Influencing the Velocity of Central Bank Digital Currencies

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Abstract

The advent of stablecoins offers new and innovative ways to improve financial inclusion, reduce transaction costs, and increase the efficiency of the global financial system. The following paper explores the assets and process necessary for creating a central bank digital currency (CBDC) on the Celo platform, as well as the potential impact on the financial system. Perhaps most importantly, the paper also introduces the idea that current technological advancements allow for a better understanding of the velocity of money, and may afford central banks the ability to influence money velocity, thus potentially creating a new transmission channel for monetary policy.

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1 Introduction

The development of distributed ledger technology holds a tremendous amount of promise for the world. Specifically, the advent of stablecoins offers new and innovative ways to improve financial inclusion, reduce transaction costs, and increase the efficiency of the global financial system. Indeed, the need for a fast, efficient, and safe delivery mechanism of money has become increasingly important in the wake of COVID-19, as governments all across the world attempt to distribute stimulus funds to their affected populations as soon as possible. But for central banks, this new technology does not come without concerns. As such, much effort has been expended on a potential response, namely the development of central bank digital currencies (CBDC).

The official sector community has produced a significant amount of important research on this topic. [Bech and Garratt, 2017] laid the foundation for how we think about CBDC, while [Adrian and Mancini-Griffoli, 2019] offered up a unique concept, highlighting the possibility of a public-private partnership approach to CBDC by suggesting a potential "synthetic CBDC". [Lannquist, 2019] provides a valuable overview of how central banks are exploring blockchain technology today. And [Agur et al., 2019] study the optimal design of a CBDC, where agents choose between cash, CBDC, and bank deposits, based on their preferences over anonymity and security.

Indeed, the preference for anonymity plays a crucial role in the discussion of CBDC. Perhaps the biggest area of focus has been the potential implementation of negative interest rates on CBDC and what this would mean for the transmission of monetary policy. However, the current assumption is that negative interest rates and anonymity are not compatible. As [Buiter and Panigirtzoglou, 2003] note, "[i]t is difficult to tax an asset when the identity of its owner is unknown to the tax authority." Since negative interest on a CBDC could be thought of as a tax, proponents of negative interest rates often prefer CBDC to function similar to bank deposits, instead of cash, where full transparency on account holders is available. This effectively limits the analysis of CBDC and its potential impact on monetary policy to traditional channels of transmission, such as interest rates.

But the technology powering the Celo platform would allow central banks to implement negative interest rates (or demurrage fees, as we think of them) on cash-like CBDC without knowing the full identity of the holders. Holders of cash-like CBDC could be pseudo-anonymous (similar to bitcoin), while also affording central banks access to real-time transactional data.[1] The implications of this could be transformative. By allowing CBDC to function like cash, while users are pseudo-anonymous, central banks could implement demurrage fees on CBDC, thus affording them the ability to influence the velocity of money. Alternatively, holders of CBDC could also be incentivized to increase their velocity of spending through the introduction of "cash back" rewards, effectively offering rebates on purchases using CBDC. Both of these methods offer intriguing ways to influence velocity, thus creating a new monetary policy channel in the process.

The velocity of money has always been a theoretical notion in monetary economics. But the technology behind the Celo protocol could allow central banks to move from the theoretical to the practical. In an era where money velocity has steadily declined throughout the world (as money supply has increased dramatically), the ability to better understand and influence velocity could have profound implications for economies all over the world.[2] To better understand how this could work, the paper is structured as follows:

Section 2 details the assets and process necessary for creating a central bank digital currency on the Celo platform. Section 3 focuses on the potential impact that a Celo-based CBDC could have on the financial system. Finally, Section 4 introduces the idea that current technological

[1] Notably, a report by the [European Central Bank, 2019] proposed the idea of allowing users to anonymously transfer CBDC using "anonymity vouchers". However, these vouchers would only allow a limited amount of CBDC to be transferred over a defined period of time.

[2] It should be noted that the focus of this paper is on the velocity of money as it relates to CBDC, not private sector cryptocurrencies. [Kereiakes, 2019] provides important insight into the currently high levels of monetary velocity on major stable-value digital currencies. Kereiakes suggests that the high levels of velocity on some cryptocurrencies are indicative of concerns about their "store of value" properties.

advancements allow for a better understanding of the velocity of CBDC-based money, and more importantly, could afford central banks the ability to influence the velocity of CBDC, thus potentially creating a new transmission channel for monetary policy.

2 Creating a central bank digital currency on the Celo platform

"[A]s long as the foundation of trust provided by central banks is in place, many forms of monetary arrangements can be built on top, using any number of different technologies."

Agustín Carstens
Bank for International Settlements
December 2019

The promise of distributed ledger technology is exciting, offering new and innovative ways to improve financial inclusion, reduce transaction costs, and increase the efficiency of the global financial system. The central banking community certainly understands and appreciates this, but they also understand the need to be vigilant in maintaining the foundation of trust in the financial system they have worked so hard to build.

For a central bank to trust a distributed ledger, [Auer, 2019] lays out a set of useful principles that will help anchor our discussion about the possibility of creating a central bank digital currency (CBDC) on the Celo platform.

First, [Auer, 2019] suggests that embedded supervision should be part of an overall regulatory framework backed by supporting institutions. A central bank should be able to rely on existing institutions, either banks or the legal system, as a paramount backstop, and should also control/prevent external reference points (e.g. oracles) against manipulating payoffs. Ideally, a platform offers the possibility for the central bank to control essential reference points, such as oracles.

Additionally, the notion of transaction finality is a prerequisite to accept the state of a ledger for a regulator. Celo's proof of stake design builds on this notion, as finality is achieved in one block by design via the incentives of the actors (e.g stakers and validators) on the platform. [Auer, 2019] discusses the notion that economic finality is given, if the cost of an attack is larger than the gain. This is possible in a proof of stake consensus blockchain (though only if a 2/3rds majority of validators collude)[3], where existing institutions can prevent long range attacks.

Finally, [Auer, 2019] concludes that embedded supervision provides an opportunity for an ecosystem to be co-created by regulators and innovators. Administrative and compliance costs can be reduced with an open-source CBDC, allowing a central bank to efficiently develop risk assessment and compliance tools on top of the protocol, which helps to set standards for interoperability.

Ultimately, a CBDC based on distributed ledger technology does not change the underlying risks of a payment system *per se*, but it could improve information for the regulator about underlying risks, as a CBDC can be automatically monitored by the central bank. Using an existing blockchain that supports the necessary requirements for hosting a CBDC reduces the development efforts for the central bank, minimizes the administrative burden for users, increases interoperability, and improves the quality of data available to the supervisor.[4]

2.1 The importance of "on-chain" reserve assets

The Celo platform, as described in [cLabs Team, 2018], is a decentralized payment system that has the ability to support multiple currencies. Its open platform design can support central bank and non-central bank digital currencies, pegged to local fiat, regional or global currencies, or even to a basket of goods. The platform is designed as a mobile-first blockchain, optimized for accessibility in data- and energy-constrained environments.

[3]See [Moreton, 2019] for an in-depth look at Celo's Proof of Stake mechanism.

[4]Similar advantages are noted by [Adrian and Mancini-Griffoli, 2019] when discussing the possibility of creating a "synthetic CBDC" by allowing private e-money providers to hold central bank reserves.

For the creation of a new currency on the platform, the decentralized stability protocol requires the reserve to hold blockchain-based, "on-chain" assets.[5] These on-chain reserve assets are vitally important for building (and maintaining) trust in the CBDC, as this collateral can be easily verified by every stakeholder. Additionally, part of the on-chain collateral can be central bank issued instruments to ensure that the central bank remains in control of collateralization.

The on-chain reserve assets used for collateral in the Celo platform are two-fold: 1) a Celo-based asset necessary for the functioning of the stability protocol and interoperability (this will be discussed in more detail below, but essentially this asset is used for contractions and expansions) and 2) an on-chain asset for which the central bank acts as guarantor. This asset is in place to guarantee the value of the overall construct and is rebalanced with the on-chain Celo asset.

For example, let's call the Celo-based reserve asset, Celo, and the central bank asset, CB Reserve. CB Reserve would be a blockchain-based promise or guarantee by the central bank to pay for future obligations. This can be seen as a blockchain-based bond, which acknowledges the liability on the central bank's balance sheet created by the issuance of CBDC.

As the World Bank already has experience issuing blockchain-based debt instruments, this could serve as a suitable model for central banks.[6] For the CB Reserve asset, the central bank could issue a blockchain-based, zero coupon bond in its local currency. This bond could be issued in any amount, but in order for the CBDC to be viewed as being fully backed by the central bank, the size of the bond would need to be greater than, or equal to, the amount of CBDC that the central bank wished to initially put into circulation. For example, if the central bank wanted to make 100 million worth of CBDC available, they would have to issue a bond that was equal to, or greater than, 100 million worth of its local currency.

