# CENTRAL BANKING IN THE DIGITAL AGE: A NEW MONEY[1]

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E40, E51, E58

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Central bank, digital, currency, readiness, index.

*Abstract:*

Countries could issue their national digital currencies in the form of central bank digital currency (CBDC). This study examines the necessity of CBDC, benefits, technological and design aspects. I propose that CBDC is a subject of economic and technological solution and propose a “Digital Currency Readiness Index”. This novel composite index includes recent data on institutional, financial, economic and technological features to measure if a country is ready or not to adopt a digital money.

## 1. Introduction

Money has three primary functions; a unit of account which enables the measurement of value, a store of said value and a mechanism to exchange it. Throughout history, starting with barter, a system of exchange has evolved from proxies, such as seashells, precious metals and to fiat money. Today, value is exchanged through plethora of ways with physical cash, through text messages or over the internet. The advent of cryptocurrencies starting in 2010, and during the 2017 bubble, has ignited great interest in figuring out what the next form of value exchange will be for the 21st century.

The central banking practices are inescapable from technologies advances. Credit card companies offer methods applicable in online retail payments, but not all consumers have a credit card. However, such payment methods and deposit accounts face counterparty-risk (Berentsen and Schär, 2018). Today, cash is the only legal tender. Many advanced economies in the world have started shifting towards more cashless transactions and increasingly adopting electronic payment methods. Cash use in Sweden, for example, has declined for many years. Swedish retailers expect the decline will continue and the cost of accepting cash will become prohibitive, so

[1] *Тайлбар*: Энэхүү судалгааны ажлын цомхотгосон хувилбар нь Швейцарь улсын хоёр дахь том банк болох Credit Suisse банкны Судалгааны академийн 2018 оны “Цахим мөнгөний ирээдүй” сэдэвт эссэний уралдаанд оролцож, нийт 20 орноос ирүүлсэн 150 гаруй бүтээлээс шалгарч, шилдэг эхний 20-ын нэг болсон ажээ. Энэхүү судалгааг хийхдээ Швейцарь улсын Базелийн их сургуулийн доктор, профессор Александр Беренценгээс зөвлөгөө авсан байна.

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that it will no longer be accepted in the future (Ingves, 2018b). With payments shifting increasingly online, and with mobile devices, central banks must be proactive and figure out ways to cope with the developments.

In addition to trading on the sheer speculation for its usefulness in the future, cryptocurrencies have been partially performing the role for money where it failed. For example, countries with failed institutions and dysfunctional economies, such as Argentina or Venezuela, have seen increased usage of bitcoin (Casey, 2018). In March of 2019, Argentine's Deputy Minister of Finance claimed that promoting crypto industry will "help to reduce its demand for USD, which will eventually contribute to stabilizing the local market and attract global investment" (Partz, 2019).

If private cryptocurrencies (e.g., bitcoin) became widely adopted and displaced central bank money, there could be adverse implications for central bank monetary policy, financial stability and the ability of the central bank to collect seigniorage.[3] Societies with decreased cash usage could see the payment market dominated by private players without a public alternative. Fung et al. (2018) concludes that private digital currencies are not always safe without government intervention, a legislation will be needed for universal adoption and a central bank digital currency (CBDC) will not drive out private ones. Confidence and trust in a currency, and its stability, is provided by a trusted authority, the central bank. Therefore, I believe that there is a great demand and a strong case for central banks to issue a national-denominated electronic base money.

Central banks have been actively researching into this topic in recent years. This indicates there is pressure for central bank money to become more competitive due to the advent of private digital money (i.e., cryptocurrencies). A survey by the Bank of International Settlements (BIS) from 63 central banks, jurisdictions covering over 80 percent of world population, showed that 70 percent of the respondents are currently, or soon will be, engaged in CBDC work. However, for the short term, 85 percent of respondents are unlikely to issue any type of CBDC. Currently, there are 5 central banks who have started pilot projects. A notable example is the Sveriges Riksbank's "e-Krona" project started in 2017. The purpose of the project is to complement cash, as well as current electronic payments, with an electronic krona, as to eventually phase out from physical cash usage (Barontini and Holden, 2019).

## 2. Structure of Money

Central bank deposits such as deposits in reserve accounts are already digital. Nonetheless, they are not categorized as CBDC. To understand how CBDC is different from existing electronic money and cryptocurrencies, it is useful to characterize money according to a control structure (Figure 1) suggested by Berentsen and Schär

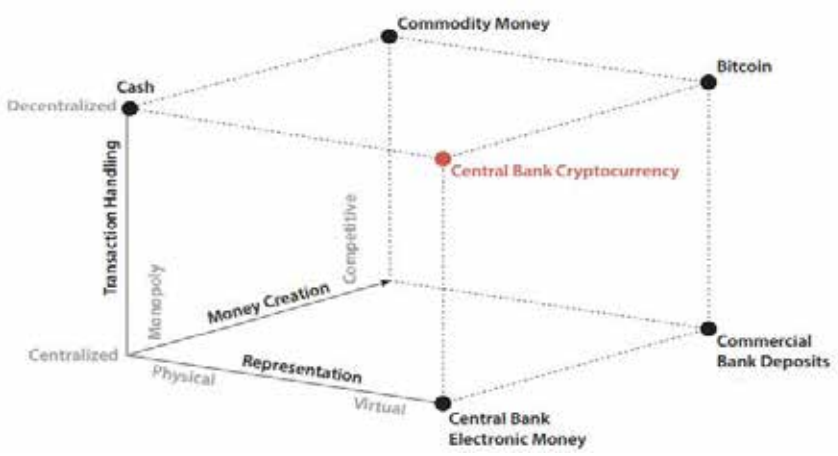
[3] However, according to Bank of Canada (2017), preserving seigniorage does not appear to provide a compelling motivation to issue a CBDC in many advanced economies.

