank implemented and subsequently terminated the system due to lower than expected usage [28]. The Central Bank of Uruguay also implemented and completed what it concluded was a successful trial with digital versions of various denominations of its currency for general use, though this was done with a central registry and not a blockchain [10] [29]. And Japanese commercial bank Mizuho is in the process of rolling out a digital payment solution in Japan in conjunction with a large number of other commercial banks and retailers [30].

A few notable central banks, including those of Canada, England, and Sweden, have done extensive research on the subject of CBDCs and their economic effects.

A few central banks are actively working on issuing a CBDC for general use. These include the National Bank of Cambodia [31] and the Eastern Caribbean Central Bank [32].

Virtually all of these projects have used open source permissioned blockchains. Most commonly used are Corda (by R3), Quorum (originally by JP Morgan), and Hyperledger Fabric (originally by IBM). A couple have used a private implementation of a modified version of Ethereum. Cambodia is using Hyperledger Iroha (originally by Soramitsu).

The People's Bank of China (PBoC) is also working on a general-use CBDC which was reportedly near issuance in September 2019 (see more details in Appendix B).

So with few exceptions, all central bank digital currency projects so far have been either for interbank clearing or securities settlement. The general-use digital currency projects are either completed pilot tests, still in the planning stage, or implemented by commercial banks rather than the central bank. And all have been on private networks. Contrary to what is sometimes reported, there are no general-use CBDC projects publicly available (questionable projects by Venezuela and Iran notwithstanding).
See Appendix B for a list of Central Bank Digital Currency projects and research by country

Central Banks' Path to Digital Currency

Given that stable coin issuers function as banks in many regards, central banks may consider regulations for stable coin issuers that are consistent with existing banking regulations. As mentioned above, this might include lending, reserve ratio, and approved asset guidelines.

The central bank may also consider letting large issuers / exchanges participate and work directly with the central bank as large domestic traditional banks do. In the U.S. this would mean deposits and clearing at the Fed as well as access to the discount window. And issuers/exchanges might work with central banks to implement interest rate capabilities (+/-) that allow the transmission of monetary policy. And a stable coin group would likely also want to work with regulators so that only regulated stable coins are listed on domestic regulated exchanges.

This would allow appropriate oversight and integration as this market grows. In fact this is the most direct path to CBDC and the benefits that might be provided to various government agencies via CBDC.

Stable Coins as CBDC

For the vast majority of CBDC trials it has been assumed that CDBC means central bank-issued digital currency. But a much more feasible plan may be central bank-authorized digital currencies. This is particularly true for the United States. The economy is so large it's unlikely that any currently envisioned solution could scale. And the risks are great.

As we've discussed, there are currently asset-backed, auditable USD stable coins. If these were regulated and required to include additional features such as banking KYC and consolidated reporting, they could effectively serve as a gradual rollout of US CBDC. And the functionality would be equivalent to banking and cash: A user needs to supply identity information to establish a bank account and withdraw cash. But cash may be spent anonymously, just as a user could transfer stable coins from their wallet to that of another user. However, whenever a user wants to bank those coins they need an account with identity information and may need to provide info on the source of the funds.

The existence of a number of regulated stable coins is also beneficial with regards to scaling. While blockchains are useful for transaction integrity, the design is inefficient with redundant processing and storage at every full node. No current cryptocurrency blockchain is likely to be able to handle a substantial portion of USD transactions. But stable coins have been issued on a number of blockchains including the Bitcoin blockchain (Omni layer), Ethereum blockchain (ERC-20 tokens), and other blockchains including those from Binance, TRON, EOS and others. Collectively these may well be able to handle substantial transaction volume. Load-balancing tools could be developed as usage increases.

In addition to KYC and consolidated reporting tools, a standard might be implemented to capture additional transaction information. Most cryptocurrency transactions represent a single transfer of coins from one address to another. No information is captured about the other side of the transaction; what is being exchanged for those coins. Implementing a standardized goods and services coding system, such as FPDS in the US, could provide enormous benefits along the lines of the originally envisioned benefits of CBDC. There would be a significant coordination effort required as each blockchain functions differently, but the benefits would be great. A regulator might specify the classification system and leave it to each stable coin or blockchain as to how they might capture that data and provide tools to then access that data.