As for the maturity of the bond, this will depend on how often the central bank envisages rebalancing the portfolio reserve. If a central bank wishes to rebalance the portfolio annually, for example, they could issue a 1-year bond and then adjust the size in any subsequent re-issues. Of course, since the bond is likely to have a zero coupon, the central bank could just issue a perpetual bond. During the year, the overall amount of CBDC in circulation is handled via the stability protocol using Celo. At the end of the year, the overall portfolio is rebalanced, to a 50/50 weight of Celo and CB reserve.

Once the central bank has issued a blockchain-based bond, the next step would be to effectively sell this bond to the reserve, after which the Celo blockchain will issue CBDC in exchange. Thus, if the central bank issued a blockchain-based bond worth 100 million and sold it to the reserve, they would receive 100 million of CBDC in return. Importantly, the Celo platform, in this case, functions as a technology to streamline, document, and implement the activities for which the central bank is already engaged.

2.2 Celo's stability protocol mechanism

Before discussing potential CBDC distribution options available to the central bank, it seems relevant to briefly touch upon the stability mechanism enabled by the Celo protocol. Please note, this is only a high-level discussion of the mechanism. [cLabs Team, 2020] provide an in-depth review of the stability mechanism. Additionally, a full review of the various stability mechanisms used by stablecoins is beyond the scope of this paper. Please refer to the work by [Bullmann et al., 2019] for a good overview of the various stablecoin structures.

Generally speaking, the stability protocol mechanism programmatically directs the reserve to constantly adjust the supply of CBDC outstanding to match market demand, supporting a stable price of the CBDC or a peg to a fiat equivalent. A sharp increase in demand for CBDC without supply adjustment would raise the price. Conversely, higher amounts of CBDC outstanding without an increase in demand would lower the price. As such, in both scenarios, the

[5] "On-chain" assets are those that are created on the Celo blockchain with an account (i.e. public/private key pair) that enables programmatic transactions.

[6] See [World Bank, 2018] for information on the World Bank's launch of a two-year, AUD110 million blockchain-based debt instrument.

Celo stability mechanism directed by the protocol adjusts supply through expansion and contraction.

The mechanism allows users to create CBDC (expansion) by sending the value of one unit of fiat currency in Celo to the reserve, or to burn CBDC (contraction) by redeeming them for one unit of fiat currency worth of Celo. The mechanism creates incentives such that when demand for CBDC rises and the market price is above the peg, an arbitrage profit can be achieved by buying the amount of one unit of fiat currency in Celo on the market, exchanging it with the protocol for one unit of CBDC, and selling that unit of CBDC for the market price. Similarly, when demand for CBDC falls and the market price is below the peg, an arbitrage profit can be achieved by purchasing CBDC at the market price, exchanging it with the protocol for the reserve asset, Celo, in the amount of one unit of fiat currency and selling the Celo to the market.

These actions are intended to drive the market price of the CBDC back towards the peg without the need for the protocol or the central bank to estimate the optimal expansion or contraction amounts. The peg, or the underlying value, can be determined by the central bank, and linked to the local fiat currency. Importantly, the central bank can also act as the oracle, allowing it to directly control the stability mechanism: for a user to buy CBDC from the reserve, or redeem CBDC with the reserve, the protocol needs an oracle to give the exact price of the reserve currency, Celo, in local fiat or in underlying currency. As the oracle, the central bank can set this price, and thus directly control the stability mechanism.

2.3 Distribution options available for CBDC

It should be noted here that the type of CBDC we are discussing in this paper is often referred to as "retail CBDC" (or "general purpose CBDC") since the digital currency would be made available to everyone. There is another version called "wholesale CBDC", which refers to digital currency that the central bank makes available only to financial institutions that hold reserves with them.

However, the terms "retail" and "wholesale" have also been used to refer to the distribution of CBDC. In order to avoid confusion, we will adopt the terminology used by the Bank of Japan, and refer to "direct" and "indirect" distribution methods.[7] Additionally, there is potentially a third channel — through exchanges — that might also be viable, which will be discussed at the end of this section.

Direct distribution of CBDC essentially means that the digital currency is distributed directly to consumers by the central bank. This would basically require the central bank to produce its own digital wallet (to hold the CBDC), manage customer accounts, and administer KYC/AML compliance protocols. Alternatively, the central bank could outsource all of this to a third party, but they would still have to manage the work of this third party to make sure all of these procedures were done properly.

A directly-distributed CBDC administered by the central bank ultimately means the general public could have a direct link with the central bank (via its wallet), instead of (or at least alongside) the more traditional bank deposit account most customers have with financial institutions. This link would allow the central bank to administer monetary policy more directly, especially if the CBDC carried an interest rate. Although this might be appealing in some instances, such a decision would likely put the central bank in direct competition with its banking industry, and could potentially disintermediate banks as the general public would likely prefer to hold its money with the central bank during times of crisis.

A less disruptive, and perhaps more appealing, distribution channel would be the indirect version, whereby the central bank sells CBDC to financial institutions that already have reserve accounts with the central bank. In essence, the central bank would simply credit the financial institution's account held at the central bank with CBDC, and debit their fiat-based reserves by the same amount. The financial institution could then offer this CBDC to their existing customer base, creating a wallet of their own.

[7] [Hayashi et al., 2019]

Although the indirect version seems straightforward, and has the advantage of keeping the traditional financial system engaged, there might be some concern about the potential disruption to credit markets, should customers decide to move some of the assets away from bank deposits and into CBDC. A more detailed discussion on bank disintermediation can be found in Section 3, but it should be noted here that one of the consequences of CBDC could be improved competition and innovation of lending-based applications.

Such a scenario could open up opportunities for the creation of lending-based apps utilizing CBDC, where users would agree to lock up some of their CBDC for a specific period of time, in exchange for earning interest on those assets.[8] This would essentially be a CBDC-based version of Certificates of Deposit. The development of these apps could come from both the private fintech community as well as traditional financial institutions. In either case, this could ultimately help improve competition and contestability within the credit market.

As briefly mentioned earlier, a third channel of distribution could be conducted through exchanges, whereby the central bank sells CBDC to an exchange (such as Coinbase) and the general public would then be able to acquire the CBDC by buying it through the exchange. In this scenario, the exchanges would be responsible for managing customer accounts and administering KYC/AML compliance protocols.

[8] For example, a similar application has been developed by Compound, allowing users to lend their cryptocurrencies.

3 Understanding the impact of a Celo-based CBDC on the financial system

"A fundamental problem in the developing world is most people are not documented and if you're not documented then you're not going to be a part of the formal economy. So as a consequence, many people still reside in the informal economy with all the associated inefficiencies."

Erik Feyen
World Bank Group
March 2019

Addressing the problem of financial inclusion is a well understood, and important, aspiration driving the development of stablecoin technology, as the [G7 Working Group on Stablecoins, 2019] notes. But the potential impact on the financial system from this technology is much broader.

To better inform our discussion about the merits of a Celo-based CBDC, we developed a framework, adapted from a report on retail CBDC by the Official Monetary and Financial Institutions Forum (OMFIF).[9] Specifically, we look at how it may impact three overarching goals that are important to central banks: 1) creating the conditions for prosperity, 2) ensuring stability in the financial system, and 3) improving the understanding and transmission of monetary policy.

3.1 Creating the conditions for prosperity

One of the main goals for a central bank specifically, and the government generally, is to create the conditions for prosperity by promoting economic growth and well-being for its citizens. This can be achieved, in part, by improving financial inclusion and increasing efficiency gains through cost reduction.

For emerging market economies, home to most of the 1.7 billion adults currently excluded from the global financial system, this is of utmost concern. In fact, the primary motivation for emerging economies with respect to the development of a general purpose CBDC is improving domestic payments efficiency and financial inclusion, according to a recent BIS survey conducted by [Barontini and Holden, 2019].

The importance of this topic to central banks has generated a number of worthwhile studies. The [Committee on Payments and Market Infrastructures, 2016] reported on the broad implications of financial inclusion with respect to the global payments system, while [Mancini-Griffoli et al., 2018] highlighted the cost reductions associated with CBDC and financial inclusion.

Indeed, the expense and inconvenience of obtaining cash for some communities can be so high that it results in the emergence of "cities without money", as highlighted by [Burgos and Batavia, 2018], with respect to the situation in Brazil.[10] Lower transaction costs from the implementation of CBDC would likely increase liquidity to such an extent, according to a study by [Barrdear and Kumhof, 2016], that it's introduction into an economy could permanently raise GDP by as much as 3 percent.

3.2 Building a mobile-first blockchain platform

Creating the conditions for prosperity is particularly salient for the Celo platform, as it forms the foundational basis for its creation. Although the world's financial system currently excludes 1 in 3 adults, it is projected that 7.4 billion smartphones will be connected to the internet by 2025, as these

[9]The OMFIF report by [Patel et al., 2019] lays out 9 key policy objectives important to central banks, as it relates to retail CBDC. For the purposes of our report, we have loosely grouped these objectives into three overarching goals.