(2018). There are three dimensions. The first dimension is representation. Money can be represented in virtual form or physical form. The second dimension is transaction handling, either through centralized or decentralized payment systems. Finally, the third dimension is money creation. Some monies are created by a monopoly, while others are issued under competition.

The ownership rights to cash, circulating freely in the economy, are always clearly defined without anyone having to keep records. It is a decentralized payment system where cash can change hands between two agents without the involvement of a third party. Commercial bank deposits are electronic money. When a payment is made, the accounts are adjusted by deducting the payment amount from the buyer and crediting it to the seller. The creation of money in the form of commercial bank deposits is competitive because they compete for deposits with their rates. The most of central bank money is already electronic. In most countries, public access to electronic central bank money is restricted. In Mongolia, for example, it can be held only by financial intermediaries.

*Figure 1*

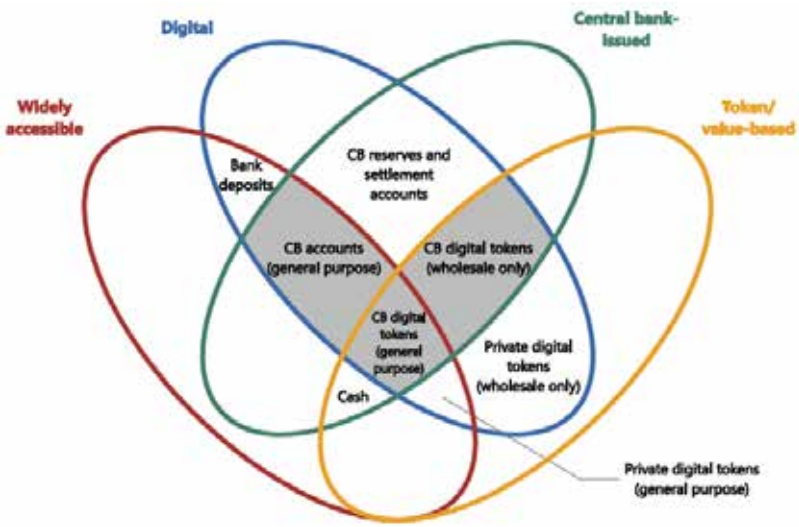
Control Structure of Money




*Source*: Berentsen and Schär (2018)

*Figure 2*

Taxonomy of Money




*Source:* Barontini and Holden (2019)

Barontini and Holden (2019) discuss different variants of CBDC highlighted by the shaded areas within the Figure 2. CBDC, basically, could be divided into "general purpose" or "wholesale only" variants. The "general purpose" variant would allow the general public to hold an account at a central bank. This would be widely available and targeted at retail transactions. The "wholesale" version would be a restricted digital token for wholesale settlements, such as interbank payments or securities settlements.

## 3. Benefits of CBDC

For monetary policy and macroeconomic effect, setting a stock of CBDC equal to 30 percent of the GDP leads to a permanent 3 percent increase in the real GDP (Barrdear and Kumhof, 2016). If CBDC is supplied through national-wide electronic wallets, nominal zero lower bound would no longer apply, which will allow a central bank to employ a negative nominal interest rate. This has wide-ranging effects during times of financial crises. This is impossible in an economy with heavy cash usage. Another unconventional monetary tool enabled by CBDC is 'helicopter drops' of money. Supplying money into the economy, with CBDC, quickly and efficiently is important in situations of weak economic activity or incoming crises. This reduces deflationary risks by circumnavigating the use of traditional monetary policy designed for physical cash-based economy (Prasad, 2018).

The adoption of CBDC means the government will have to play a larger role in payments market. Setting up payment infrastructure that facilitates CBDC would

create a positive externality, like how the first telephone lines were introduced and benefitted the society greatly. When the first telephone line was installed, it was not the most useful, as there would be no one to call. However, as more people utilize the line and connect to the telephone network, the value of having the phone increases. The same can be said for payment markets. Just like the telephone lines, the value of a payment system proportionally increases with the number of people using it. Payments can also be regarded as collective utilities (Ingves, 2018b).

CBDC improves financial stability in the economy and leads to better contestability, efficiency in payment systems and reduced transaction cost (Bank of Canada, 2017; Prasad, 2018). According to the BIS survey, the most important reason for central banks to consider issuing CBDC is improved payment safety and efficiency. And the least important reasons are financial inclusion and cross-border payments efficiency (Barontini and Holden, 2019).

Among many positive impacts CBDC would have on the financial stability, it seems that increased usage of local currency would be important to many emerging economies. If central bank money no longer defines the unit of account and replaced by crypto assets, then the central bank’s monetary policy becomes irrelevant. Dollarization is an analogy; it is when a large part of the domestic financial system operates with a foreign currency (He, 2018). Similar scenario plays out with cryptocurrencies in economies with severely devalued local currencies.[4] This has been aptly termed ‘dollarization 2.0’ by Christine Lagarde (2017). I expect that CBDC, if interest-bearing, would be able to alleviate dollarization and dollarization 2.0 by making the local currency more attractive.

