Central Bank Digital Currency and the Future of Monetary Policy*

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We consider how a central bank digital currency (CBDC) can transform all aspects of the monetary system and facilitate the systematic and transparent conduct of monetary policy. Drawing on a very long strand of literature in monetary economics, we find a compelling rationale for establishing a CBDC that serves as a stable unit of account, a practically costless medium of exchange, and a secure store of value. In particular, the CBDC should be universally accessible and interest-bearing, and the central bank should adjust its interest rate to foster true price stability.

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1. Introduction

For there was once a time when no such thing as money existed....a material was selected which, being given a stable value by the state, avoided the problems of barter by providing a constant medium of exchange. That material, struck in due form by the mint, demonstrates its utility and title not by its substance as such but by its quantity, so that no longer are the things exchanged both called wares but one of them is termed the price. And today it is a matter for doubt whether one can talk of sale when no money passes.[1]

Julius Paulus Prudentissimus, circa 230 C.E.

In ancient Rome, the emperor's chief legal advisor described the fundamental rationale for a government-issued currency using terms that remain familiar to modern monetary economists: (i) a *unit of account* for the pricing of goods and services; (ii) a *method of storing value*; and (iii) a *medium of exchange* that facilitates economic and financial transactions. Moreover, the Roman jurist recognized that the utility of currency depends not on its material substance but on its nominal quantity; that is, the efficacy of the currency hinges on public confidence in the authorities' management of the monetary system.[2]

Nearly two millenia later, as electronic devices and high-speed networks have become practically ubiquitous, central banks around the globe are now actively exploring the possibility of establishing sovereign digital currencies.[3] Just like paper currency and coins, central bank digital currency (CBDC) would be fixed in nominal terms, universally accessible, and valid as legal tender for all public and private transactions. Consequently, CBDC is essentially different from the various forms of virtual currency (such as bitcoin, ethereum, and ripple) that have been created by private entities and whose market prices have exhibited very sharp fluctuations in recent years.[4]

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[1] Paulus served as chief legal advisor to the Roman emperor Severus Alexander (222-235 C.E.), during a period of multiple revisions to the designated purity and weight in silver of the Roman denarius. He was granted the honorific "prudentissimus" and his commentaries were later included in the *Digest*, a legal compendium produced by the Byzantine emperor Justinian. The excerpt shown here is taken from section 18.1 of the *Digest*; the translation from the original Latin is that of Watson (2010), p.55.

[2] Schumpeter (1954, p.67) interpreted Paulus' text as indicating that "people, in handling money in everyday transactions, usually take a coin at its nominal value without any conscious thought of the commodity value of its materials."

[3] For example, the Sveriges Riksbank has an accelerated timeframe for deciding whether to launch a CBDC (Boel 2016 and Skingsley 2016), the People's Bank of China is experimenting with technical specifications (Fan 2016), and the Bank of England is conducting a multiyear investigation (Broadbent 2016). See also recent perspectives from officials at the European Central Bank (Mersch 2017) and Norges Bank (Nicolaisen 2017).

[4] See McCallum (2015) and Weber (2016). As of July 2017, the market capitalizations for bitcoin, ethereum, and ripple were about $42 billion, $25 billion, and $9 billion, respectively, and the year-to-date changes in their unit prices were roughly 250 percent, 3000 percent, and 4000 percent, respectively *(http://coinmarketcap.com)*.

In this paper, we analyze the key features of CBDC, with the aim of formulating a set of design principles rather than a technical blueprint. In particular, we consider the following issues: (1) Should CBDC payments involve transfers between accounts held at the central bank, or digital "tokens" that can be transferred directly from payer to payee? (2) Should cash be abolished, or should the central bank establish a schedule of fees for transferring funds between CBDC and paper currency? (3) Should CBDC be interest-bearing or indexed to an aggregate price index rather than having a constant nominal value like cash and coins? (4) What are the implications of CBDC for the central bank's monetary policy strategy and operating procedures? (5) How will CBDC affect the interactions between the central bank and the fiscal authorities?

In considering these issues, we assume that the central bank's objective is to maximize the effectiveness of CBDC in fulfilling the basic functions of any public currency, namely, its efficiency as a medium of exchange, its security as a store of value, and its stability as the unit of account for economic and financial transactions. Using those criteria, we identify the following characteristics of a well-designed CBDC:

- An *account-based* CBDC could serve as a practically costless medium of exchange. Such accounts could be held directly at the central bank itself or made available via public-private partnerships with commercial banks.

- An *interest-bearing* CBDC could provide a secure store of value, with a rate of return in line with other risk-free assets such as short-term government securities. The CBDC interest rate could serve as the main tool for conducting monetary policy.

- To facilitate the *gradual obsolescence of paper currency*, CBDC could be made widely available to the public, with a graduated schedule of fees on transfers between cash and CBDC. Consequently, adjustments to the CBDC interest rate would not be constrained by any effective lower bound.

- The monetary policy framework could foster *true price stability*, that is, the real value of CBDC would remain stable over time in terms of a broad consumer price index. Such a framework would facilitate the systematic and transparent conduct of monetary policy.

This analysis draws on a very long strand of literature in monetary economics. The quest for a stable unit of account was pursued by luminaries like Jevons (1875), Marshall (1877),

Wicksell (1898), Fisher (1913), Buchanan (1962), and Hayek (1978).[5] The rationale for an efficient medium of exchange was highlighted by Friedman (1960), who argued that government-issued money should bear the same rate of return as other risk-free assets. These two goals—that is, a stable unit of account and an efficient medium of exchange—seemed to be irreconcilable due to the impracticalities of paying interest on paper currency, and hence Friedman advocated a steady deflation rather than price stability. But the achievement of both goals has now become feasible via a well-designed CBDC.[6]

As a practically costless medium of exchange, CBDC would significantly enhance the efficiency of the payments system. For example, a recent IMF study has pointed out that the introduction of CBDC would facilitate more rapid and secure settlement of cross-border financial transactions.[7] CBDC would be particularly beneficial for lower-income households, who tend to rely heavily on cash, and for small businesses, which incur substantial costs for handling cash or substantial interchange fees for taking payments via debit and credit cards. At a macroeconomic level, researchers at the Bank of England have estimated that the productivity gains from adopting CBDC would be similar to those of a substantial reduction in distortionary taxes.[8]