[10]Citing calculations from Diebold, [Burgos and Batavia, 2018] note that obtaining cash in Brazil can be expensive and inconvenient, because "an ATM in Brazil is, on average, 60 percent to 70 percent more expensive than in other parts of the world" due to the addition of enhanced security measures necessary for each unit.

devices spread throughout emerging markets.[11] As such, we believe that cryptocurrencies accessible on mobile phones hold great promise in bringing financial inclusion to the world's underbanked.

Despite this potential, cryptocurrencies have not significantly impacted these populations over the last 10 years. Using cryptocurrencies is still much too complex for the average person and price volatility makes them undesirable for merchants to accept as payment. Additionally, blockchain networks are often inaccessible to unbanked and underbanked populations due to data constraints from their mobile providers.

Influenced by extensive research in emerging markets and developing countries — Argentina, Brazil, Colombia, Kenya, Lebanon, Mexico, the Philippines, and Tanzania — Celo is a blockchain platform optimized for mobile data usage and designed to be accessible by anyone with a basic smartphone. Using the Celo platform, CBDC can be transferred faster and cheaper than traditional bank wires using globally accessible technology.

Additionally, since CBDC can be completely programmable, and the platform is open sourced, a wide array of complementary financial services could be created without costly intermediaries. As developers build applications on the Celo platform, participants can access the same financial services much of the world takes for granted — loans, insurance, savings, and investment vehicles.

3.3 Ensuring stability in the financial system

While the goal may be to improve financial inclusion and create the conditions of prosperity for all, central banks will, of course, want to make sure they do so in a manner that ensures financial stability, enhances the security, reliability, and resiliency of the system, and complies with AML/KYC regulations.

Regarding financial stability, one of the biggest concerns is the issue of bank disintermediation, whereby the introduction of CBDC displaces the traditional role of financial institutions, and ultimately raises the cost of credit. Research done by [Agur et al., 2019] suggests that any uptake in CBDC will always bring about a decline in both cash and bank deposits, thus consequently leading to some bank disintermediation in the system, though the extent of which depends on how closely CBDC competes with deposits.

The issuance of CBDC on the Celo platform, as currently envisioned, would seek to maintain the current two-tiered system, in which financial institutions retain their role as financial intermediaries. Additionally, if CBDC is designed to more closely align with the features of cash, instead of bank deposits, the potential impact could be further limited.[12]

It is important to remember, however, that if the goal of CBDC is to improve financial inclusion and allow access to the formal economy to those that currently reside in the informal economy, then CBDC would implicitly be addressing a problem not currently solved by the traditional financial system, thus further mitigating any concerns about disintermediation.

Ultimately, as [Agur et al., 2019] note, the optimal CBDC design represents a trade off between bank intermediation and the social value of maintaining diverse payment instruments. Nonetheless, research by [Keister and Sanches, 2018] suggests that introducing a CBDC "often raises welfare" despite the potentially negative effects associated with bank disintermediation.

[11] According to the Ericsson Mobility Report: https://www.ericsson.com/4acd7e/assets/local/mobility-report/documents/2019/emr-november-2019.pdf

[12] Alternatively, research by [Barrdear and Kumhof, 2016] suggests that if CBDC were designed to compete more closely with bank deposits it could potentially improve systemic stability as it gives policymakers another tool to help during business cycle shocks, as they would be able to control either the quantity or the price of CBDC in a countercyclical fashion.

3.4 The resiliency of a decentralized system

Perhaps one of the main advantages of the Celo protocol is its decentralized nature, which ensures the system's resiliency, avoiding any issues related to single points of failure, which are endemic to centralized systems.

The current real time gross settlement (RTGS) system employed by central banks "remains vulnerable to single points of failure given its centralised nature", according to [Patel et al., 2018]. Indeed, [Furche et al., 2017] remind us of the incident in October 2014 when the Bank of England's RTGS system suffered a temporary outage, prompting the need to deploy alternative settlement forms for the entire day.

Instead, the Celo network deploys a Byzantine Fault Tolerance (BFT) consensus protocol run by a large and well-defined set of validator nodes (via a proof of stake election), which secures the system. The nature of BFT is such that even if up to one third of validators are offline, faulty, or malicious, the rest of the validators are able to reach agreement as to accuracy, and blocks continue to be created. A full analysis of Celo's Proof of Stake mechanism is provided by [Moreton, 2019].

3.5 Complying with existing regulations

Central bank adoption of CBDC would not displace the existing regulatory obligations of financial institutions within the banking system, and thus would be unlikely to alter the existing compliance risk profile of the financial system. Indeed, it could potentially enhance the ability of financial institutions, as well as central banks, to manage the highest compliance risks, particularly money laundering and sanctions risks. Financial institutions that currently bear compliance responsibility would continue to bear that responsibility under a CBDC regime.

For example, despite the pseudo-anonymous nature of the Celo platform — potentially requiring only a light identity, such as a phone number, to process transactions — financial institutions would still be required to comply with traditional customer identification and due diligence requirements, and implement travel rule compliant payment processes. Additionally, the transparent nature of the distributed public ledger, combined with modern analytic techniques, would likely lead to more effective transaction monitoring capable of providing a more comprehensive picture of illicit financial flows for law enforcement and national security purposes than currently possible.

CBDC on Celo also affords central banks the ability to provide privacy protections and pursue financial inclusion objectives within their risk tolerances to a degree not currently possible. For example, to increase financial inclusion or provide cash-like privacy for lower risk transactions, a central bank could permit private, frictionless, and inexpensive un-hosted wallet transactions below a certain value threshold or with certain characteristics through smart contracts programmed into the CBDC itself. From a compliance perspective, CBDC provides new mechanisms to lower compliance costs for financial institutions, while at the same time supporting more effective compliance.

3.6 The transmission of monetary policy

Apart from ensuring the stability of the financial system, central banks will also want to ensure they maintain appropriate channels for the transmission of monetary policy. Central banks traditionally influence monetary policy through the interest rate channel.[13]

Specifically, central banks change the rate of interest they charge financial institutions on overnight loans. An increase in this interest rate subsequently increases borrowing costs for banks,

[13]Research by [Brunnermeier et al., 2019] suggests that even if other digital currencies and stablecoins start to play a more prominent role in the payment system, a central bank will retain its power over monetary policy as long as its currency remains the unit of account money. The authors define the unit of account by reference to "some fiat interest-bearing liability of the central bank". Importantly, the issuance of CBDC on the Celo platform would not eliminate the central bank's liabilities as the unit of account, thus allowing the central bank to continue influencing monetary policy through the interest rate channel.

which are typically passed on to customers in the form of higher rates on loans and, potentially, higher fees. Higher borrowing costs incentivize people to borrow less (because it's more expensive) and save more (because of higher returns), thus slowing down the economy. A decrease in this interest rate typically has the opposite effect.

Creating a CBDC on Celo would not impede this traditional monetary policy channel. Central banks would maintain the full authority to change the rate on overnight loans to financial institutions. The overall impact of their policy decision, however, would be affected by whether or not there was an interest rate associated with the CBDC.

If the CBDC behaved more like cash, and thus carried no interest rate, then interest rate decisions made by the central bank should behave much as they do now. Increasing borrowing costs for banks should still result in higher costs for customers, thus acting like a brake on the economy, for example.

The main difference would occur if CBDC were designed to carry an interest rate of its own. Much has been discussed about this possibility, with the main benefit being that it would provide the central bank with a direct link to the general public, whereby any change in the rate of interest available on CBDC would have a direct impact on monetary policy. In effect, central banks would be bypassing financial institutions to some extent, but the ultimate impact should still be quite similar.

For example, if the central bank decided to raise interest rates on CBDC, it would likely incentive people to hold more in CBDC as they would earn an increased rate of return. Consequently, financial institutions would likely be prompted to raise the rate of interest they pay on bank deposits to a level higher than the rate paid on CBDC, so as to encourage customers to keep their money with the bank and not switch to CBDC. In order to recoup the higher costs associated with the increased interest paid on deposits, banks would likely increase the rate of interest they charge on loans, thus making the cost of capital more expensive, and resulting in the slow down of the overall economy.

3.7 Negative rates offer a different approach

Of course, the most discussed use case around interest-bearing CBDC, is that in which CBDC carries a negative interest rate. Until recently, it was believed that, although negative interest rates might be possible theoretically, in reality they were seen to be highly impractical. If short-term interest rates on bank deposits were pushed below zero, it was widely believed people would simply switch their financial assets into cash to avoid paying the negative interest rate. This is often referred to as the "zero lower bound" problem of monetary policy. With CBDC, it is believed that central banks may be able to overcome this issue and charge negative interest, but many believe this would only be viable if CBDC replaced cash, as people might also be inclined to switch into cash if rates on CBDC were significantly negative.