## 4. Design Features of CBDC

CBDC refers to wide ranging potentials designs and policy choices, but with no single commonly accepted definition. CBDC is not a cryptocurrency and it does not necessarily have to be implemented with ‘distributed ledger technology’ (DLT). The primary design principle for CBDC is that it is:

- electronic,
- universally accessible for 24/7,
- supplement to existing cash,
- denominated in the sovereign currency,
- legal tender and liability of a central bank,
- reserves, banknotes and CBDC have one-to-one convertibility,
- potentially be interest-bearing; under realistic assumptions paying a rate that would be different to the rate on reserves. This characteristic makes CBDC an option secondary monetary policy tool. The rate will be the lowest in the economy because CBDC will be the most-liquid asset and

[4] Increased usage of bitcoin in Argentina is one example (Casey, 2018).

holders do not face counterparty risk since a central bank cannot become illiquid (Berentsen & Schär, 2018),
- There could be two versions; retail and wholesale,
- The central bank supplies CBDC according to demand and it is perfectly elastic.

An interest-bearing CBDC might pay positive, zero or negative rates. Interest rate on CBDC could be utilized as an instrument of monetary policy, or it could be used to regulate demand for CBDC. Alternatively, a non-interest-bearing CBDC could be considered closer in essence to central bank cash (Meaning et al., 2018). If the objective is to create a form of CBDC that resembles cash, the key characteristics are anonymity and DLT. However, as I will discuss in the next section, DLT and anonymity are not suitable for CBDC.

There could be two versions of CBDC; retail CBDC for household and non-financial businesses only and a wholesale CBDC which can be used as a settlement asset in financial markets by firms that do not currently have access to central bank reserves (Meaning et al., 2018). The central bank could allow households and firms to open accounts with them. It is technologically feasible for many central banks to set up electronic deposit accounts for all of country's residents. Or central banks could require commercial banks to open a central bank account for their customers. Presumably, these accounts would not normally be interest bearing and would be used for payments rather than as a channel for financial intermediation by the central bank (Prasad, 2018).

## 5. Technological Aspects

I consider both decentralized and centralized methods to implement CBDC. It is not the case that current centralized inter-bank payment systems are inefficient. Decentralized systems are being considered, because it can add functionality to payment platforms (Heun, 2018). Trust is the foundation of the financial system, and it can be fragile. Bitcoin was designed to replace that trust with verification, accomplished quite innovatively using 'proof-of-work' mechanism. However, the ecosystem in which CBDC could exist demands of at least one trusted authority (Scorer, 2017). That means the core features of Bitcoin, or any altcoin, would be unnecessary. The fundamental idea of DLT is that, for a reward, a group of validators reach a consensus in order to decide which transaction should be recorded.

A 'permission-less' DLT, used in Bitcoin, is one in which anyone can act as a validator, at any time, without establishing credentials. This process could be manipulated with the '51 percent attack', for instance. In order to prevent this, heavy investment in processing power by Bitcoin miners have been made and, consequently, the system requires enormous amounts of energy to operate (Scorer, 2017). The Economist (2018) has reported that the global power consumption for Bitcoin network

is at least 2.55 gigawatts – almost the same as the entire country of Ireland. This is a weakness of a public blockchain model. The cost of the ‘proof-of-work’ needed to update the blockchain requires a vast amount of hardware and electricity resources.

One of the biggest blockchain platforms, Ethereum was hacked in May 2016. When the hacker took around USD 50 million worth of Ethereum currency from ‘decentralized autonomous organization’, the community decided to erase the history of the network up until the hacking. This resulted in a fork of Ethereum and raised serious concerns over its governance. The failure of cryptocurrency communities to reach a consensus on a technical strategy for growth and frequent hacking are fatal flaws of privately-issued digital currencies (Yermack, 2017).

The value of fiat currencies is maintained by monetary policy and their status as legal tender, while the value of crypto assets rests on the expectation that others will also value and use them. A recent report by IMF (2018a) confirms that privately issued cryptocurrencies do not currently satisfy the essential functions of money and have high price volatility. CBDC should not be permission-less cryptocurrency. The reason is because there is reputational risk for central banks. It would be undesirable if a central bank issued cryptocurrency and it was used for criminal purposes. It is irrational for central banks to require commercial banks to follow ‘know your customer’ (KYC) and ‘anti-money laundering’ (AML) regulations, if central bank itself issues anonymous and permission-less digital money (Berentsen & Schär, 2018).

If a form of DLT were to be used to implement CBDC, that could be a ‘permissioned’ system, where the validators are known and authorized. A costly ‘proof-of-work’ mechanism would not be needed, and simpler consensus mechanisms could be employed. This scheme offers advantages in governance, security and privacy while potentially complying with KYC and AML regulations. DLT provides a high level of resilience that avoids a single point of failure and a potential to make the payment systems more efficient and cheaper. Furthermore, DLT has scaling capabilities, which would be crucial for any widely available CBDC, if it issued through electronic wallet for the entire population.

However, it appears that the net benefit operating distributed ledger for payment systems instead of a centralized system is not evident enough yet, while there is a payment system that works perfectly fine (Heun, 2018). Existing centralized systems can achieve high levels of resilience by operating multiple backups. Implementing CBDC with existing technology is feasible (Berentsen & Schär, 2018; Meaning et al., 2018).

On the other hand, if everyone makes payments with CBDC, the volume of transactions compared to the current RTGS systems would increase dramatically (Scorer, 2017). Central banks may not want to expand their computing or operational capacity to cope with this. DLT will allow multiple firms to provide this computing

capacity on demand and could enable the central bank to set the rules of a CBDC, without the requirement to operate the entire infrastructure. Nevertheless, if CBDC is implemented through a centralized system, the central bank can create a standard for digital currency in which the private sector would be responsible for creating the storage and transaction applications.