The interest-bearing design of CBDC and the obsolescence of paper currency would also contribute to greater macroeconomic stability, because interest rate adjustments would no longer be constrained by any effective lower bound in response to severe adverse shocks.[9] That lower bound has been a key reason why many central banks currently aim at positive inflation rates of 2 percent or more, whereas CBDC will essentially eliminate the need to maintain such an "inflation buffer" or to deploy alternative monetary policy tools such as quantitative easing or credit subsidies. Moreover, in the event of a severe economic downturn, CBDC would facilitate the provision of money-financed fiscal stimulus.[10] Indeed, Friedman (1948) highlighted the complementarities between monetary and

[5] See also Bordo (1984), Black (1987), Cagan (1987), Patinkin (1993), and the papers collected in Dorn and Schwartz (1987) and Dorn (2017).

[6] True price stability was *not* achieved during the classical gold standard era; rather, the general price level exhibited substantial fluctuations and persistent drift due to shifts in the relative supply and demand for gold. For further analysis and discussion, see Bordo (1984) and Bordo, Dittmar, and Gavin (2007).

[7] See He et al. (2017).

[8] See Barrdear and Kumhof (2016).

[9] Goodfriend (2000, 2016), Buiter (2009), Agarwal and Kimball (2015), and Pfister and Valla (2017) discuss the merits of eliminating the effective lower bound on nominal interest rates.

[10] For example, as noted by Dyson and Hodgson (2017), funds could be deposited directly into the CBDC accounts of lower-income households, thereby cushioning their purchasing power from the effects of the downturn as well as from the temporarily negative level of the CBDC interest rate.

fiscal expansion under such circumstances.

The initiation of CBDC would represent a fairly natural progression in light of current trends in monetary operations. For example, most central banks already pay interest on the reserves of commercial banks, which comprise a substantial portion of the total monetary base. The Federal Reserve has expanded its capacity to pay interest to an even wider range of counterparties by borrowing funds in the U.S. Treasury repo market.[11] Moreover, the Federal Reserve Banks now maintain segregated deposit accounts for systemically important financial market utilities (FMUs), so that the customers of those FMUs may rest assured that their funds are secure, liquid, and interest-bearing.[12]

As for monetary policy strategy, aiming at true price stability would be substantively different from the current practice of inflation forecast targeting. As noted above, most central banks have a positive inflation target (typically 2 percent or higher) and place no weight on previous deviations of inflation from target ("let bygones be bygones"), so that the aggregate price level follows a random walk with upward drift. By contrast, under a price level target, consumer prices would still exhibit transitory fluctuations but monetary policy will ensure that the aggregate price level returns to its target over time. Thus, households and businesses would be able to formulate their plans with confidence that the cost of a representative basket of consumer items (as measured in terms of the CBDC) would be reasonably stable over the medium run and roughly constant at planning horizons of 5, 10, 20 and even 50 years into the future. Such stability could be particularly beneficial for lower-income households and small businesses, which typically have little or no access to sophisticated financial planning advice or complex financial instruments that can help insure against such risks.

The widespread use of CBDC and the obsolescence of paper currency would be helpful in discouraging tax evasion, money laundering, and other illegal activities.[13] This benefit is significant for advanced economies but likely to be even more pertinent for developing economies where a large fraction of economic activity is conducted using cash and hence the

[11] As of mid-July 2017, the Federal Reserve's reverse repurchase agreements stood at around $400 billion, comprising about one-sixth of its interest-bearing liabilities and roughly one-tenth of its total liabilities. Information about the design of the Federal Reserve's reverse repo facility and the expanded range of counterparties is available at *https://www.newyorkfed.org/markets/rrp_faq.html*.

[12] For example, segregated reserve accounts at the Federal Reserve Bank of Chicago have been created to hold the funds of customers of the Chicago Mercantile Exchange *(*http://www.cmegroup.com/notices/clearing/2017/03/Chadv17-107.html*)* and the initial margin accounts of customers of ICE Clear Credit *(https://www.theice.com/publicdocs/clear_credit/circulars/Circular_2017_015_FINAL.pdf).*

[13] Rogoff (2016) considers how large-denomination bills facilitate various forms of illegal activity.

incidence of tax evasion is very high. The feasibility of CBDC has been demonstrated in Ecuador, where CBDC has become widely available through a simple and secure platform (i.e., two-step verification with cellphones and text messages).[14] Likewise, Kenya's government has been a pioneer in establishing a public-private partnership for providing low-cost digital payments.[15]

Finally, given the rapid pace of recent and prospective innovations in payments technology, it might not be prudent for central banks to take a passive and inertial approach to CBDC. Rather, policymakers should be alert to a number of salient risks associated with scenarios in which the central bank does not produce any form of digital currency, including loss of monetary control and greater susceptibility to severe economic downturns. In light of such considerations, it seems sensible that many central banks are moving expeditiously in considering the adoption of CBDC.

The remainder of this paper is organized as follows: Sections 2 to 4 consider how the design of CBDC can facilitate its role as a medium of exchange, store of value, and unit of account, respectively. Section 5 considers the implications of CBDC for the central bank's monetary policy framework. Section 6 concludes.

2. Efficient Medium of Exchange

In this section we focus on the design elements of CBDC that pertain to its role as an efficient medium of exchange. Some characteristics are intrinsic to any government-issued currency, namely, it can be held by anyone and serves as legal tender for all public and private payments.[16] However, a crucial issue is whether CBDC should be more closely parallel to cash or to a debit card. Our analysis indicates that the former approach would have significant drawbacks, whereas the latter design would provide a simple and practically costless medium of exchange that could be provided directly by the central bank or via public-private partnerships with commercial banks. Moreover, the initiation of CBDC would likely facilitate the obsolescence of paper currency and coins.

[14] See *https://www.bce.fin.ec/en/index.php/electronic-money-system*.