Instead of trying to influence the price of money — as interest rates do — a more interesting, and unique, approach might be to influence the velocity of money. Since all transaction data for a CBDC would be available on the blockchain, it would be possible to know exactly when a user sends and receives CBDC. Thus, in theory, it could be possible to incentivize users to speed up or slow down the amount of transactions, thus influencing the velocity of CBDC-based money, and by extension the overall economy. At the very least, central banks will have better transactional data and thus better insight into the actual velocity of CBDC. We discuss this idea in more detail in the following section.

4 Making the velocity of money practical

"[T]he emergence of token-based money makes practical what was formerly a purely theoretical notion in monetary economics."

Agustín Carstens
Bank for International Settlements
December 2019

One of the most theoretical notions in monetary economics is perhaps that of money velocity. As [Higgins, 1978] reminds us, the current method of understanding the velocity of money is only an abstraction: "it is impossible to trace each dollar and count the number of times it is used to finance expenditures".

As such, we are left inferring the speed with which each banknote moves through the financial system by using the ratio of a country's economic output (e.g. GDP) to the amount of its base money (e.g. money supply). Additionally, given this limited understanding, economic principles teach us to simply hold the value of velocity constant in any equation so as to focus on the impact of other variables, such as money supply.

But the technology behind token-based stablecoins allows us to move from the theoretical to the practical. Although [Carstens, 2019] (above) was referencing distributed ledger technology and the classical analysis of money as it relates to historical ledger transactions, he could just as well have been discussing central bank digital currencies and the velocity of money.

Indeed, we aim to do just that. In this section, we explore the possible ramifications of a CBDC[14] on measuring velocity, the impact of introducing CBDC on current velocity, and the possibility that technology may allow central banks to actually influence the velocity of CBDC, thus providing them with another potential channel for the transmission of monetary policy.

4.1 Understanding the true velocity of money

As previously mentioned, the very notion of money velocity is entirely theoretical. Velocity is currently defined in economic theory using the following formula:

$$Velocity = \frac{Nominal\,GDP}{Money\,Supply} \tag{1}$$

The idea behind this theory is that since we are unable to trace every banknote and count the number of times it is used to buy goods and services, we will infer money's velocity in a system by dividing the value of all goods and services produced in an economy by all of the money[15] currently in the system.

With CBDC, however, the velocity of money is no longer theoretical. We don't have to infer how many times a banknote is used, because the blockchain technology powering CBDC would allow a central bank access to real-time transactional data. Thus, every time CBDC is used to buy groceries, for example, this transaction would be available in real-time. Additionally, the open-source nature of the platform means that risk assessment tools for regulators, focused on transaction assessments and compliance, could be developed at very low, fixed costs.

Understanding the true velocity of money, as it pertains to CBDC, would become practical for central banks. More importantly, as [Burgos and Batavia, 2018] note, having access to historical transaction data, especially the ability to "observe the economy's response to shocks or

[14] For clarity, the CBDC discussed in this section is based on the form and framework of a Celo-based CBDC as detailed in Section 2, unless otherwise noted.

[15] In this instance, we refer to money using the Federal Reserve's definition of M1, which includes funds readily accessible for spending, and consists of: 1) banknotes, 2) traveler's checks, 3) demand deposits, and other checkable deposits.

policy changes almost immediately and more accurately" would be extremely valuable, especially from a macroeconomic stability perspective.

4.2 CBDC as a medium of exchange

Of course, at this stage, the issuance of CBDC is, itself, still only a theoretical notion. A recent BIS survey conducted by [Barontini and Holden, 2019], showed that while 70 percent of the 63 central bank respondents were engaged in CBDC work, only five had actually progressed to running pilot programs, and none of them have actually implemented CBDC, as of yet. [Kiff, 2019] provides a good overview of all the central banks currently focused on CBDC.

But what if CBDC itself were no longer theoretical? What impact would the practical implementation of CBDC have on an economy's velocity of money? To understand that, we must first remember that money itself is simply a financial instrument that serves as a unit of account, store of value, and a medium of exchange. The introduction of a CBDC is not expected to have any impact on money's status with regards to either the unit of account or the store of value function, but it will have an important effect on the medium of exchange.

As [Shirai, 2019] notes, the medium of exchange function allows people to use money to efficiently transact goods and services amongst themselves without having to form an inconvenient barter system. Throughout the years, technological advancements — from ATM machines to credit cards — have changed the method people use to transact money. And these changes can impact the velocity of money quite significantly.

Each medium of exchange — no matter if it's cash, credit card, or CBDC — has both costs and benefits associated with it. Using one medium over another requires making certain tradeoffs. To understand how the demand for a particular medium of exchange affects the velocity of money, we can use the Baumol-Tobin inventory model of cash management that was independently developed by [Baumol, 1952] and [Tobin, 1956]. [Higgins, 1978] summarizes this model by noting that the demand for money is inversely related to the yield that could be earned on an alternative asset, such as a government bond.

The Baumol-Tobin model assumes an individual receives an income at the beginning of every period and spends this money at a constant rate over the course of the period. For simplicity, the model further assumes the individual can choose between two assets: an interest bearing asset (such as a government bond) or cash (which does not offer an interest rate). The theory behind this model suggests that, all else being equal, a person would prefer to earn as much from their money as possible, and should thus prefer bonds over cash. However, government bonds serve as a poor medium of exchange for goods and services, so, in the original model, cash was necessary to facilitate transactions.

To determine the optimal demand for cash, the model defines the total costs of cash flow management as the sum of two components: transaction costs and forgone interest. Transfers between cash and interest bearing assets would likely incur a cost, either in the form of explicit costs like transaction fees or in the form of implicit costs through inconvenience. Holding cash would incur an opportunity cost of interest forgone, compared to holding an interest bearing asset.

The individual either maximizes interest or, equivalently, minimizes the total cost of his cash flow management. This optimisation yields the following relationship between real money demand and that of income (Y), transaction costs (c) and interest rates (i):

$$Money\ Demand = \sqrt{\frac{cY}{2i}}\ . \tag{2}$$

It describes the money management behaviour of an individual in terms of the average amount of cash holdings as a function of income, transaction costs, and interest rates. An increase in transaction costs leads to an increase of money demand as it becomes more costly to transfer cash to interest bearing assets. Conversely, a rise in interest rates decreases the demand for money, as the opportunity costs for interest forgone increases[16]. Financial innovations have the potential to lower transaction costs both explicitly by reducing transaction fees, as well as implicitly by making transfers easier and more convenient.

Using the transaction demand function of the Baumol-Tobin model for the entire economy, yields a formula for the velocity of transaction demand:

$$Velocity = \sqrt{\frac{2i\,Real\,GDP}{c}}\ . \tag{3}$$

The sensitivity of velocity with regard to transaction costs and interest rates is opposite to the sensitivity of money demand. Therefore, financial innovations with lower transaction costs or more convenient handling might increase velocity. As such, [Higgins, 1978] posits that financial innovations that lower the effective cost of converting earning assets into money contribute to the "upward trend in the income velocity of the narrowly defined money supply".

[Kamada, 2017] extends the Baumol-Tobin model, comparing digital currency with paper currency, to investigate the optimal currency choice for transactional purposes. While the original model is sensitive to the income elasticity of money demand and the interest rate elasticity, demand in the extended version is additionally sensitive to taxes, the costs of holding cash, and the general costs of digital currency. These general costs take into account psychological components, like stress from using an unfamiliar technology and the potential inconvenience due to low circulation.

By comparing the total costs of money management for cash, non-governmental digital currency, and CBDC, the authors define regimes of preference between the different kinds of currencies. Lower transaction costs, better circulation, and increasing confidence towards digital currencies reduce the total cost and increase the preference for digital currency. Network effects are also considered as they might significantly impact transaction costs; a higher number of users leads to lower transaction cost/higher circulation, and lower transaction costs attracts more users. The authors consider this an important aspect with respect to the long run implications of their model. With very low transaction costs, the analysis of [Kamada, 2017] suggests that digital currency, whether issued by the central bank or provided by a private sector entity, has the potential to become a major medium of exchange. Preference between a CBDC and a non-governmental digital currency depends strongly on their taxation and interest rate.

Importantly, the extended model by [Kamada, 2017] does not focus specifically on the potential impact that introducing CBDC into an economy would have on its velocity of money. However, the benefits of CBDC would suggest that its introduction into a financial system should increase the velocity of money. Compared to cash, for example, CBDC is easier and cheaper to manage. Additionally, it's far more efficient to transact in CBDC, and more secure to hold than cash. As such, it could be expected that CBDC would lower the effective cost of transferring into and out of other higher yielding assets, thus increasing the velocity of money.