## 7. Digital Currency Readiness Index

To analyze levels of readiness of countries for CBDC, I propose Digital Currency Readiness Index (DCRI).[5] The index defines readiness as country's level of development with respect to institutional, financial, technological and economic factors that support CBDC. Depending on each country's readiness, I clustered them into 3 group levels.[6]

### 7.1. Methodology

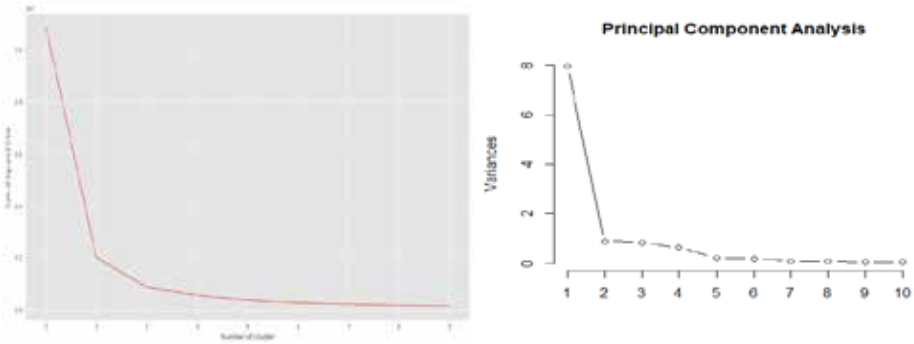
The composite index comprises of 11 individual indicators.[7] Firstly, the indicators are normalized into z-scores. Then, outliers and countries with more than 3 missing values have been taken out of the dataset. Missing data for some indicators has been approximated by the average of countries with similar features. I used Principal Component Analysis (PCA)[8] to weigh the results and chose the first component (Figure 3, right) as the index score, which was then rescaled between 0 and 1.

Grouping of countries, based on their ranking, is needed to determine understand readiness in a context. I have applied K-Means Clustering Algorithm on the 11 indicators after transforming them with PCA. The number of clusters has been experimentally determined by the 'elbow method' (Figure 3, left), where it shows after how many clusters the marginal variance plateaus and becomes insignificant to add more cluster centers. As a result, the clustering analysis identified 3 groups of countries; Group Level 1, Group Level 2 and Group Level 3.

[5] See Appendix Figure 6 for the full Digital Currency Readiness Index.
[6] See Appendix Table 3 for more detail on how countries are grouped.
[7] See Appendix Table 1 and 2 for description of each indicators and correlations.
[8] See Appendix Table 4 for PCA Variance table.

*Figure 3*

K-Means Clustering Sum of Squared Error for Differing Numbers of Clusters (Left), and Variance of Principal Components (Right)




*Source*: Author

### 7.2. The future is already here – it's just not evenly distributed

The index scores hint at what reforms are required for countries to adopt CBDC. The policy consideration for countries in Group Level 1 is, they are ready to start with experimentations and pilot projects. Group Level 2 shows signs of going cashless, improving ICT infrastructure and crypto-assets regulations. Although Level 2 economies can adopt CBDC now, solutions would be limited. Group Level 3 needs more investment in financial, technological and institutional framework. Economies in this cluster still heavily use cash, have tendency to ban or uphold light oversight over crypto-assets, lack ICT affordability and need to strengthen their institutions and financial markets. These group levels point to a need for policy to be flexible and tailored to developments by each individual country. Policy recommendations can be further made by examining an individual country's position among countries in the same readiness group level or similar index score and countries in the next level of readiness or higher index score to help identify where policy is the most likely to have the most beneficial effects.

### 7.3. Robustness

To test for robustness, I compared DCRI with MasterCard Cashless Index (MCI) and Digital Evolution Index (DEI). The correlation with MCI is 0.95, which indicates relationship between cashless-ness and adoption of digital money. The correlation with DEI is 0.93. This signals association between CBDC readiness and digital economy progress. These correlations closely match the robustness of 'Digital Money Readiness Index' constructed by Thomas et al. (2014) which conceptualized digital money as socio-technical system. The main distinction between the index of Thomas et al. and DCRI is, DCRI focuses more on the roles crypto-assets and financial inclusiveness play in adoption of digital currencies, specifically CBDC.

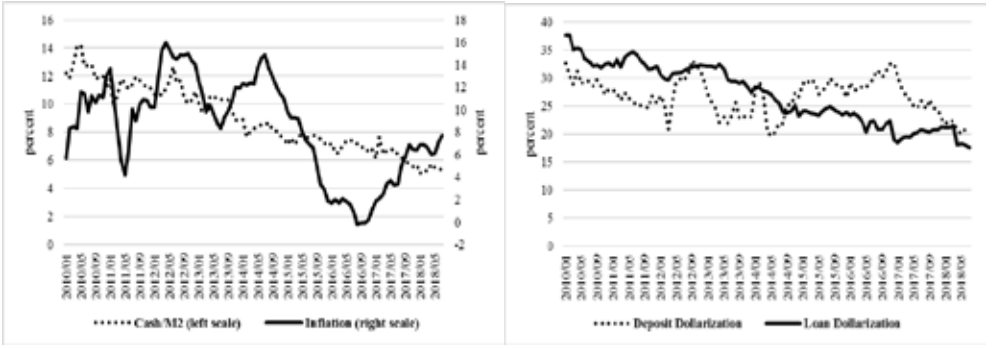
## 8. A Case for Mongolia

From 2010 to 2018, the ratio of cash to the monetary aggregate M2 fell from 12.22 percent to 5.33 percent. The deposit dollarization rate decreased from 32.62 percent to 21.54 percent and the loan dollarization rate decreased from 37.65 percent to 17.66 percent decreased, respectively (Figure 4). In 2012 and 2014, when inflation was high, devaluing the local currency, we observe spikes in dollarization rates. Nevertheless, there has been a steady decline for both cash in circulation and dollarization in the economy.