And not least are the political benefits of a private sector solution in a country such as the US where private sector solutions are generally favored over government programs.

Conclusion

Stable coins have the potential to profoundly change banking and the provision of financial services.

Stable coin issuers and exchanges are the new banks. They're just not recognized or regulated as such yet.

Stable coins represent the most direct path to the development of central bank digital currencies and the realization of their potential benefits. Rather than assuming that CBDC means Central Bank-Issued Digital Currency, authorities should also consider Central Bank-Authorized Digital Currencies issued by regulated private entities.

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Appendix A: Stable Coin Implementations

The first widely distributed stable coin was Tether (USDT), issued by a company of the same name, with common ownership to crypto-exchange Bitfinex. It was first issued in 2015. Over time USDT proved extremely popular, especially for allowing crypto-only exchanges to have a proxy for the US dollar. This allowed traders to trade in and out of cryptocurrencies seamlessly on any given crypto-only exchange that supported USDT. However both Bitfinex and Tether were dogged with financial questions, in the case of USDT as to whether it was properly backed by USD as it claimed. Tether contracted with respected accounting firm Friedman, which has been prominent in the crypto space. Friedman issued a preliminary report in September of 2017 indicating that Tether was fully-backed by USD [33]. But the report was a memo rather than an audit; it looked at bank balances at a snapshot in time without verifying source or longevity of funds, and did not further investigate a substantial account that was held in an individual’s name “for the benefit of Tether”. Nevertheless Tether publicized the report and

continued the relationship with Friedman, purportedly working towards a full audit. But in January 2018 Tether dissolved the relationship with Friedman without achieving an audit [34]. Tether subsequently engaged heavyweight legal firm Freeh Sporkin & Sullivan LLP to vouch for its balances backing USDT [35] [36]. But again it was not an audit. Research in February 2018 from BitMEX [37]) does not draw conclusions as to whether it is fully backed, but expects that it would be supported.

Tether was not actually the first stable coin, though it was close. That distinction goes to BitShares' BitUSD, which we'll discuss below. But Tether was the first to gain widespread use. Its popularity, even with the financial questions surrounding it, likely contributed other firms deciding to get in on the market for stable coins.

TrustToken created a platform, procedures, and contracts to tokenize real-world assets [38] to be held in escrow and governed by smart contracts. In March 2018 TrustToken issued a tokenized US dollar stable coin called TrueUSD, symbol TUSD, that became available on Bittrex [39]. In April 2019 TrustToken also created fully-backed TrueGBP stable coins for British Pounds [40] and later that same month issued TrueAUD for Australian Dollars while at the same time announcing 2019 Q2 support for and TrueCAD for Canadian Dollars and TrueEUR for Euros, and later 2019 support for TrueHKD for Hong Kong Dollars [41].

Seattle-based startup Stably created stable coin StableUSD, symbol USDS. Their whitepaper was first released in November 2017 and revised several times throughout 2018 [42]. USDS was first issued and supported by Bittrex in December 2018 [43]. Like most stable coins, it is an ERC-20 token trading on the Ethereum blockchain. In addition, Stably states that USDS is protocol agnostic and that versions trading on the EOS and Stellar networks are under development (ibid).

Both USDS and TUSD are audited by Cohen & Company and escrowed by Prime Trust LLC and allow users to verify escrow [44], [38].

In September of 2018 Gemini issued stable coin GUSD pegged to the US dollar, which it has referred to as the first regulated stable coin [45] [46]. Paxos also issued the USD backed stable coin PAX on the Ethereum network in September 2018, which, like GUSD, was approved by the New York Department of Financial Services with funds held in FDIC insured banks [47]. Within 3 months it had been used in $5B of transactions [48]

Circle was founded in 2013 to focus on cryptocurrency market opportunities and counts Goldman Sachs and crypto-mining titan Bitmain among its investors [49]. In February 2018 Circle acquired cryptocurrency exchange Poloniex [50], which was a U.S.-based crypto-only exchange. Together with Coinbase, Circle founded CENTRE whose whitepaper, v2 from May 2018, lays out a very broad vision of asset back stable coins, starting with US dollar-based USDC [51]. CENTRE is both an open consortium, in the sense that it invites additional members to join, and it is a suite of protocols, procedures, and smart contracts through which stable coins can be issued and backed (ibid) [52]. USDC was launched in October 2018 [53], and announced in June 2019 that over $745B of USDC had been issued [54]

In addition to those discussed above, several stable coins have been created that use algorithmic methods to stabilize the value, rather than being backed by the asset itself (e.g. USD).