Further versions of this report will endeavor to provide a more analytical approach to understanding the potential impact that introducing a Celo-based CBDC into an economy will have on its velocity of money.[17]

4.3 The importance of money velocity

While the potential boost to money velocity from the introduction of a CBDC into an economy is interesting, and the insights gleaned from observing real-time transactional data would be invaluable, the ability to actually influence the velocity of money could be transformative.

[16] If transactions had zero costs and caused no inconvenience, individuals would keep all their wealth in the form of interest rate bearing assets. If interest rates were zero, individuals would hold all their wealth in cash.

[17] Interestingly, although the topic of credit cards is not the focus of this report, studies suggest that the introduction of credit cards (as an alternative transaction medium) has negatively impacted the demand for money. Studies by [Duca and Whitesell, 1991] and [King, 2004] both cite, and build on, the work of Akhand and Milbourne (1986), in which they extend the Baumol-Tobin inventory model to include credit cards, and find that credit cards reduce the demand for money, and therefore lower its velocity.

But first we need to understand why the velocity of money is important. To do that, we start by rewriting Equation 1 to the following:

$$Money\ Supply\ x\ Velocity = Nominal\ GDP \tag{4}$$

Equation (4) implies that money supply and velocity can be used to impact nominal GDP. However, given the limited understanding that currently exists around velocity, economic principles suggest we should hold the value of velocity constant, and focus instead on money supply.

So, let's assume that in Equation (4) we hold velocity constant at 2, meaning that every banknote will be used twice to buy goods and services. If the money supply is currently at $500, then nominal GDP would be equal to $1000 ($500 x 2). Assuming that velocity remained constant at 2, we would need to increase money supply if we wanted to increase nominal GDP. For example, if money supply were increased to $600, Equation (4) suggests that nominal GDP should increase to $1200.

Of course, theory does not always work perfectly in the real world. Following the Great Financial Crisis that began in 2008, central banks around the world dramatically expanded the monetary base through quantitative easing policies to jumpstart economic growth. Despite the significant infusion of money, growth has not increased by a similar magnitude, because the velocity of money steadily declined during this period, offsetting some of the impact from the expanded money supply (see the charts in the Appendix for more detail).[18]

Before we discuss the potential reasons for the decline in velocity during periods of economic stress, let's return to our discussion of Equation (4), this time keeping money supply constant. However, it is not enough to simply state that if money supply was held constant at $500 and velocity was increased from 2 to 4, that the nominal GDP would grow from $1000 to $2000. We need to understand why that should be the case.

To illustrate this concept, let's assume we have a small economy consisting of a baker, a carpenter, and a farmer. For argument's sake, let's also assume that the carpenter has $10, and that's the only medium of exchange in the economy. If the carpenter uses the $10 to buy bread from the baker, and the baker then takes that $10 and goes to the farmer to buy more wheat, the velocity of money in this economy is 2, as the same $10 was used in two separate transactions. Additionally, the overall economic output is $20.

However, let's now assume that, having sold all her wheat to the baker, the farmer decides she needs to build a bigger silo to store more wheat, so she pays the carpenter $10 to build a bigger silo. The carpenter spends the $10 buying more bread from the baker, who turns around and buys $10 of wheat from the farmer.

These three additional transactions illustrate the importance of money velocity. The total supply of money remained fixed at $10, but the number of transactions, and thus the velocity, increased from 2 to 5, raising the economic output from $20 to $50.

4.4 The conflicting roles of money

During times of optimism and economic growth, people are usually quite willing to spend money and thus its velocity either remains stable or even increases, helping to further boost the overall economy. But during periods of economic stress and uncertainty, people tend to worry more about saving money than spending it.

If, in our example above, the carpenter was worried about finding more work, she may decide to save the $10 she got from the farmer for building the silo and not spend it on bread from the baker. And without selling bread to the carpenter, the baker will not earn money to buy more wheat from the farmer and the economy will grind to a halt. This is, of course, an overly simplistic example, but it serves to help illustrate what happens in an economy where people decide to hoard

[18]Importantly, as [Copic, 2020] notes, such considerations extend beyond monetary policy and are also relevant with respect to fiscal policy.

their money and not spend it.[19]

This example also illustrates the fact that the various functions of money can actually conflict with one another, to the detriment of the overall economy. As noted earlier, money serves as a unit of account, a store of value, and a medium of exchange. During times of economic stress, people often favor money's store of value function and hoard as much as possible. While this may be a natural and understandable reaction, the economy, as we have shown, also relies on money maintaining its role as a medium of exchange.[20]

4.5 Solving the problem of hoarding

To solve the problem of hoarding, and subsequently increase the velocity of money, an idea was proposed more than a century ago, when Silvio Gesell, a German economist, published *The Natural Economic Order* in 1916 and introduced the world to the idea of "stamped" money. Observing the tension between money as a store of value and a medium of exchange, [Gesell, 1916] felt it was necessary to make money "decay" in much the same way as the goods it was used to procure.

As such, Gesell proposed that, at the beginning of each month, banknotes would need to be affixed with a special stamp to maintain their validity. Such a system would incentivize people to spend the banknote before the end of the month, when a new stamp would be needed.

Indeed, during the Great Depression, Gesell's theory of "stamped" money was most notably put into practice in the small Austrian town of Wörgl. Although the experiment lasted just over a year, it was credited with increasing employment growth and gained notoriety among the era's most well-known economists, including John Maynard Keynes and Irving Fisher.

[Keynes, 1936] believed Gesell's idea of stamped money to be "sound" and even developed a framework for pricing the stamp.[21] [Fisher, 1932] was far more flattering, calling Gesell's idea an "ingenious scheme" and perhaps the "most efficient method of controlling hoarding and probably the speediest way out of a depression".

Fisher also believed that once the corresponding increase in the price level following the introduction of stamped money was appreciable, the hoarding of other money (such as bank deposits) would also cease. In other words, Fisher believed stamped money would "simply prime the pump or start the machinery going, both by providing new purchasing power and by putting a penalty on any delay in using it."

Although the economic theory behind Gesell's idea was, as Keynes noted, "sound", it's implementation proved difficult to achieve on a large scale. At the turn of the 21st century, the economic community revisited Gesell's idea as a way to possibly overcome the "zero lower bound" problem — an issue whereby monetary policy was believed to be constrained, due to the notion that short-term nominal interest rates could not go below zero, because at that point people would exchange (negative) interest-bearing assets for cash, which has no interest rate.

[Buiter and Panigirtzoglou, 2003] suggested that implementing a "carry" tax on money (modern day parlance for Gesell's idea of a "stamp" tax) could eliminate the zero lower bound problem. However, they believed that a carry tax on physical banknotes would be "awkward" and thus their preference was for such a tax to be applied to bank reserves.

The problem for [Buiter and Panigirtzoglou, 2003], with respect to paying negative interest

[19] [Copic, 2020] provides a real-world example: Following the Great Financial Recession in 2008, the U.S. government sent stimulus checks to citizens in an attempt to boost the economy by providing additional funds to be spent. However, according to a University of Michigan report "only 20% of those who received checks used the money for new purchases, while 48% paid off existing debt, with the rest going into savings."

[20] Interestingly, [Brunnermeier et al., 2019] raise the idea of the "unbundling of the roles of money" noting that mobile networks have reduced the cost of switching between currencies to such a point that there is no longer a strong incentive to use only one currency as a store of value, a medium of exchange, and a unit of account.

[21] [Keynes, 1936] suggested that the cost of the stamp should be "roughly equal to the excess of the money-rate of interest (apart from the stamps) over the marginal efficiency of capital corresponding to a rate of new investment compatible with full employment".

on physical currency, was that the holders were anonymous and therefore it would be difficult to levy a tax on them. Indeed, current discussions around implementing a negative interest rate on CBDC assume that the holders of it will not remain anonymous. But for some, anonymity is an important concern, the loss of which could prompt many to favor cash over CBDC.[22]

4.6 Creating a new transmission channel for monetary policy

Technology now affords central banks a way around this "awkward" problem. A demurrage fee[23] can be implemented on CBDC, thus turning Gesell's theoretical notion into a practical solution (see Box 1). Although this fee can be thought of as effectively a negative interest rate, the important difference is that a central bank can implement a demurrage fee on a Celo-based CBDC, while allowing CBDC holders to remain pseudo-anonymous (similar to bitcoin).