According to the World Bank (2017) survey on financial inclusiveness, the percentage of respondents in Mongolia who made or received digital payments in 2016 was 85.27 percent, which is 23.44 percent above the global mean. While the volume of transaction made through POS (Point of Sale) machines was 256.1 billion Togrogs in 2013, it was 1664.6 billion Togrogs in 2018 (Figure 5). This is a rapid advance in people's payment behavior. Mongolian society is becoming progressively cashless.

*Figure 4*

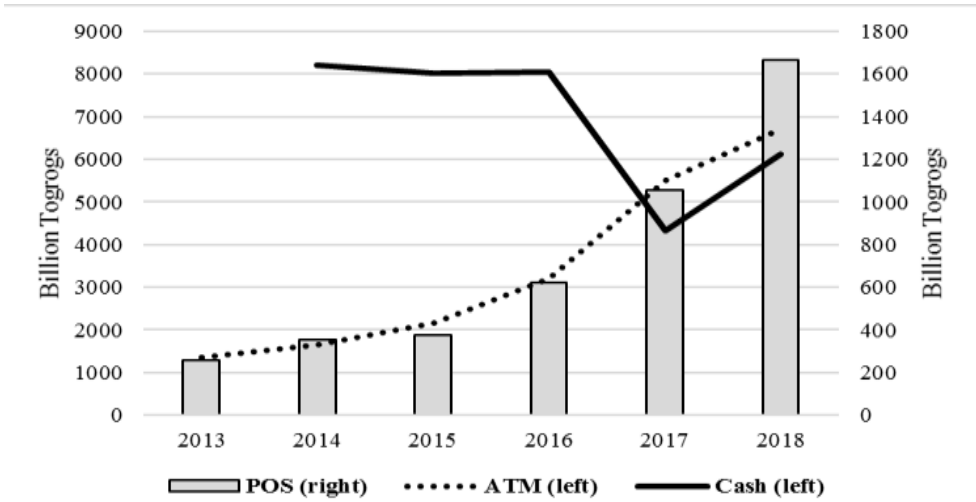
Inflation Rate and Cash in Circulation as a Fraction of M2 Money Supply (Left), and Dollarization Rate (Right) in Mongolia




*Source:* Bank of Mongolia

*Figure 5*

Transaction Volume by Methods of Payment




*Source:* Bank of Mongolia

In 2018, Bank of Mongolia issued a regulation on electronic currency. It states that electronic money does not include cryptocurrencies, should be backed by fiat money, maintain one-to-one convertibility and could be transacted with willing third parties. After this, a major advancement regarding digital currency was when the Bank of Mongolia granted Mobicom a license to issue its own digital currency in accordance with the regulation (Suberg, 2018). The currency is called ‘Candy’, succeeds its previous version which existed as a token on Ethereum, and could be used for various goods and services.

The Central Bank of Uruguay (CBU) has concluded a 6-month pilot program on CBDC in 2018 and currently in evaluation stage. Starting in 2017, the CBU issued and circulated 20 million e-Pesos, without using DLT. Of those 20 million, 7 million e-Pesos were distributed via third party payment system providers, who placed equivalent amount of real pesos in a central bank account. Storage, management, control of circulation and call center was managed by IBM. Management of users, transfers and transactions were handled by IN Switch Solutions, Inc. Like how it was discussed in Section 6, the CBU made the private sector responsible for matters other than issuing and regulating CBDC. Transactions of e-Pesos were instant and peer-to-peer, via mobile phones using either text messages or the e-Peso app. After the pilot program was concluded, all e-Pesos were cancelled and turned into real pesos (Barontini and Holden, 2019).

*Table 1*

Comparison of Mongolia and Uruguay in terms of DCRI Indicators

| Indicators | Mongolia | Uruguay |
|---|---|---|
| Digital Currency Readiness Index (0-1) | 0.39 | 0.46 |
| Regulatory Quality (0-100) | 50.96 | 73.56 |
| Rule of Law (0-100) | 41.83 | 72.12 |
| Government Effectiveness (0-100) | 42.31 | 67.79 |
| Number of Bitcoin Nodes | 0 | 4 |
| Networked Readiness Index (1-7) | 4.3 | 4.5 |
| Global Competetiveness Index (1-7) | 3.90 | 4.15 |
| Global Innovation Index (0-100) | 35.90 | 34.20 |
| Crypto-Asset Regulation (1-4) | 3 | 4 |
| Made or received digital payments in 2016 (% of respondents age 15+) | 85.27 | 59.34 |
| Used a mobile phone or the internet to access a bank account in 2017 (% of respondents age 15+) | 38.38 | 15.76 |
| Used a debit or credit card to make a purchase in 2016 (% of respondents age 15+) | 60.81 | 50.56 |

*Source:* See Appendix Table 2

Mongolia is in the Group Level 3 with readiness score 0.39, together with Uruguay with score 0.46. Both countries have some similarities in terms of its economic, financial and readiness indicators. Uruguay has a long history of dollarization. Between 2001 and 2017, credit dollarization in Uruguay averaged 57 percent, while deposit dollarization averaged 78 percent. The data from 2017 shows a slight dip in both credit and deposit dollarization—to 52 percent and 75 percent, respectively (IMF, 2018b). Uruguay has policy interest rate at 9.25 percent, while Mongolia has it at 11 percent as of April 2019. Both countries' inflation rate is around 7 percent as of February 2019. In terms of digital payment integration and financial inclusion, Mongolia has higher percentage than Uruguay does (Table 1). However, Mongolia scored lower for institutional and government effectiveness.