As mentioned above, BitUSD was the first notable stable coin being first issued in 2014 and trading on Bitshares network in 2015 [55]. It is backed by BitShares' BTS token and governed by somewhat

complex issuance and margin rules meant to keep the value very close to $1USD [56] [57] . It has worked reasonably well, though in early December 2018 its value dropped to close to $0.70 USD and remained substantially below $1 for several months. It has since recovered to near parity with the dollar. The BitShares blockchain network is effectively a decentralized exchange meant to be able to trade any tokenized assets in terms of their cryptocurrency BTS with minimal fees. BitShares has also several other stable coins pegged to the target asset values including BitCNY, BitEUR, BitBTC, BitGold and BitSilver, but trading in all pairs except BitCNY/BTS is very thin[2] (which btw is a common problem for decentralized exchanges).

Like BitShares, MakerDAO has also created a DAI stable coin for USD whose value is maintained algorithmically via somewhat complex rules governing collateral ("collateralized debt positions") through which users can generate the stable coin DAI [58] In the case of DAI, the algorithms are implemented via a smart contract on the Ethereum blockchain and ETH is the initial backing asset – other digital assets may be eligible in the future (ibid). Given that the value of ETH fluctuates relative to USD or other real-world currencies, and that there has been substantial demand for DAI this sometimes requires holders to put up additional fees to attempt to maintain the peg [59].

Basecoin/Basis was a project that aimed to issue a stable coin that would be algorithmically stabilized by adjusting supply with demand. It attracted substantial funding from a number of big players including Andreessen Horowitz, Bain Capital, and Google Ventures [60]. But in December 2018, after 18 months of planning, the project foresaw too many regulatory roadblocks to continue and decided to shut down [61].

And then there is Libra, announced by Facebook on June 19, 2019, with expected launch in 2020. Libra is intended to be a stable coin pegged to a basket of currencies, for use in any country.

[2] See https://coinmarketcap.com/exchanges/bitshares-asset-exchange/

Appendix B: CBCD Projects and Research by Country

Bahamas

The Central Bank of the Bahamas announced project Sand Dollar in March 2019 with company NZIA Limited as the solutions provider [62].

Brazil

Brazil's central bank investigated the use of several different blockchains in 2016 and 2017, including a private implementation of Ethereum, Hyperledger Fabric, R3's Corda, and Quorum, and tested the latter three. The final report on these initial tests was released August 31, 2017. Those latter three, Fabric, Corda, and Quorum, were tested with the bank's alternative interbank payments system, commonly referred to by its acronym SALT. It used Hyperledger Fabric 0.6 which it found to be adequate though with some privacy limitations and minor difficulties with version 0.6 as version 1.0 was imminent. It had greater issues with R3's Corda as it too was upgrading versions, and so decided to not complete the test. It also had some difficulties with Quorum's version of Ethereum, particularly a choice between privacy and a guarantee against double spend. It expected improvement in using Quorum with future involvement from the Zerocoin Electric Coin Company and JP Morgan [16].

Cambodia

Although Cambodia has been ambiguous as to whether cryptocurrencies are legal [1], the country has been working with Soramitsu since 2017 to implement a digital currency for both financial institutions and residents, using the Hyperledger Iroha blockchain [31] [63].

Canada

The Canadian Central Bank, The Bank of Canada, has been particularly active in exploring distributed ledger technology. In March 2016 they began Project Jasper which involved working with Payments Canada, R3 Labs, and 7 Canadian banks [64]. The project was initially in two phases, the first using the Ethereum blockchain and the second using R3's Corda [14]. While the project demonstrated capabilities and potential for savings in terms of reconciliation, it also highlighted some challenges including the tradeoffs between scalability and decentralization (ibid) [65]. Overall it was viewed as promising but not ready for live implementation in the immediate future (ibid). A third phase of project Jasper, also involving R3's Corda, continued into 2018 and included securities settlement [18]. The Bank of Canada has also published a substantial number of research articles on blockchain fintech and CBDC economics [66] [67].