Box 1: Example of demurrage fee implementation

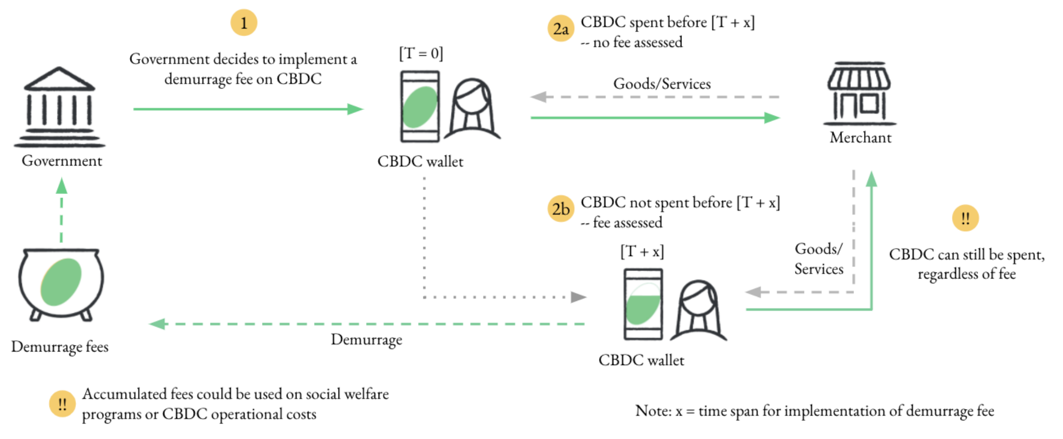
The flow chart below illustrates how a demurrage fee could potentially be implemented on a CBDC. When the government, or central bank, decides to implement a demurrage fee (Step 1) they will need to decide the fee amount and the time span after which the demurrage fee will be applied – in our example this time span (which could be a week, a month, etc) is denoted by "x".

For the purposes of this example, let's assume at the start (T=0), a user has 100 units of CBDC in her wallet, and the government has decided to implement a demurrage fee of 1% that will be applied on all CBDC balances at the end of every month (x=1 month).

At T=0, before the demurrage fee is applied, the holder of CBDC has essentially two choices. If she chooses to spend the CBDC before the end of the month (T+x), then no demurrage fee will be assessed (Step 2a). However, if she waits until the end of the month (T+x), then a demurrage fee of 1 unit (1% of 100 units) will automatically be deducted from her CBDC total, leaving her with 99 units in her wallet (Step 2b).

Despite the application of a demurrage fee, it should be noted that the user can still spend the remaining CBDC. In fact, demurrage fees will continue to be assessed at the end of every period (e.g. the end of the month) on all remaining CBDC balances. So, if the user spends 9 units of CBDC, from her total of 99, before the end of the following month, then another demurrage fee of 0.9 units (1% of 90 units) will be assessed. This process will continue every period on all remaining CBDC balances.

All demurrage fees assessed will be remitted back to the government. These fees can be used at the discretion of the monetary authorities, and could be used to fund social welfare programs (e.g. unemployment benefits) or on operational costs related to the CBDC, for example.



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[22] [Davoodalhosseini, 2018] suggests that the loss of anonymity from CBDC makes it more costly relative to cash.

[23] Whether referred to as a demurrage fee, negative interest rate, carry tax, or a stamp tax, the effect is the same – increase the velocity of money by making it more expensive to hoard, thus incentivizing people to spend it at a faster rate.

Additionally, CBDC technology allows for control over more than just implementing a fee. Whereas Gesell's model implemented a periodic tax (e.g. once a month), central banks can now choose the specific frequency. For example, a demurrage fee could also be applied on a constant (linear) basis or even an increasing (logarithmic) scale. It should also be noted that the fee itself can be used for various applications: for instance, it could be sent to the reserve to support the stability mechanism or it could be used to support other initiatives by the central bank, including the funding of social welfare programs.

Of course, the implementation of a demurrage fee is not without its critics. Keynes believed that if the fee associated with a stamp deprived currency notes of their liquidity premium, then another substitute (such as bank deposits, foreign currency, or precious metals) would fill the role. With respect to CBDC, the most likely substitute would be physical banknotes. But cash does not come without costs of its own.

[Adrian and Mancini-Griffoli, 2019] note that the cost of managing cash can be very high in some countries. [Bergara and Ponce, 2018] cite the specific example of Uruguay, where the cost associated with cash is estimated to be 0.58 percent of GDP, and falls almost exclusively on the private sector: banks (13.7 percent), retailers (67.3 percent), and households (17 percent). [Assenmacher and Krogstrup, 2018] also note that recent experience suggests the lower bound is actually somewhat below zero due to storage and handling fees associated with cash.

This suggests that as long as the demurrage fee applied to CBDC is lower than the cost of managing cash, the incentive to switch should be limited. Of course, if there remain concerns that a demurrage fee on CBDC will prompt consumers to hoard cash, the central bank could take up the option proffered by [Rogoff, 2014] and remove large value banknotes from circulation since, as he notes, hoarding costs are much greater if only small bills remain in circulation.

Related to the concerns about cost, [Buiter and Panigirtzoglou, 2003] warn that "[t]axing currency would be regressive since only the relatively poor hold a significant fraction of their wealth in currency". However, a report from [Burgos and Batavia, 2018] seems to mitigate this concern, at least in some countries, as they suggest that a tokenized CBDC would serve as a "very low cost medium of exchange" and thus would be "particularly beneficial to low-income families, who tend to rely heavily on physical money, but also to small businesses that incur high costs related to cash handling or high transactional rates when making/receiving payments using cards."

Another critique was offered up by [Agarwal and Kimball, 2015], who argue that the reason Gesell's idea of a stamp tax on currency has not been implemented on a national level is due, in part, to the "political difficulties occasioned, because it requires an inconvenient and highly salient bureaucratic machinery to implement it and because it looks like a tax, to which a large section of the population is therefore averse."

Instead of stamping physical banknotes, they suggest that a government could also discourage hoarding of paper currency in three ways, by targeting its withdrawal, storage, or redeposit. Ultimately, [Agarwal and Kimball, 2015] propose that the best way to accomplish a negative interest rate would be to implement a "time-varying paper currency deposit fee" between private banks and the central bank.[24]

However, such a framework would require private banks to pass this fee along to their customers. But, evidence from various European countries that have implemented negative interest rates on deposits held at the central bank, suggest that private banks are loathe to pass these fees on to retail customers for fear of losing business. Thus, the effects of central bank policy are being muted by the decisions of private financial institutions.

Instead, implementing a demurrage fee on CBDC would ensure that central bank policy was being enacted. And if such a policy is able to influence the velocity of money, then central banks would gain a new monetary policy transmission channel.

[24] Similarly, [Bordo and Levin, 2017] suggest a "graduated schedule of fees for transfers between cash and CBDC".

4.7 Exploring a more "positive" approach to influencing CBDC velocity

Instead of incentivising transactions through the introduction of a demurrage fee, a positive incentive scheme could also be devised with potentially similar impacts on velocity. Specifically, central banks may wish to introduce the idea of "cash back" on CBDC purchases (see Box 2). Under this scenario, consumers would be refunded a certain percentage of their CBDC purchases to incentivize them against hoarding. Thus, the more they spend, the more they get back.

Various credit cards currently offer such schemes, but not everyone has access to credit cards, especially in emerging market economies, so such a mechanism may further support financial inclusion in these countries. Additionally, the use of CBDC in this scenario would be beneficial to merchants as well since they would not have to pay the often large fees associated with credit card purchases.

The funding of a "cash back" scheme also presents some unique incentive structures. Given that the central bank would be the issuing authority for CBDC, they would, of course, have the ability to implement (and thus fund) any type of cash back scheme they wanted, and could thus increase/decrease the potential rebate amount to influence the velocity of their CBDC. In fact, a central bank could configure the protocol to algorithmically change the rebate rate based on macroeconomic conditions (like the unemployment rate, for example).

But perhaps the most useful scenario would occur if a "cash-back" enabled CBDC were available during a crisis, such as the COVID-19 situation currently devastating the global economy. Apart from the obvious advantages a CBDC would have during such a crisis, whereby stimulus funds could be distributed instantly (compared to the weeks and months it normally takes), providing a cash back incentive could prompt consumers to spend their stimulus funds, instead of hoarding them, thus boosting the overall economy.

Furthermore, the central bank, in coordination with the fiscal authorities, would also have the ability to target certain industries with added rebates, thus incentivizing consumers to spend even more money on certain sectors of the economy, potentially mitigating the need for government bailouts. For example, if such a system were available during a global pandemic (like COVID-19), added rebates could be applied to medical and health care expenses. And once the crisis subsided, increased rebates could be shifted to focus on hard-hit sectors of the economy, such as tourism and retail, for example. Indeed, even during "normal" times, governments could direct various rebates to focus on other national priorities such as climate change by offering incentives on the purchase of energy efficient cars and appliances.[25]

Of course, funding for cash-back schemes does not have to come solely from the government. Individual merchants could also offer (and thus fund) rebates for CBDC-related purchases that could be tied to loyalty programs. In fact, the money that merchants save on credit card fees could be used to offset these potential rebates and help drive traffic to their store.

[25] In many countries around the world, such incentives already exist and are administered through tax policies. However, the receipt of such rebates are often delayed until annual taxes are filed. Applying instant rebates on specific purchases using blockchain technology would have a more immediate impact on the economy.