Mongolia is gradually progressing towards more advanced payment systems and decreased cash usage. As mentioned in previous sections, CBDC could be utilized as a secondary monetary tool, used to ease inflation, and would incentivize people to hold onto local currency, if it was interest-bearing, thus potentially decrease dollarization. As we can see from the above data[9] and the example of Uruguay, there is a compelling case for the Bank of Mongolia and affiliated institutions to conduct preliminary research and start thinking of experiments on issuing CBDC. As it was done with the 'e-Peso' project, the Bank of Mongolia's potential pilot project, say

[9] Figure 4, Figure 5 and Table 1.

‘e-Togrog’, could be implemented with centralized systems and in cooperation with local telecom, IT and payment solutions providers.

## 9. Further Regulatory Considerations

There are many questions to be addressed still. One is to determine if CBDC is only for residents or if non-residents also can hold, which have implications on exchange rate and capital flows. A potential solution is to limit central bank's role in money creation with respect to balance sheet and debt relationships. Plus, it is necessary to first test CBDC for a group of users and limit the amount of money held in CBDC accounts, to prevent bank runs (Berentsen & Schär, 2018). Another approach is to establish regulatory ‘sandboxes’ where new financial technologies can be tested in supervised environment (He, 2018). It is essential to note that introduction of CBDC could be complicated political process. It took 24 years before the Sveriges Riksbank was given monopoly over note issuance (Fung et al., 2018).

## 10. Conclusion

The approach to CBDC is a combination of economic, financial, legal and technological developments. This essay measured systemic readiness of countries for CBDC using a composite index. It appears there is connection between cashlessness, technological advances and digital currency readiness. Through closer examination, CBDC could be centralized in creation and transaction. Central banks could open accounts for the population or could mandate commercial banks to do so. If CBDC is interest-bearing, it could be used as secondary monetary policy tool.

A monetary system with CBDC has never existed anywhere. There is little historical or empirical evidence that could show the consequences of CBDC. Central banks have been actively researching into CBDC in recent years. Countries and central banks should be proactive in approaching CBDC and aware of the risks. There are ample use-cases and demand for CBDC in digital era. It is stable and bears no counterparty risk. Confidence in currency, and its stability, can only be provided by central banks. Therefore, central banks must remain relevant by providing more stable units of account than crypto-assets and making central bank money attractive in the digital economy.

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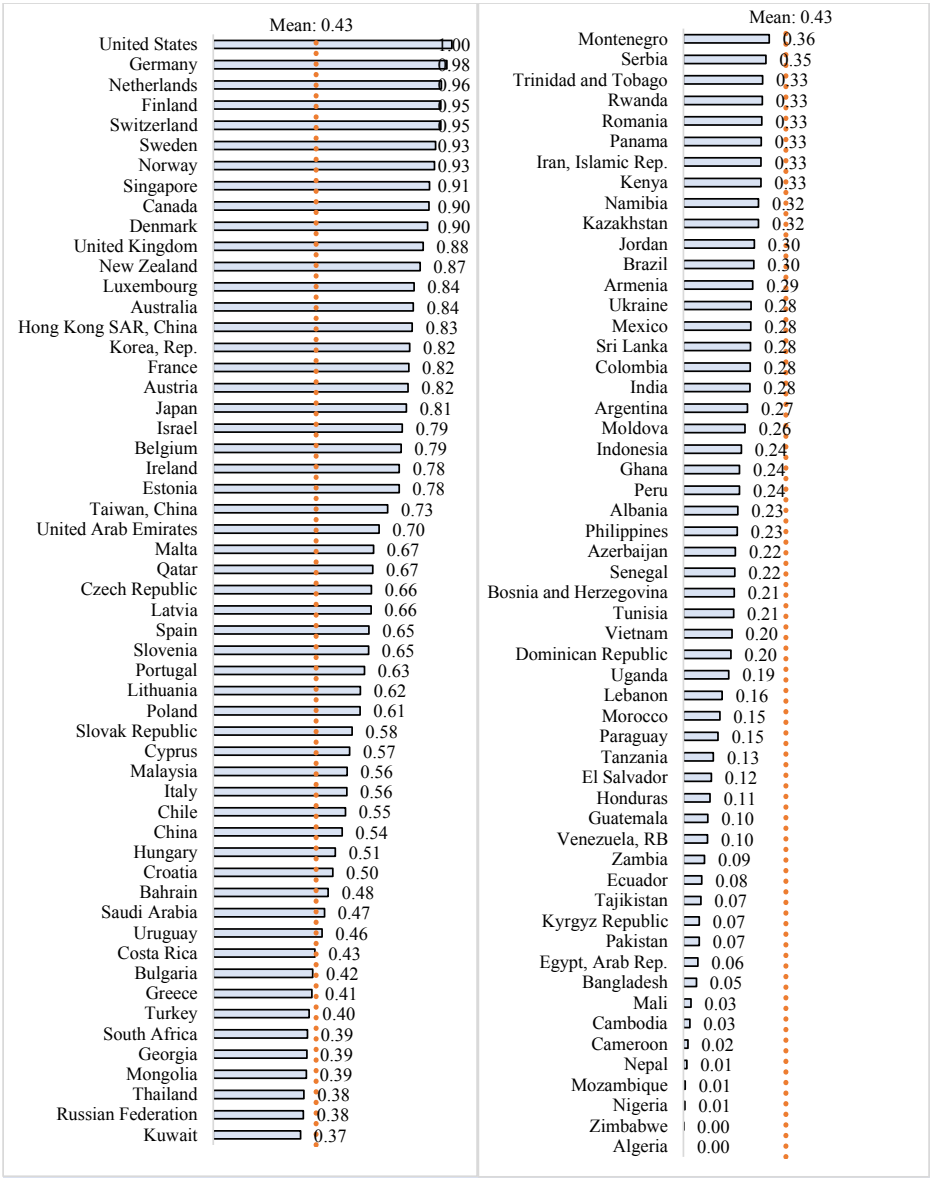
## Appendix