China

China's central bank, the People's Bank of China (PBoC) has been investigating digital currencies since early 2014 [68]. In 2016 China wrote blockchain into their five year plan and in 2017 China opened the Digital Currency Research Institute (DCRI) with the plan to develop a digital currency [69] [70]. In 2018 PBoC Governor Zhou Xiaochuan confirmed that the bank was working on developing its own digital currency [71], though Jiang Quoqing from the PBoC DCRI later said that the digital currency would not compete with existing currency, and need not involve blockchain [72]

It has been reported that the PBoC is still considering different possibilities for design, though a permissioned network with nodes run by PBoC and major banks is likely [73]. Based on recent postings, it appears that PBoC may be developing their own proprietary blockchain rather than implementing an existing offering [74]. According to Yao Qian [73] the digital currency system will be on a private cloud managed by PBoC allowing PBoC to administer monetary policy. It will also include a wallet client

developed by PBoC that will be used by all participants and a verification center for identity information (ibid). Currency ownership is registered, and a big data center is used for analysis (ibid).

In September 2019 it was reported that a new director had taken leadership of the project and that it was close to implementation [75].

Curaçao and Saint Marten

CBCS signed an agreement with Barbados-based Bitt Inc. in August 2018 to investigate a digital version of their currency, the Curaçao and Sint Maarten Guilder [76]

Denmark

In December 2017 the central bank published a study in which it determined that CBDCs offered no net benefits to Denmark and therefore were not envisioned in the near future [77].

Eastern Caribbean

In early 2018 the Eastern Caribbean Central Bank announced plans to issue what it expects will be the world's first CBDC [32]. The ECCB expects about 12 months of development and testing before gradual rollout in 2020 (ibid).

Ecuador

Ecuador implemented a digital cash program in December 2014, possibly the world's first, which drew substantial interest and activity in its first few months of operation [78]. However the program was closed as of the end of 2017 [28]. The system was a way for users to use mobile devices to transfer balances kept track of by the central bank. But after a couple years it had failed to attract a sufficient user base and it was determined that the private sector may be able to provide better digital mobile payment solutions [79].

England

The Bank of England has published substantial research on CBDC [80] [81]. In 2017 in designing a new real-time settlement system it determined that while DLT might hold promise, it was not sufficiently mature at the time [82].

European Central Bank

See Japan and the European Union

France

France implemented Project MADRE which used an implementation of Ethereum to share credit identifiers, but was not CBDC [83].

Germany

The German Bundesbank in conjunction with the stock exchange Deutsche Börse implemented Project BLOCKBASTER, which was a prototype for securities settlements. Digital coins were created during the trading day to facilitate settling trades, and then were completely refunded/destroyed at the end of each trading day. Two tests were done, one used Hyperledger Fabric (of which Deutsche Börse was one of founding members) on AWS, and the other used Digital Asset's DLT product [20].

Iran

Iran created a cryptocurrency at least in part due to sanctions from the US. But the PayMon (PMNT) does not appear to have gained any traction.

Israel
In 2017 the Bank of Israel began a study and in2018 published a summary of CBDCs around the world and indicated that the group would continue their research [84].

Japan and the European Union
Beginning in December 2016 the Bank of Japan (BoJ) and the European Central Bank (ECB) together implemented project Stella to test securities settlement with DLT. The second phase, completed in March 2018, tested a number of different conceptual designs from both cash and securities on the same ledger to working with each on separate unconnected ledgers. The banks used three different blockchains in their tests, one with R3's Corda, one with the Elements blockchain, and one with Hyperledger Fabric. The details of the architectures and transaction flows were reported for each of the blockchain tests. The tests identified some complexities that would have to be overcome in a cross-ledger implementation using Corda. However cross-ledger solutions involving Elements, Hyperledger Fabric, or both, were straightforward [85]. A third phase for cross-border settlements was completed in June 2019 [23].

Lithuania
The Bank of Lithuania used a hackathon in 2018 to create a limited edition digital collector coin, backed by silver, to commemorate their centennial. The bank is also planning blockchain tests for the country's financial sector in 2019 [86].