[15] Safaricom Ltd. currently provides digital payments (using the M-Pesa platform) to about 25 million Kenyan customers (*https://www.safaricom.co.ke/annualreport_2016*). Its two largest shareholders are Vodafone (50 percent) and the Kenya Treasury Department (25 percent).

[16] Fung and Halaburda (2016) identify these intrinsic features as distinct from other design elements of CBDC.

A. Tokens vs. Accounts

In particular, one potential design (analogous to cash) would be for the central bank to issue *CBDC tokens* that would circulate electronically among private individuals and firms and that might only rarely be redeposited back at the central bank.[17] Like bitcoin, this approach would use some form of distributed ledger technology (DLT) for verifying the chain of ownership of each token and validating payment transactions, without requiring the direct involvement of the central bank or any other clearinghouse.[18] In contrast to bitcoin and other virtual currencies, however, the central bank would determine the supply of CBDC tokens, which would be fixed in nominal terms and serve as legal tender. Moreover, the central bank could establish transparent procedures for incorporating appropriate updates to the DLT software—a challenge that has proven to be difficult in the case of virtual currencies.[19]

Under the alternative design (analogous to debit cards), individuals and firms would hold funds electronically in *CBDC accounts* at the central bank or in specially designated accounts at supervised depository institutions.[20] Under this approach, the central bank would process each payment transaction by simply debiting the payer's CBDC account and crediting the payee's CBDC account.

One crucial advantage of an account-based system is that CBDC payments could be practically instantaneous and costless. Of course, during the initial creation of each CBDC account, the identity of the account holder would need to be verified using procedures like those followed in obtaining a drivers' license or opening an account at a commercial bank. From that point onward, however, payment transactions could be conducted rapidly and securely (e.g., using two-step verification with a cellphone and digital pin), and the central bank would be able to monitor any unusual activity and implement additional anti-fraud safeguards as needed.

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[17] Motamedi (2014) and Koning (2014) each proposed a token-based CBDC using the nicknames "bitdollar" and "fedcoin", respectively. For further discussion, see Andalfatto (2015) and Raskin and Yermack (2016a).

[18] Danezis and Meiklejohn (2016) formulate a design for a token-based CBDC in which verification would be performed by a limited number of authorized institutions and hence would be substantially more efficient than the design of bitcoin.

[19] For example, in mid-2016 the Ethereum user community was divided on the appropriate response to a major security breach and hence there was a "hard fork" into two distinct currencies (now referred to as "ethereum" and "ethereum classic"). In mid-2017 the Bitcoin user community seemed headed towards a similar outcome due to concerns about scalability, but at present it appears that situation will be resolved by a "soft fork."

[20] Scorer (2017) provides a lucid and insightful discussion of these alternatives and concludes that central banks should implement digital currency using accounts rather than tokens.

By contrast, the cost of verification for a token-based system would be inherently expensive. The entire chain of ownership of every token must be stored in an encrypted ledger (the blockchain), and a copy of that ledger must be stored on each node of the payment network. New payment transactions are collected into blocks that must be verified before being added permanently to the ledger. This verification process—referred to as mining—involves computational procedures that are highly complex and energy-intensive.[21] For example, in the case of bitcoin, miners' revenue is equal to about 0.8 percent of the total value of payment transactions.[22] In effect, a token-based CBDC might be preferable to existing forms of payment but would be far less efficient than an account-based CBDC.[23]

The efficiency gains from establishing an account-based CBDC would be substantial. Consumers typically pay substantial fees (2 to 5 percent or more) for withdrawing cash from automated teller machines, while retail businesses incur substantial costs for sorting, cleaning, and verification of cash as well as interchange fees for taking payments via debit and credit cards. To gauge these effects at an aggregate level, Barrdear and Kumhof (2016) analyzed a dynamic stochastic general equilibrium (DSGE) model of the U.S. economy; in their benchmark scenario, the adoption of CBDC permanently raises the level of real GDP by about 3 percent.

B. Alternative Forms of Acccounts

As noted above, an account-based CBDC could be implemented via accounts held directly at the central bank.[24] Such an approach would be reminiscent of the early years of central banking, when individuals and nonfinancial firms held accounts at the Bank of England and the Sveriges Riksbank; during that era of paper bookkeeping, however, maintaining a large number of private accounts became increasingly impractical, and hence such accounts were

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[21] In the case of bitcoin, the difficulty threshold is adjusted automatically every two weeks in response to changes in the computational capacity of the network, thereby ensuring that new blocks are added to the blockchain about once every 10 minutes. For example, during the 12 months ending in July 2017, that difficulty threshold grew by a factor of about 4 (*http://blockchain.info/stats*).

[22] Bitcoin costs are very transparent because miners' revenue is denominated in bitcoin and recorded in the blockchain (*https://blockchain.info/charts/cost-per-transaction-percent*). These costs mostly reflect electricity; i.e., miners are currently processing about 520 trillion gigahash per hour, and each gigash requires about 0.75 watts of electricity, so total usage is about 40 terawatt-hours per year—roughly similar to the electricity consumption of a large U.S. city of about 2.5 million people.

[23] Researchers are actively investigating alternative forms of DLT that would involve much lower verification costs, such as algorithms involving "proof of stake" instead of "proof of work"; see Zamfir (2015) and Buterin (2016). However, such algorithms may allow some imperfections in the accuracy of the blockchain—a property that might be plausible for a virtual currency but probably not acceptable for the design of CBDC.

[24] Under this approach, legal safeguards would be essential for protecting the privacy of all CBDC transactions, similar to the regulations for protecting personal and proprietary information obtained by government agencies.

eventually discontinued. By contrast, in the current environment of immense data storage and high-speed network capacities, providing CBDC via accounts at the central bank is now eminently feasible, as evident from the recent experience of Ecuador.

Alternatively, following the approach of Dyson and Hodgson (2017), CBDC could be provided to the public via specially designated accounts at supervised commercial banks, which would hold the corresponding amount of funds in segregated reserve accounts at the central bank. This approach may be particularly beneficial to smaller banks that have a strong orientation towards "relationship banking." In many communities, such banks play a crucial role in providing financial services to disadvantaged households, small businesses, and entrepreneurs.