*Figure 6*

The Digital Currency Readiness Index (Scale: 0-1)




*Source:* Author

*Source:* Author

*Table 2*

Detailed explanations for each of the 11 indicators integrated into the Digital Currency Readiness Index

| Indicators | Source | Detail |
|---|---|---|
| **Regulatory Quality (scale: 0-100)** | Worldwide Governance Indicators, 2018; released by The World Bank (URL: http://info.worldbank.org/governance/wgi/#home) | Reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. |
| **Rule of Law (scale: 0-100)** | | Reflects perceptions of the extent to which agents have confidence in and abide by the rules of society, and the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. |
| **Government Effectiveness (scale: 0-100)** | | Reflects perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. |
| **Number of Bitcoin Nodes** | 10,106 nodes as of November 11th, 2018 (URL: https://bitnodes.earn.com/) | The estimated size of the Bitcoin network is counted by finding all the reachable nodes by IP addresses in the network. This is data is integrated into the composite index because it is important to see a country's activity on crypto and how that could relate to the broader adoption of digital currency. |
| **Networked Readiness Index (scale: 1-7)** | Global Information Technology Report 2016; released by World Economic Forum (URL: http://www3.weforum.org/docs/GITR2016/WEF_GITR_Full_Report.pdf) | The Index, total of 53 individual indicators, measures the capacity of countries to leverage ICTs for increased competitiveness and well-being. It rests on six principles: 1) a high-quality regulatory business environment is critical in order to fully leverage ICTs and generate impact; 2) ICT readiness – as measured by ICT affordability, skills and infrastructure – is pre-condition to generating impact; 3) fully leveraging ICTs requires a society-wide effort: the government, the business sector, and the population at large each have a critical role to play; (4) ICT use should not be an end in itself. The impact that ICTs have on the economy and society is what ultimately matters; (5) the set of drivers—the environment, readiness, and usage—interact, co-evolve, and reinforce each other to form a virtuous cycle; and (6) the networked readiness framework should provide clear policy guidance. |

| | | |
|---|---|---|
| **Global Competitiveness Index (scale: 1-7)** | Global Competitiveness Report 2017-2018; released by World Economic Forum (URL: http://www3.weforum.org/docs/GCR2017-2018/05FullReport/TheGlobalCompetitivenessReport2017%E2%80%932018.pdf) | Tracks the performance of close to 140 countries on 12 pillars of competitiveness. It assesses the factors and institutions identified by empirical and theoretical research as determining improvements in productivity, which in turn is the main determinant of long-term growth and an essential factor in economic growth and prosperity. The Global Competitiveness Index consists of 3 main sub-indexes: basic requirements, efficiency enhancers and innovation and sophistication. |
| **Global Innovation Index (scale: 0-100)** | Global Innovation Index 2018; released by Cornell University, INSEAD, World Intellectual Property Organization (URL: http://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2018.pdf) | Measures a nation's capacity and success in innovation. It is comprised of 80 indicators and 7 main pillars: institutions, human capital and research, infrastructure, market sophistication, business sophistication, knowledge and technology outputs and creative outputs. |
| **Crypto-Asset Regulation (scale: 1-4)** | Regulation of Cryptocurrency Around the World, June 2018; released by the United States Law Library of Congress (URL: https://www.loc.gov/law/help/cryptocurrency/cryptocurrency-world-survey.pdf) | This is a qualitative report that surveyed the legal and policy landscapes surrounding cryptocurrencies in 130 countries. The scoring of each country based on the regulation as follows: banned - 1, quasi-illegal - 2, little oversight/unregulated - 3, government oversight/regulated - 4. The more attention and legal framework there are to facilitate crypto usage, the higher the score. |
| **Made or received digital payments in 2016** | The Global Findex Database 2017; released by The World Bank (URL: https://globalfindex.worldbank.org/) | Measures the percentage of all the survey respondents above the age of 15, whether if they have made or received digital payments in 2016. This implicitly determines how much a country already adopted the digital payment systems. |
| **Used a mobile phone or the internet to access an account in 2017** | | Measures the percentage of all the survey respondents above the age of 15, whether if they used a mobile phone or the internet to access an account in 2017. This measure of financial inclusiveness is important for the composite index, because in order to have central bank money for all, the population needs digital access to their bank accounts. |
| **Used a debit or credit card to make a purchase in 2016** | | Measures the percentage of all the survey respondents above the age of 15, whether if they used debit and credit card to make a retail purchase in 2016. This, in a way, indicates how much a country has progressed towards going cashless |