Marshall Islands
The Marshall Islands do not have a central bank; the US dollar is the currency used. In 2018 the Marshall Islands announced that they would be developing their own cryptocurrency, called the sovereign or SOV, for use in the country. There was criticism from the IMF and others with the IMF saying that the potential gains were considerably smaller than the economic, reputational, governance and other risks [87]. And the president, who supports the currency's creation, narrowly survived a recall.
The plan for the SOV is that it would be developed by an Israeli company, Neema. There would be a fixed amount created by a crowd sale ICO and the government would not control the money supply. The government would however advise that it be used for transactions locally, alongside the dollar. The advantages envisioned include reducing the high costs of remittances. There are no technical specifications and the CEO of Neema said they were exploring options in terms of the technology [88]. As of June 2019, the plan appears to be proceeding. The plan is that the SOV will be run by a board of directors on which the government has two seats, and the development company, now listed as SFD, also has two seats, and an additional three directors will be appointed by the initial four. The initial creation will be funded by 20% of the ICO proceeds which will also give the board an additional 30% of the funds. The remaining 50% will be used as backing [89] [90].

Norway
In 2018 Norway's central bank, Norges Bank, did a study of CBDCs including their uses, effects, alternatives, and risks. The report noted several design possibilities and concluded that more study was needed [91].

Saudi Arabia and UAE
In January 2019 the Saudi Arabian Monetary Authority and the United Arab Emirates Central Bank jointly announced Project Aber, a plan to develop a test of cross-border payments using blockchain. The test plans to use a common digital currency for the payments [24].

Scotland

The Royal Bank of Scotland (which is a commercial bank, not a central bank) has been an early and active tester and user of blockchain applications. In 2015 it was experimenting with its own cryptocurrency, joined the R3 consortium, and did a trial project using Ripple [92]. In 2016 it began a test project for interbank multi-currency clearing using a blockchain. It chose Ethereum as the most advanced smart contract environment available at the time, and modified the source for its own requirements. The test involved a number of Irish banks as well as Deloitte [25]. Project Emerald, as it was called, is now available as an open source commercial product supported by GFT Technologies.

Senegal

Senegal-based regional commercial bank Banque Régionale du Marchés, aka BRM bank, worked with eCurrency Mint Ltd. to create a digital payments processing solution in 2017, though it did not use a blockchain [93]. The plan was to expand the payment processing to other countries in the West African Economic and Monetary Union. However the central bank was not involved and in fact said it wouldn't consider it [27]. Usage does not appear to have caught on.

Singapore

MAS announced in November 2016 that it would be partnering with a number of banks including Bank of America as well as provider R3 in project Ubin to test an interbank payment system using DLT. The first phase pilot was completed in March 2017 and a summary report was produced by Deloitte [94]. Phase 2, a real-time interbank settlement system test, included a number of technology partners. In addition to being implemented on R3's Corda, the test was also implemented on Hyperledger Fabric with assistance from IBM, and on Quorom with assistance from ConSenSys. All tests were implemented on Microsoft Azure [12]. The phase 2 project was summarized in a November 2017 report from Acccenture [19]. MAS followed those tests with a project in conjunction with the Singapore Exchange (SGX) that successfully tested settlements of tokenized asset trades using DLT. A number of solution architectures were tested including one by Anquan Capital using their own blockchain, which in turn used the Zilliqa network, for trading as well as the Quorum blockchain for the MAS cash ledger. It found that there would need to be a work-around for atomic swaps with Quorums zero-knowledge proofs. Another tested architecture was designed by Deloitte and used Hyperledger Fabric for the SGX side and Ethereum for the MAS side. A third architecture was implemented by NASDAQ using a ledger based on the Chain Core blockchain for the SGX securities side and Hyperledger Fabric for MAS bond issuance and settlement (see Accenture report).

South Aftrica

The South African Reserve Bank (SARB) conducted project Khokha for domestic wholesale interback payments using the Quorum blockchain. It began in late 2017 and involved the central banks, seven local banks, ConSenSys and PricewaterhouseCoopers. In June 2018 the SARB announced that the project successfully met objectives including block throughput, and could process all daily transactions in a two hour window [17].