The feasibility and potential benefits of such public-private partnerships are apparent from the recent experience of Kenya. Moreover, the U.S. Federal Reserve System has recently instituted a roughly similar approach in establishing segregated accounts for maintaining the funds of customers at systemically important financial market utilities (FMUs).[25]

Finally, CBDC need not be aimed at monopolizing the payments system but could instead be complementary to the payment services provided by private entities. Indeed, individuals and businesses would remain free to hold funds at private institutions and to make payments using private networks and virtual currencies.[26] In fact, a number of financial institutions are actively engaged in developing new payment networks using DLT and other innovative approaches.[27] In the absence of competition from CBDC, however, such private networks might exhibit increasing returns to scale and become quasi-monopolistic, which might in turn result in rather complex and opaque government regulations aimed at mitigating systemic risk and preventing price gouging of consumers and small businesses. Conseqently, moving forward with public-private CBDC partnerships might seem appealing even to many large multinational banks.[28]

[25] The Commodity Futures Trading Commission has issued regulations pertaining to the use of such Federal Reserve accounts *(http://www.cftc.gov/PressRoom/PressReleases/pr7421-16)*.

[26] See Selgin (2008).

[27] See Arnold (2016), Brainard (2016a,b), and Powell (2017).

[28] As noted above, Paulus specifically referred to the role of the government in providing currency to facilitate market competition and efficiency. See also Smith (1776) and Friedman and Schwartz (1986).

C. Paper Currency

In many countries around the globe, the demand for paper currency has been diminishing rapidly as consumers have turned increasingly to using credit and debit cards as well as cellphones and online payment methods. For example, Swedish households used cash for about 15 percent of their retail transactions last year—only half the usage rate observed four years earlier.[29] Indeed, a prominent global payments firm recently launched a campaign aimed at incentivizing small businesses to stop accepting cash at all.[30]

Nonetheless, these trends are not uniform across countries or types of households. The amount of cash in circulation is about 10 percent of GDP in the eurozone and in Switzerland and exceeds 20 percent of GDP in Japan.[31] Even in Sweden, about one-third of the households in a recent Riksbank survey indicated that they would not be able to cope with the disappearance of cash.[32] Those survey results also point to significant variations across demographic groups, with the greatest use of cash by the elderly and by individuals with relatively low levels of education and income.

Such considerations weigh strongly against abruptly abolishing the use of cash. Rather, the central bank could facilitate the gradual obsolescence of cash by making CBDC widely available to the public and by initiating a graduated schedule of fees for transfers between cash and CBDC. To avoid imposing a burden on lower-income households, the fee could be minimal (or perhaps none at all) for making small and infrequent transfers (e.g., a small weekly cash deposit or withdrawal), whereas the fees would be substantial for larger and more frequent transfers. In effect, such a fee structure would be the inverse of the typical ATM, which charges a fixed fee regardless of the amount of cash withdrawn. Moreover, as discussed below, this fee structure would be crucial for ensuring that the continued existence of paper currency did not constrain the central bank's ability to reduce nominal interest rates to negative levels in response to a severe adverse shock.

Such arrangements would also foster individual freedom of choice while discouraging tax evasion, money laundering, and other illegal activities. If desired, individuals would still be able to preserve their anonymity by engaging in small transactions using cash, or

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[29] *http://www.riksbank.se/en/Statistics/Payment-statistics/*

[30] *http://investor.visa.com/news/news-details/2017/Visa-to-Help-US-Small-Businesses-Go-Cashless/default.aspx*

[31] See figure 1 of Segendorf and Wretman (2015) and the commentary of Wheatley (2017).

[32] *http://www.riksbank.se/Documents/Statistik/Betalningsstatistik/2016/svenska_folkets_betalningsvanor_161031_eng.xlsx*

alternatively, virtual currencies or other private payments. But the graduated fee schedule described above would serve as a significant tax on black-market transactions, and such activities would be increasingly difficult with the accelerating obsolescence of cash. Moreover, with the widespread availability of CBDC, it would be reasonable to phase out the issuance of large-denomination paper currency bills.[33]

3. Secure Store of Value

Now we turn to the aspects of CBDC that can enhance its role as a secure store of value. In particular, if funds are deposited and retained in a CBDC account over some time period, what happens to the value of such funds? Should the nominal amount of CBDC remain constant (as with paper currency and coins) or be indexed to the general price level (thereby preserving its real value) or earn interest like that paid on short-term government securities?

Here we briefly consider each of these approaches in terms of the benefits to CBDC holders as well as potential spillover effects to the broader financial system.

Option #1: Constant Nominal Value

Funds in CBDC accounts could have a constant nominal value, just like paper currency.[34] In effect, the CBDC accounts of the general public would be treated distinctly from the reserves of commercial banks held at the central bank, which are generally interest-bearing. Consequently during periods of positive nominal interest rates, households and businesses would be incentivized to minimize the amount of funds held in CBDC accounts, and hence the total value of CBDC might remain fairly modest.

As in current practice, the central bank could conduct monetary policy by adjusting short-term nominal interest rates. However, its ability to push nominal interest rates below zero would be tightly constrained, because depositors could readily move their funds into CBDC earning zero interest. Consequently, in a protracted period of weak aggregate demand and deflation, the central bank would likely need to rely on other tools such as quantitive easing; alternatively, the government would need to engage in fiscal stimulus to boost aggregate demand and thereby push the price level back up to its target.

With such constraints on the conduct of monetary policy, it would be reasonable to maintain—or perhaps even expand—the inflation buffer in order to mitigate the severity

[33] See the analysis and recommendations of Rogoff (2016).