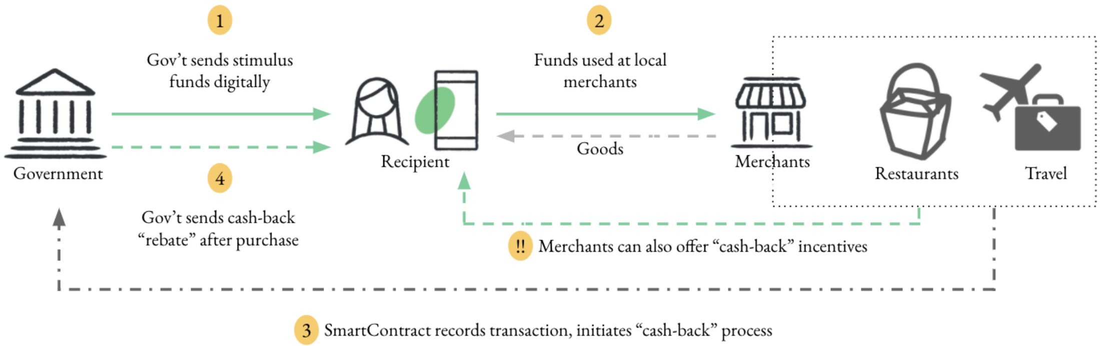
Box 2: Example of cash-back implementation

The flow chart below illustrates how a cash-back scheme could potentially be implemented on a CBDC. For example, during a time of crisis, a government may wish to send its citizens money to help support them and stimulate the economy. Additionally, the government may also want to ensure that these stimulus funds are spent in a timely manner at local merchants.

For the purposes of this example, let's assume that the government decides to send all of its citizens 100 units of CBDC to help stimulate the economy (Step 1). Additionally, the CBDC is programmed such that when the recipient spends the units at an authorized, local merchant, they will receive a cash-back reward (or rebate) of 10%.

Thus, if a recipient were to spend 10 units of CBDC at a local merchant (Step 2), a SmartContract would record the transaction and initiate the cash-back process (Step 3). Following the purchase, the government would automatically deposit 1 unit of CBDC (10% of 10 units) into the recipient's wallet (Step 4).

It's important to note that the government, or central bank, does not have to be the only entity funding a cash-back scheme. Indeed, merchants can also offer cash-back incentives to potential customers. For example, if a local restaurant wanted to offer a 10% rebate to all purchases, on top of the 10% offered by the government as part of the stimulus funds, then a recipient who spent 10 units of CBDC at that restaurant, would ultimately receive a rebate of 2 units of CBDC (1 from the government, and 1 from the restaurant).



5 Conclusion

The purpose of this analysis was to highlight the contribution that introducing a central bank digital currency on the Celo platform could have with respect to monetary policy. Instead of exclusively focusing on policies that influence the price of money, as interest rates do, this paper has proposed a different approach: influencing the velocity of money.

The velocity of money has always been a theoretical abstraction. Since we are unable to trace every banknote and count the number of times it is used in the economy, we are left inferring money's velocity by using the ratio of a country's economic output to its money supply. Given this limited understanding, economic principles teach us to simply hold the value of velocity constant in any equation so as to focus on the impact of other variables.

But the technology behind token-based stablecoins allows us to move from the theoretical to the practical. With CBDC, the velocity of money is no longer theoretical. We don't have to infer how many times a banknote is used, because the blockchain technology powering CBDC would allow a central bank access to real-time transactional data. More importantly, this same technology enables central banks to influence the velocity of money by implementing demurrage fees on CBDC, thus turning Gesell's theoretical notion of "stamped" money into a practical solution. Or alternatively, offering "cash back" on CBDC purchases as another way of influencing consumer spending, and thus velocity. Indeed, central banks could even create a hybrid scheme, combining demurrage fees with cash-back incentives (see Box 3).

It's important to note that while this paper highlights some innovative ways in which technology can support monetary policy, it does not opine on the normative views associated with implementing demurrage fees or cash back schemes. The idea of negative interest rates on currency may seem barbaric to some, but as [Rogoff, 2014] argues, it is "arguably no more barbaric than inflation, which similarly reduces the real purchasing power of currency." At the very least, central banks will have better transactional data and thus better insight into the actual velocity of CBDC. Future versions of this paper will utilize real data from pilot-based projects to underpin this idea with real transaction data.

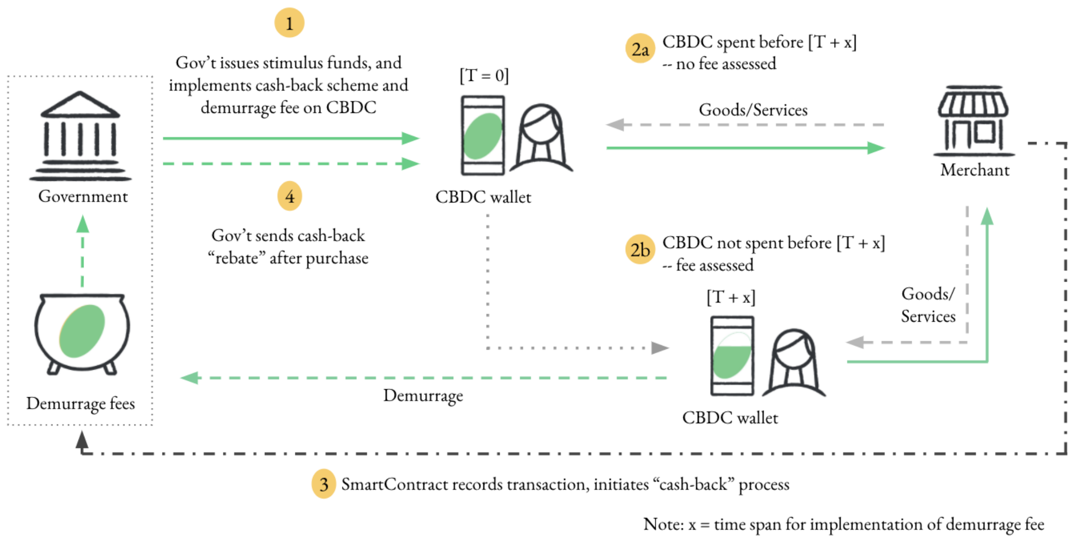
Box 3: Example of a hybrid scheme

The flow chart below illustrates how a hybrid scheme, combining both a demurrage fee with a cash-back rebate could potentially be implemented on a CBDC. For the purposes of this example, let's assume the government decides to send all of its citizens 100 units of CBDC to help stimulate the economy (Step 1). Additionally, the CBDC is programmed to carry a demurrage fee of 1% (assessed at the end of every month) and a cash-back rebate of 10%.

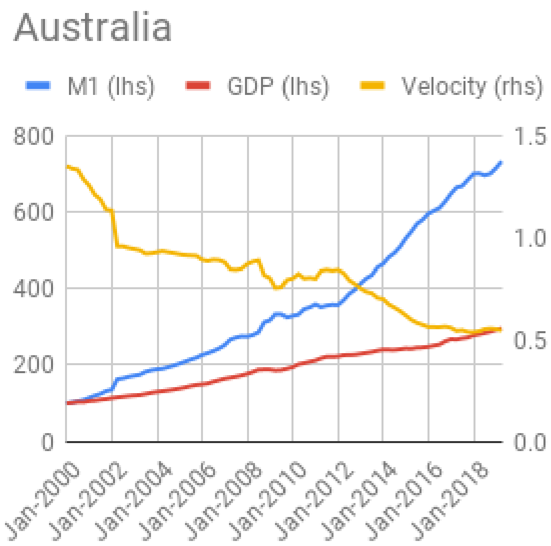
If all 100 units of CBDC are spent before the end of the month (Step 2a), the recipient will receive a rebate of 10 units, and will not be assessed any demurrage fee (Steps 3 & 4).

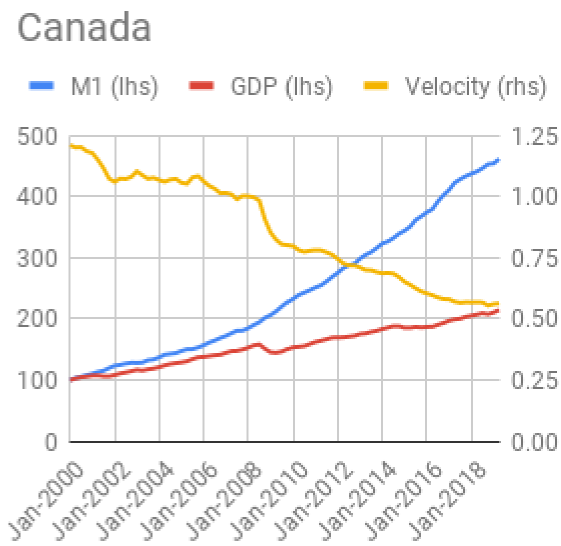
If none of the funds are spent before the end of the month, then a demurrage fee of 1 unit (1% of 100 units) will be assessed, leaving the recipient with 99 units (Step 2b). However, once these units are spent, the recipient will then be eligible for the cash-back rebate. Thus, if these 99 units are subsequently spent before the end of the following month, the recipient will receive a rebate of 9.9 units (Steps 3 & 4).