*Source:* Author

*Table 3*

Correlation Table for 11 Individual Indicators

| PCA Weight | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -0.3238 | 1. | **Regulatory Quality** | 1 | | | | | | | | | | |
| -0.3322 | 2. | **Rule of Law** | 0.9219 | 1 | | | | | | | | | |
| -0.3383 | 3. | **Government Effectiveness** | 0.9266 | 0.9485 | 1 | | | | | | | | |
| -0.1455 | 4. | **Number of Bitcoin Nodes** | 0.2797 | 0.2860 | 0.3127 | 1 | | | | | | | |
| -0.3404 | 5. | **Networked Readiness Index** | 0.8880 | 0.8919 | 0.9262 | 0.3577 | 1 | | | | | | |
| -0.3233 | 6. | **Global Competitiveness Index** | 0.8230 | 0.8318 | 0.8904 | 0.4321 | 0.9310 | 1 | | | | | |
| -0.3375 | 7. | **Global Innovation Index** | 0.8541 | 0.8675 | 0.8965 | 0.4122 | 0.9152 | 0.8983 | 1 | | | | |
| -0.1613 | 8. | **Crypto-Asset Regulation** | 0.4383 | 0.3667 | 0.4130 | 0.1617 | 0.3984 | 0.3413 | 0.4013 | 1 | | | |
| -0.3188 | 9. | **Made or received digital payments in 2016** | 0.7432 | 0.7976 | 0.8036 | 0.2944 | 0.8147 | 0.7176 | 0.8255 | 0.3639 | 1 | | |
| -0.2833 | 10. | **Used a mobile phone or the internet to access an account in 2017** | 0.6130 | 0.7046 | 0.6671 | 0.3266 | 0.6938 | 0.6390 | 0.7175 | 0.2798 | 0.8444 | 1 | |
| -0.3269 | 11. | **Used a debit or credit card to make a purchase in 2016** | 0.7657 | 0.8185 | 0.8296 | 0.3237 | 0.8700 | 0.7748 | 0.8639 | 0.3555 | 0.9401 | 0.8028 | 1 |

*Source:* Author

*Table 3*

Countries grouped by their levels of Digital Currency Readiness

| Levels of Readiness | Countries |
|---|---|
| **Level 1** – Materially ready countries with ample ICT solutions and facilitating financial regulations. With existing technologies and regulations, these countries are ready to adopt CBDC. | United States, Germany, Netherlands, Singapore, Canada, United Kingdom, France, China, Russian Federation |
| **Level 2** – These economies are in transition or almost ready to implement national digital currency systems. The countries are going cashless and technological infrastructure is emerging or already exist. | Finland, Switzerland, Sweden, Norway, Denmark, New Zealand, Luxembourg, Australia, Hong Kong SAR China, Republic of Korea, Austria, Japan, Israel, Belgium, Ireland, Estonia, Taiwan (China), United Arab Emirates, Malta, Qatar, Czech Republic, Latvia, Spain, Slovenia, Portugal, Lithuania, Poland, Slovak Republic, Cyprus, Malaysia, Italy, Chile, Hungary, Croatia |
| **Level 3** – Characterized by lack of ICT infrastructure and limited financial services. In this level, cash still plays a big role in the economy, cashless payment systems are still being adopted and developed, with varying degree of attitudes towards privately-issued cryptocurrencies and the country’s overall technological innovation is incipient. These countries still need further improvements in technological, financial and legal framework. In countries with weak government institutions and unstable financial systems, private cryptocurrency may be more attractive and there are risks of AML/CFT. | Bahrain, Saudi Arabia, Uruguay, Costa Rica, Bulgaria, Greece, Turkey, South Africa, Georgia, Mongolia, Thailand, Kuwait, Montenegro, Serbia, Trinidad and Tobago, Rwanda, Romania, Panama, Iran, Kenya, Namibia, Kazakhstan, Jordan, Brazil, Armenia, Ukraine, Mexico, Sri Lanka, Colombia, India, Argentina, Moldova, Indonesia, Ghana, Peru, Albania, Philippines, Azerbaijan, Senegal, Bosnia and Herzegovina, Tunisia, Vietnam, Dominican Republic, Uganda, Lebanon, Morocco, Paraguay, Tanzania, El Salvador, Honduras, Guatemala, Venezuela, Zambia, Ecuador, Tajikistan, Kyrgyz Republic, Pakistan, Egypt, Bangladesh, Mali, Cambodia, Cameroon, Nepal, Mozambique, Zimbabwe, Algeria, Nigeria |

*Source:* Author

*Table 4*

PCA Standard Deviation and Variance Table

| Components | Standard Deviation | Proportion of Variance | Cumulative Proportion |
|---|---|---|---|
| PC1 | 2.818568 | 0.722200 | 0.722200 |
| PC2 | 0.944122 | 0.081030 | 0.803240 |
| PC3 | 0.913309 | 0.075830 | 0.879080 |
| PC4 | 0.794848 | 0.057430 | 0.936510 |
| PC5 | 0.469250 | 0.020020 | 0.956530 |
| PC6 | 0.430479 | 0.016850 | 0.973370 |
| PC7 | 0.301025 | 0.008240 | 0.981610 |
| PC8 | 0.273438 | 0.006800 | 0.988400 |
| PC9 | 0.240378 | 0.005250 | 0.993660 |
| PC10 | 0.191948 | 0.003350 | 0.997010 |
| PC11 | 0.181312 | 0.002990 | 1.000000 |

*Source*: Author