[34] As discussed in Boel (2016), the Sveriges Riksbank has been actively considering this approach.

of the lower bound on nominal interest rates. Alternatively, if the central bank specified a target for the price level (rather than the inflation rate), it might be sensible for that target to have a positive trend, i.e., the trajectory of prices would be stabilized around an upward-sloping path rather than a constant target.[35]

Option #2: Stable Real Value

The real value of funds in CBDC accounts could be preserved by indexing these funds to past changes in the general price level. Such an approach would essentially encapsulate the "tabular standard" proposed by Jevons (1875) and Marshall (1877) and the "compensated dollar" of Fisher (1913). The rationale for indexing currency and other financial contracts was compelling under the gold standard, because the general price level was subject to large and persistent fluctuations.[36] By contrast, the rationale for indexing CBDC might be much less clear, as long as the monetary policy framework ensures that the price level remains reasonably stable (as discussed below).

Of course, the practical obstacles to indexation were daunting during the gold standard era, whereas indexing CBDC would now be fairly straightforward from a technical perspective. In particular, the nominal value of CBDC funds would increase temporarily during periods when the price level was rising above target and then diminish as the price level subsided back to target.

Nonetheless, indexation of CBDC would be highly problematic whenever aggregate demand is depressed and hence real interest rates drop below zero. During such episodes, financial market participants would be incentivized to shift the bulk of their assets into CBDC bearing a zero real interest rate. In effect, such indexation would induce a *zero lower bound on real interest rates*, which would pose a much more severe constraint on monetary policy than a zero lower bound on nominal rates. Consequently, the central bank would likely need to rely heavily on other monetary policy tools such as quantitative easing; alternatively, fiscal policy could end up bearing primary responsibility for fostering economic recovery and restoring price stability.[37]

[35] See King (1999) and Svensson (1999a,b).

[36] See Bordo (1984) and Bordo et al. (2007).

[37] A variant of this approach would be to provide asymmetric indexation analogous to that of U.S. Treasury Inflation-Protected Securities (TIPS), i.e., the nominal value of digital currency funds would be increased if the price level exceeded its target but not reduced if the price level dropped below target. Such a scheme would impose a constraint like that of cash, namely, a zero lower bound on nominal rates instead of real rates.

Option #3: Interest-Bearing CBDC

From a technical perspective, the central bank could easily pay interest on CBDC. In effect, all funds held at the central bank would bear the same nominal interest rate, regardless of whether those funds belonged to an individual, firm, or financial institution. This approach would encapsulate the analysis of Friedman (1960), who argued that in an efficient monetary system, government-issued money should bear the same return as other risk-free assets. That reasoning underpins the arrangements of many central banks around the world, which pay interest on the reserves of commercial banks held electronically at the central bank. In fact, the Federal Reserve now pays interest to an even wider range of financial counterparties through its reverse repo facility.[38]

Paying interest on CBDC might well enhance the competitiveness of the banking system. Depository institutions that engage in customer-focused "relationship banking" would not be affected, whereas depositors in other less-competitive institutions would have the option of shifting funds into CBDC accounts.

In a growing economy with a stable price level, the interest rate paid on CBDC would typically be positive. However, if the economy encountered a severe adverse disturbance that exerted downward pressure on the general price level, it should be feasible for the central bank to reduce interest rates as needed to foster economic recovery and price stability.[39]

At present, paper currency poses a significant constraint on the central bank's ability to cut its policy rate in response to severe adverse shocks. Cash accrues zero interest and hence becomes increasingly attractive as a store of value when nominal interest rates are negative. In effect, if rates on bank deposits and other short-term assets were pushed too far below zero, the financial system could undergo a severe disintermediation into cash, similar to what transpired during the bank panics of the early 1930s.

That constraint on monetary policy could be eliminated by establishing a graduated schedule of fees on transfers between cash and CBDC. In particular, imposing substantial fees on relatively large or frequent tranfers would serve as a "wedge" that would make it unprofitable for investors to disintermediate into cash during a period of negative nominal interest rates.

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[38] The design of the Federal Reserve's reverse repo facility and its range of counterparties is available at *https://www.newyorkfed.org/markets/rrp_faq.html*.

[39] In recent years, a number of major central banks (including the European Central Bank and the Bank of Japan) have paid negative rates on bank reserves.

With such arrangements in place, monetary policy would no longer be constrained by an effective lower bound on nominal interest rates.

Thus, the interest rate on CBDC could serve as the primary tool of monetary policy, thereby mitigating the need to deploy alternative monetary tools such as quantitative easing or to rely on fiscal interventions in order to restore price stability. Moreover, the lower bound on nominal interest rates has been a primary motivation for maintaining a positive inflation buffer. Major central banks currently have inflation targets of 2 percent, and in the wake of the financial crisis some economists have advocated raising those targets.[40] With interest-bearing CBDC, there would no longer be a compelling need to maintain any inflation buffer.

4. Stable Unit of Account

Providing a stable unit of account facilitates the economic and financial decisions of individuals and businesses, including the determination of wages and prices, the spending and saving decisions of consumers, and the specification of financial contracts. It should be noted, however, that stabilizing the value of the currency in terms of a broad price index (rather than a single commodity) cannot be achieved merely by issuing a legal edict. Indeed, in a market economy, it is logically impossible to define the value of the currency in terms of the general price level, because the prices of individual goods and services are set by businesses operating in specific markets rather than determined by a central planner. Consequently, price stability can *only* be accomplished by the appropriate setting of monetary policy.

Of course, even after the introduction of CBDC, the central bank could continue to maintain a positive inflation target. But with the elimination of the effective lower bound on nominal interest rates, it would become feasible to foster true price stability. In particular, the monetary policy framework could ensure that the value of CBDC remains stable over time in terms of a general index of consumer prices.

Apart from mitigating the effective lower bound, previous analysis has cited two other factors that would potentially warrant the continued targeting of a positive inflation rate: (i) systematic measurement bias, and (ii) downward nominal wage rigidity (DNWR).[41]

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[40] Blanchard et al. (2010) and Ball (2013) analyze the merits of expanding the inflation buffer.