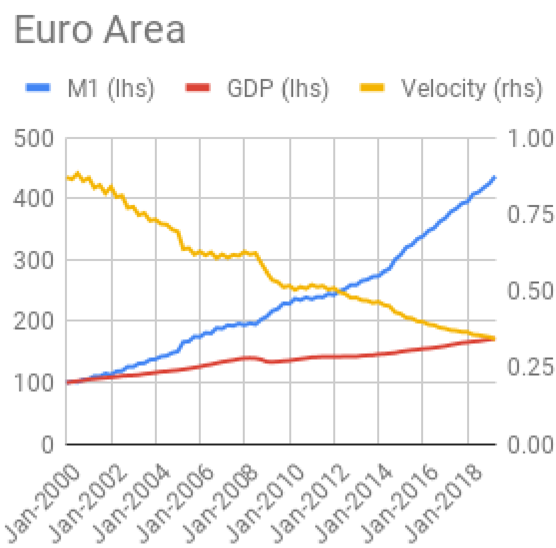
Importantly, the demurrage fees collected by the government could be used to help offset the cost of the cash-back rewards, and improve the long-term financial viability of such a program.

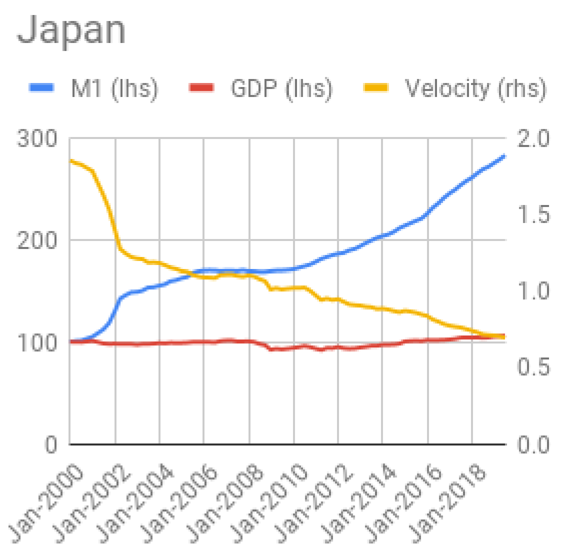


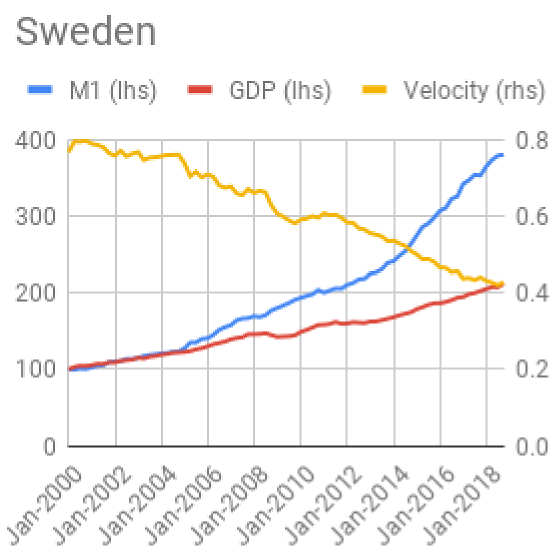
Appendix

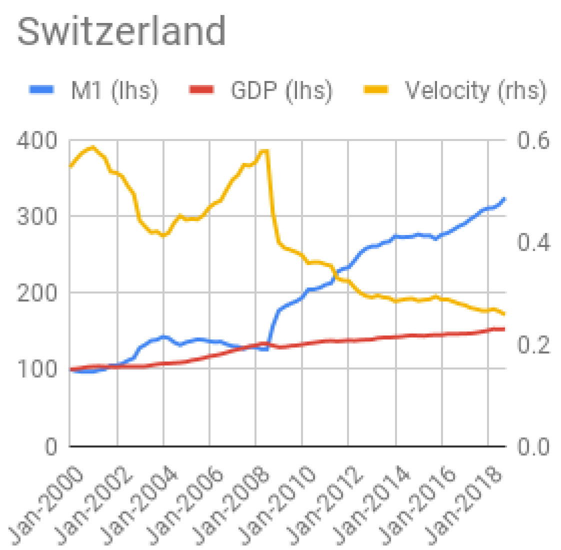

Australia
M1 (lhs)
GDP (lhs)
Velocity (rhs)
800
600
400
200
0
1.5
1.0
0.5
0.0
Jan-2000 Jan-2002 Jan-2004 Jan-2006 Jan-2008 Jan-2010 Jan-2012 Jan-2014 Jan-2016 Jan-2018

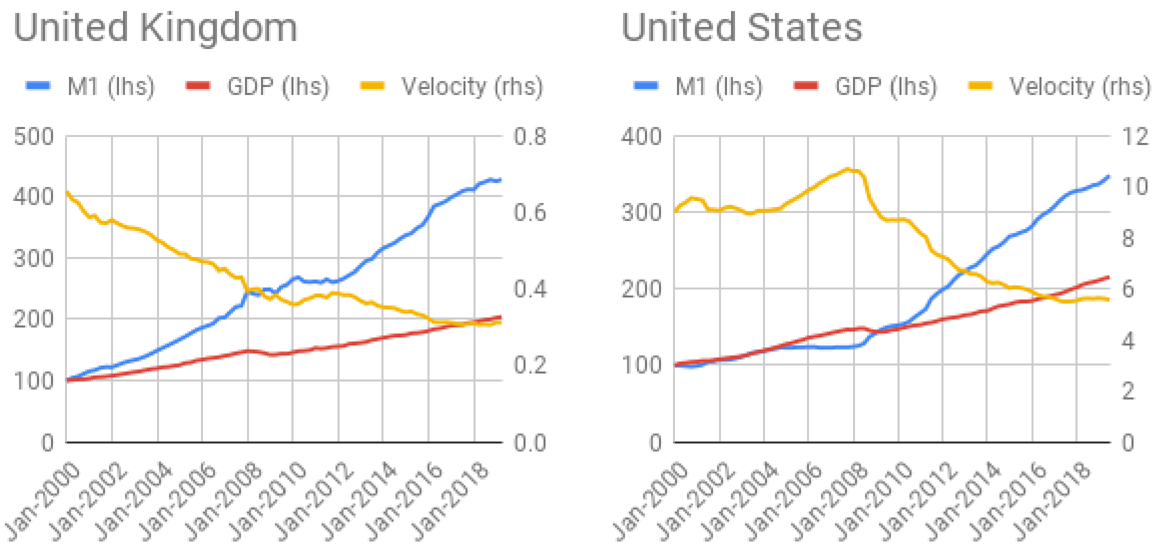

Canada
M1 (lhs)
GDP (lhs)
Velocity (rhs)
500
400
300
200
100
0
1.25
1.00
0.75
0.50
0.25
0.00
Jan-2000 Jan-2002 Jan-2004 Jan-2006 Jan-2008 Jan-2010 Jan-2012 Jan-2014 Jan-2016 Jan-2018


Euro Area
M1 (lhs)
GDP (lhs)
Velocity (rhs)
500
400
300
200
100
0
1.00
0.75
0.50
0.25
0.00
Jan-2000 Jan-2002 Jan-2004 Jan-2006 Jan-2008 Jan-2010 Jan-2012 Jan-2014 Jan-2016 Jan-2018


Japan
M1 (lhs)
GDP (lhs)
Velocity (rhs)
300
200
100
0
2.0
1.5
1.0
0.5
0.0
Jan-2000 Jan-2002 Jan-2004 Jan-2006 Jan-2008 Jan-2010 Jan-2012 Jan-2014 Jan-2016 Jan-2018


Sweden
M1 (lhs)
GDP (lhs)
Velocity (rhs)
400
300
200
100
0
0.8
0.6
0.4
0.2
0.0
Jan-2000 Jan-2002 Jan-2004 Jan-2006 Jan-2008 Jan-2010 Jan-2012 Jan-2014 Jan-2016 Jan-2018


Switzerland
M1 (lhs)
GDP (lhs)
Velocity (rhs)
400
300
200
100
0
0.6
0.4
0.2
0.0
Jan-2000 Jan-2002 Jan-2004 Jan-2006 Jan-2008 Jan-2010 Jan-2012 Jan-2014 Jan-2016 Jan-2018



Source: Federal Reserve Bank of St. Louis (M1 and GDP data indexed to 2000 by authors)

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