Sweden

Sweden's central bank, the Sveriges Riksbank, has recognized for some time that the use of cash is steadily decreasing in Sweden and has issued two reports on their e-krona research project [95] . In the first report dated September 2017 blockchain technology was judged to be too immature and unable to process foreseeable transaction volume to be considered immediately. It was also determined that the e-krona should be meant to facilitate smaller payments and transactions between consumers, businesses, and the government, and would not be used to effect monetary policy. The e-krona system

should also enable interoperability with existing and new payment processors, and did not determine whether the central bank itself should be a payments processor. A solution with both registered account balances for normal processing, and a value-based e-krona for off-line processing was suggested. The former would enable e-krona account balances to accrue interest, though that capability was not anticipated to be used in the near future. The latter would enable small anonymous transactions, within KYC/AML limits (ibid).
In the second report dated October 2018, the central bank expanded on the recommendations and conclusions of the first report. The same hybrid account-based and small value-based system was suggested, with limits for the latter being in-line with EU and Swedish AML regulations. However while the bank had legal authority to issue value-based digital currency, it noted that it would seek additional legislation to implement an account-based or hybrid approach. The bank also mentioned the potential usefulness of interest-bearing e-krona accounts (positive or negative rates) in monetary policy. The report also provided some interesting detail on the envisioned structure of the system; a single platform with a central registry in which at least the regulatory framework would be owned by the central bank, through which payments would be settled [96].

Switzerland

Switzerland has been one of the most progressive countries in Europe with regards to cryptocurrencies. And the Zug valley is one of the world's crypto-hubs. In June 2019 the Swiss stock exchange asked the central bank to issue a CBDC to facilitate clearing [21].

Thailand

The Bank of Thailand conducted Project Inthanon Phase I from August 2018 to January 2019, with several banks in the country and R3 as the technology partner, testing interbank payments and liquidity management . Phase I was successful and the bank is conducting Phase II, scheduled to be completed in 2019 Q3. The second phase will test reconciliation of central bank issued debt as well as data interchange [15].

Tunisia

The Tunisia Postal service, a common money transfer agent in the country and effectively a bank, worked with Monetas, DigitUS and others to issue what it called the world's first digital currency on a blockchain in 2015 [26] [97]. It was not actually a CBDC as the central bank was not involved. However DigitUS and the central bank are currently researching issuing a full CBDC [98] [99]. As for Monetas, it has had repeated financial difficulties in the subsequent years and was put into liquidation in April 2019 [100].

UAE

UAE announced its intention to issue a cryptocurrency dubbed emCash in September 2017 in partnership with British security firm Object Tech [101]. In October 2018 it was announced that UAE would partner with Pundi X to create POS terminals to enable emCash payments in partnership with UAE credit agency EmCredit [102]. The Pundi X payment systems support ERC20 tokens so that may be the plan for emCash, though there do not appear to be any technical specifications published.
Also see Saudi Arabia and the UAE above.

United States

The U.S. Federal Reserve has been interested in the potential of DLT for payments settlement for some time and in 2016 published a paper detailing their views of the prospect for the technology [103]. The U.S. Federal Reserve bank of Boston implemented proof-of-concept experiments using distributed ledger technology for interbank settlements, first using Ethereum and then using Hyperledger Fabric

[13]. There were several reasons to choose the latter over the former including; a natively permissioned blockchain and more efficient consensus mechanisms than proof of work (ibid). Among the challenges they found however were; working with a rapidly evolving technology with upward revisions sometimes implementing breaking changes, the immaturity of some SDKs, and complexity and scalability of channels (ibid). The Boston Fed remains interested in the technology and particularly with the concept of using a supervisory node on the blockchain (ibid).

Uruguay

In April 2018 Uruguay completed an e-Peso pilot test program that had begun in November 2017. The program was a registry of ownership of several digital banknote denominations and did not use blockchain [10] [29]. It was considered a success in terms of proof of concept and its immediate goals of making wages and benefits available in free bank accounts, incentivization, and mandating large payments to be done electronically (ibid), [104].

Venezuela

Venezuela created a cryptocurrency at least in part due to sanctions from the US. But the Petro (PTR) does not appear to have gained any traction.