[41] Concerns about systematic measurement bias in the U.S. CPI were raised by the Boskin Commission in 1996 *(https://www.ssa.gov/history/reports/boskinrpt.html)*. Akerlof, Dickens, and Perry (1996) documented the low incidence of nominal wage cuts for U.S. and Canadian employers and formulated a macro model with DNWR

However, recent analysis using individual price records indicates that the magnitude of measurement bias is very small for an appropriately chain-weighted price index.[42] As for DNWR, the Japanese experience is informative: DNWR was prevalent until the mid-1990s but essentially vanished during the era in which consumer inflation was persistently close to zero; moreover, the level of unemployment has not exhibited any marked shifts despite the substantial swings in trend inflation that have occurred over the past several decades.[43] That experience and other recent evidence bolsters the view of Bewley (2005) that wage-setting practices are mainly influenced by perceptions of fairness and reciprocity rather than money illusion. Indeed, a clear and credible commitment to true price stability would enhance the accuracy of those perceptions and thereby facilitate the transparency of wage negotiations.[44]

A large body of literature has analyzed the macroeconomic effects of targeting the price level rather than the inflation rate. These studies have generally concluded that price-level targeting can provide substantial benefits to macroeconomic stability if the policy framework is transparent and the commitment to price stability is credible. Moreover, consistent with analysis of optimal monetary policy and simple benchmark rules, the stance of monetary policy should respond to real economic activity as well as to the price level.[45] Thus, such frameworks are often characterized in the literature as *flexible price-level targeting,* as distinct from the now-conventional practice of flexible inflation targeting.[46]

Finally, it should be noted that an abrupt shift from a positive inflation target to a stable price level could be disruptive to the economy and the financial system. Consequently, the transition process would need to be carefully planned and managed, so that this transition would be well understood and fully incorporated into the planning of households and firms.

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in which reducing the steady-state inflation rate to zero could induce a substantial increase in the equilibrium unemployment rate.

[42] Handbury, Watanabe, and Weinstein (2013) examine this topic using "the largest price and quantity dataset ever employed in economics" and find that when measured inflation is zero, the measurement bias is about 0.25 percent for a Törnqvist index and about 0.5 percent for the methodology used for the U.S. PCE. See also Johnson, Reed, and Stewart (2006) and Greenlees and McLelland (2011).

[43] Kuroda and Yamamoto (2014) analyze both micro-level and macro data and find that DNWR was present in Japan thru the early-to-mid 1990s but disappeared after 1998.

[44] Fallick, Lettau, and Wascher (2016) find significant evidence for DNWR in the U.S. labor market and examine alternative hypotheses about its impact, concluding that *"the most compelling reason for the lack of macroeconomic consequences from DNWR relates to the possibility that firms take a multi-year view about their labor costs when implementing their compensation practices."*

[45] For example, see Taylor (1993), Clarida, Gali, and Gertler (1998, 1999), and Woodford (2003).

[46] See Svensson (1999a,b), Svensson and Woodford (2003), and Woodford (2003). We do not adopt that particular terminology here because the word *"flexible"* could be misinterpreted as referring to an opaque and discretionary approach to determining monetary policy.

5. Monetary Policy Framework

Over the past few decades, monetary economists have reached a broad consensus that the conduct of monetary policy should be systematic and transparent, thereby facilitating the effectiveness of the monetary transmission mechanism as well as the central bank's accountability to elected officials and the general public.[47] The launching of CBDC provides a landmark opportunity to enhance the transparency of the central bank's monetary policy framework, including its nominal anchor, its tools and operations, and its policy strategy.

A. Nominal Anchor

As noted above, the monetary policy framework should provide a transparent nominal anchor that facilitates the private sector's economic and financial decisions.[48] In recent decades, central banks have made remarkable progress along these lines through the adoption of specific numerical inflation objectives.[49]

In theory, the central bank's inflation target would be permanently and credibly fixed at a specific value. But in practice, the choice of the target has seemed somewhat subjective and arbitrary. Thus, while many central banks currently have a target of 2 percent, some policymakers have expressed preferences for a lower target, and some economists have advocated raising the target to mitigate the effective lower bound on nominal interest rates.[50] Unfortunately, such debates could inadvertently undermine the credibility of the central

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[47] For example, in its "Statement of Longer-Run Goals and Policy Strategy" (adopted in 2012 and unanimously reaffirmed annually since then), the Federal Open Market Committee (FOMC) states: *"The Committee seeks to explain its monetary policy decisions to the public as clearly as possible. Such clarity facilitates well-informed decision-making by households and businesses, reduces economic and financial uncertainty, increases the effectiveness of monetary policy, and enhances transparency and accountability, which are essential in a democratic society."* (https://www.federalreserve.gov/monetarypolicy/files/FOMC_LongerRunGoals.pdf)

[48] For example, the FOMC's "Statement of Longer-Run Goals and Policy Strategy" states: *"Communicating this symmetric inflation goal clearly to the public helps keep longer-term inflation expectations firmly anchored, thereby fostering price stability and moderate long-term interest rates and enhancing the Committee's ability to promote maximum employment in the face of significant economic disturbances."*

[49] See McCallum (1996), Bernanke and Mishkin (1997), and Bernanke, Laubach, Mishkin, and Posen (1999). For empirical analysis of the benefits of inflation targets, see Levin, Natalucci, and Piger (2004), Gürkaynak, Levin, and Swanson (2010), and Beechey, Johannsen, and Levin (2011).

[50] For example, at a time when core PCE inflation was running at about 1 percent, Greenspan (2004) stated: *"Our goal of price stability was achieved by most analysts' definition by mid-2003. Unstinting and largely preemptive efforts over two decades had finally paid off."* From 2009 to 2011, the Federal Reserve published information about FOMC participants' assessments of the appropriate inflation target, which ranged from 1.5 to 2 percent. Warsh (2017) has advocated a target range of 1 to 2 percent, whereas Blanchard et al. (2010) and Ball (2013) have advocated raising the inflation target substantially.

bank's nominal anchor—especially if the public starts wondering whether the setting of the inflation target may be susceptible to the vagaries of politics and election outcomes.

By contrast, with the adoption of interest-bearing CBDC, the central bank could establish a constant price level target that would be a natural focal point for expectations and hence serve as a enduring and credible nominal anchor. Of course, as with inflation targeting, the price level target would need to be specified in terms of a particular price index, but that specification would not be modified subsequently except for compelling technical reasons. To facilitate transparency, the index would ideally be constructed from publicly-posted prices of final goods using a published methodology that would be reproducible by private-sector analysts. Moreover, to ensure continuity over time, the index would utilize chain-weighting rather than relying on any specific base year.[51]

B. Tools and Operations

To facilitate transparency and public accountability, the interest rate on CBDC would serve as the primary tool of monetary policy. In particular, policymakers would be able to push market interest rates below zero in response to a severe adverse shock, and hence the central bank would be able to provide an appropriate degree of monetary accommodation without resorting to measures aimed at modifying the size or composition of its balance sheet—often referred to as quantitative easing or credit easing.

Thus, the central bank's balance sheet could become very transparent. In particular, the central bank would generally hold short-term government securities in the same quantity as its liabilities of digital currency. The central bank's operating procedures would be correspondingly transparent: It would simply engage in purchases and sales of short-term government securities so that the supply of CBDC would move in line with changes in demand for CBDC.

Finally, the central bank would still need to retain its capacity to serve as the lender of last resort. In particular, during a financial crisis the central bank would have the ability to expand the quantity of CBDC to provide emergency liquidity to supervised financial institutions. Alternatively, the central bank could provide those funds to another public agency, such as the deposit insurance fund. In either case, appropriate legal safeguards

[51] For example, the appropriate U.S. price index might be the chain-weighted CPI or the market-based PCE price index. For many other central banks, the price level target might be specified using the same index that is currently being used to characterize the central bank's inflation target.

would be essential to ensure that the central bank's role as lender of last resort did not undermine its ability to carry out its commitment to price stability.

C. Policy Strategy

In characterizing the central bank's monetary policy strategy, one potential approach would be to specify a *price level targeting rule*.[52] Such a rule could be expressed in terms of the deviation of the price level from target and the deviation of economic activity from its sustainable longer-run path, but the rule would not explicitly involve the CBDC interest rate. In effect, the targeting rule represents an optimal-control strategy for managing the short-run tradeoffs between price stability and other aspects of macroeconomic stability. Consequently, this approach may be feasible and effective in a setting where the central bank has a clear understanding of the monetary transmission mechanism (i.e., the dynamic relationship between the setting of the policy rate and the behavior of prices and real economic activity).

Nevertheless, the experience of recent years has clearly underscored the shortcomings and limitations of the current state of knowledge about macroeconomic dynamics. Moreover, given the prospect of continued rapid developments in automation and financial technology, the extent of uncertainty about the monetary transmission mechanism might well heighten further rather than diminishing back towards the relative confidence (or complacency) that prevailed prior to the global financial crisis.[53]

Thus, an alternative approach would be for the central bank to frame its policy strategy in terms of a *simple benchmark rule*. As emphasized by Taylor (1993, 1999), such a benchmark would not be followed in a purely mechanistic fashion but rather used to clarify the central bank's overarching strategy and explain its specific policy decisions.

To provide a concrete example, we assume that CBDC is interest-bearing so that the stance of policy can be framed in terms of adjustments to the CBDC interest rate. Thus, our benchmark rule is analogous to the Taylor Rule but oriented towards stabilizing the price level rather than the inflation rate, and hence can be expressed as follows:

$$i_t \;=\; \tilde{\pi}_t \;+\; r_t^* \;+\; \alpha(\tilde{p}_t - p^*) \;+\; \beta(p_t - p^*) \;+\; \delta(y_t - y_t^*)$$

where i_t denotes the interest rate on CBDC, p_t denotes the price level, p^*denotes the target price level, $\tilde{p}_t$ denotes a "core" measure of the price level (i.e., smoothed to remove

[52] See Svensson (1999a,b), Woodford (2003), and Eggertsson and Woodford (2003).

[53] For example, just before the onset of the global financial crisis, Blanchard (2008) wrote that *"the state of macro is good."*

transitory fluctuations in volatile components), $\tilde{\pi}_t$ denotes the core inflation rate, r_t^* denotes the equilibrium real interest rate, and $(y_t - y_t^*)$ denotes the output gap (that is, the deviation of real GDP from its potential level). The interest rate should respond more strongly to the core measure than to fluctuations in the overall price index ($\alpha >> \beta > 0$) and should respond appropriately to movements in the output gap ($\delta > 0$).

As in the Taylor Rule, this specification can be interpreted as a benchmark for adjusting the real interest rate in response to fluctuations in economic activity and prices. In particular, when the price level is at its target and output is at potential, then the *ex post* real interest rate $i_t - \tilde{\pi}_t$ equals its equilibrium value r_t^*. That value could reflect historical average real rates, as in the Taylor Rule, or could be specified as the median estimate of professional forecasters, as in Levin (2014). The coefficient values in this benchmark rule (α, β, and δ) could be chosen to generate robust macroeconomic stabilization outcomes based on evaluations of a wide array of alternative macroeconometric models.[54]

This policy strategy echoes various proposals to target the level of nominal GDP.[55] In fact, our benchmark rule would be equivalent to that approach if p_t were specified as the GDP price index and the coefficients β and δ were constrained to be equal. Nonetheless, our analysis indicates that such an approach would be inferior to the framework proposed here. In particular, the GDP price index is a value-added deflator, not an index of final goods prices, and hence not appropriate for anchoring the unit of account. Moreover, the GDP price index exhibits some counterintuitive properties, e.g., a fall in the price of imported fuel induces an increase in the GDP price index.

D. Monetary-Fiscal Interactions

The interest rate spread between CBDC and short-term government securities would generally be negligible, given the practically costless arbitrage between these two assets. Consequently, shifts in the size of the central bank's balance sheet would have no direct fiscal consequences. Furthermore, with the obsolescence of paper currency, the government would no longer receive any substantial seignorage revenue, and the central bank would simply cover its own expenses by imposing miniscule fees on payment transactions.

Moreover, the maturity composition of the stock of government securities held by the public would be determined by the fiscal authorities, *not* the central bank.[56] Indeed, that division of

[54] See Taylor (1999), Levin et al. (1999, 2003), and Levin et al. (2006).

[55] See Taylor (1985), Hall and Mankiw (1994), and Sumner (2011).

[56] See Greenwood et al. (2014).

responsibilities was the standard practice prior to 2008; since that time, a number of central banks—including the Federal Reserve, the Bank of England, the Bank of Japan, and the European Central Bank (ECB)—initiated large-scale purchases of government bonds to exert downward pressure on longer-term yields under circumstances in which conventional monetary policy was constrained by the effective lower bound on nominal interest rates.

Finally, it should be noted that while government spending and taxes can have a significant influence on wages and prices, it would be a grave error to task fiscal policy with stabilizing the price level over time. The prudent approach is for the central bank to maintain primary responsibility for this mission, while the fiscal authorities only become involved under extraordinary circumstances; this arrangement is broadly consistent with modern practice and echoes the conclusions of Simons (1936).

6. Conclusion

Central banks have generally been renowned as conservative institutions—staid, cautious, and inertial. For example, following the collapse of Bretton Woods and the "Great Inflation" of the 1970s, it took more than a decade before explicit inflation targets were instituted in a few small open economies; another decade had elapsed before the ECB clarified its inflation objective (*"close to but below 2 percent"*), and yet another decade until numerical inflation goals were finally adopted by the FOMC and by the Bank of Japan.[57] By contrast, in recent years many central banks have taken extraordinary lender-of-last-resort actions and have deployed a remarkable array of unconventional monetary policy tools.[58]

In this paper, we have found a compelling rationale for adopting CBDC as a practically costless medium of exchange, secure store of value, and stable unit of account. However, one crucial question is whether central banks should move expeditiously in considering its adoption. In particular, it might seem prudent to defer such consideration while monitoring developments in private payments and experiences of "early adopters" of CBDC, even if such a deferral involves foregone benefits. Nonetheless, policymakers should be aware of several salient risks of taking a relatively passive and inertial approach:

[57] Levin and Taylor (2013) examine how U.S. longer-term inflation expectations drifted upwards from 1965-80 in the absence of an explicit inflation goal. Bordo and Eichengreen (2013) analyze the links between the collapse of Bretton Woods and the onset of the Great Inflation. Bordo and Siklos (2017) consider the evolution of central banking practices and find that the typical pattern involves small open economies as pioneers and larger economies as later movers.

[58] See Borio and Zabai (2016) for a recent synopsis and discussion.

Macroeconomic instability. Suppose that paper currency becomes obsolete and the central bank does not produce any form of digital currency, so that all payments are made using privately-issued money (including virtual currencies). Under these assumptions, the recent analysis of Fernández-Villaverde and Sanches (2017) indicates that the economy may be subject to indeterminacy and that there may not be any equilibrium that exhibits stable prices. In contrast, their analysis finds that price stability *can* be assured by the issuance of CBDC in conjunction with an appropriate monetary policy framework. It should be emphasized that such concerns are not merely academic but have been flagged recently by central bankers. For example, Nicolaisen (2017) specifically warns about the risks associated with a scenario in which the Norwegian economy no longer has any functional legal tender.

Loss of monetary control. Suppose that paper currency becomes obsolete and that the monetary base solely comprises banks' reserves held at the central bank. Will the interest rate on reserves (IOR) stay tightly linked to market interest rates, so that the central bank can continue to adjust monetary conditions as appropriate? According to the textbook view of monetary operations, IOR provides a floor for the interbank lending rate, and with a sufficiently high degree of reserves, effectively pins down the level of market rates. However, that textbook view has been contradicted by recent U.S. experience, in which IOR has been persistently *higher* than the overnight interbank rate as well as the short-term Treasury bill rate. Indeed, concerns about potentially weak linkages between market rates and IOR played a key role in motivating the Federal Reserve's launching of its reverse repo facility in order to engage with a much wider set of counterparties. Of course, that logic naturally leads to the rationale for introducing an interest-bearing CBDC that can be held by anyone and that ensures the central bank's ability to manage market interest rates over time.

Systemic risks. Payments networks typically exhibit substantial externalities and increasing returns to scale. Thus, in the absence of competition from CBDC, the entire payment system might well become quasi-monopolistic. Under such circumstances, any significant operational problem within the payment network could pose substantial risks to the entire financial system and to the macroeconomy.

Susceptibility to severe downturns. Although a decade has passed since the onset of the global financial crisis, there should be no illusion that a similar shock could occur in coming years rather than being relegated to the distant future. Moreover, the "new normal" level of interest rates appears to be substantially lower than in the past. Thus, in the absence of an interest-bearing CBDC, the effective lower bound could pose an even tighter and more lasting constraint on conventional monetary policy, which would in turn limit the effectiveness of forward guidance (which seems most potent at horizons of a year or two)

and large-scale purchases of government securities (which are intended to push down longer-term yields). In such circumstances, the central bank of a small open economy might still be able to provide monetary stimulus via foreign exchange operations aimed at depreciating its currency, but such an approach could prove infeasible or untenable for larger economies. Alternatively, the central bank might provide stimulus through credit subsidies or by financing public infrastructure spending or income transfers to households, but the viability of such coordinated monetary-fiscal policy measures could be highly dependent on the vagaries of politics. Thus, in the absence of CBDC, the central bank might find itself with no real policy alternatives, i.e., "out of ammunition." In such circumstances, the severity of the economic downturn and sluggish recovery could be similar to what transpired in the 1930s rather than to the experience of the past decade.

In light of these considerations, a passive and inertial approach towards CBDC may *not* be the most prudent strategy. Rather, many central banks are now moving expeditiously in considering CBDC and in investigating its logistical and technical details. Indeed, since our paper started with a quotation from a classical jurist, it seems fitting to conclude by quoting from two modern experts, one of whom is a distinguished legal scholar:

"Central bankers throughout the world, from Canada to Ireland, have recently indicated that they might issue digital currency in the future. Yet the U.S. has been absent from the debate. As the world's central monetary power, America should play a leading role in studying the benefits and pitfalls of a digital-currency future....The march of digital commerce may eventually make the benefits seem overwhelming, and it would be wise to be ahead of the game rather than trying to catch up at the last minute."

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