

T.R.
ISTANBUL UNIVERSITY
INSTITUTE FOR GRADUATE STUDIES IN SOCIAL SCIENCES
DEPARTMENT OF ECONOMICS (ENGLISH)

MASTER OF ARTS IN ECONOMICS

**TRANSFORMATION OF BANKING: NEGATIVE
INTEREST RATES AND CENTRAL BANK
DIGITAL CURRENCY DESIGN PRINCIPLES
AND IMPLICATIONS**

Muhammet DOĞAN

2504180007

THESIS ADVISOR

Assist. Prof. GÖKHAN ÖVENÇ

ISTANBUL – 2020

ABSTRACT
TRANSFORMATION OF BANKING: NEGATIVE INTEREST RATES AND
CENTRAL BANK DIGITAL CURRENCY DESIGN PRINCIPLES AND
IMPLICATIONS
MUHAMMET DOĞAN

This thesis argues the feasibility of phasing out paper currency, not entirely but mostly, to provide a solution to the lower bound of nominal interest rates. The study also attempts to shed light on possible expansion in monetary policy tools by eliminating the zero lower bound of nominal interest rates. Thus, it suggests a substitution, not entirely, of paper currency, which is a digital currency, belongs to a central bank. The main benefits and challenges regarding the CBDC will be briefly discussed. This thesis's scope to analyze the CBDC, whether it can be displaced bank deposits and cause runs from bank deposits to CBDC.

Four design principles have stated for a monetary system that includes CBDC and possible solutions regarding the digital bank run. According to the principles, (I) CBDC should bear interest, adjustably. (II) CBDC and reserves should be separated and not directly convertible. (III) There should be no guarantee for the convertibility of deposits to CBDC. (IV) CBDC should only be issued for eligible securities.

This study intended to serve as useful background material for both negative interest rate policies and the central bank digital currencies. Regarding the bank runs with the introduction of the CBDC, although the policies' effectiveness will depend on the design, the design principles are essential. In particular, the central bank should control CBDC with either a price rule or the quantity rule to have an effective mechanism to meet the demands in a time of need.

In order to argue CBDC's potential impact, it is necessary, to begin with, an explicit designation of the real-world example of a CBDC and how it might operate. Since the system naturally enables to impose negative interest rates on the central bank's liability, the works first propose a CTC ratio to handle the cash demand elastically against bank deposits and CBDC. After the separation of the money's roles, cash will be a less preferred form of the central bank money since the CBDC will be the new legal tender. The study discusses how central banks could design and operate such a system and raise some unanswered questions regarding the system.

Keywords: Central Bank Digital Currencies, Negative Interest Rate Policy, Unconventional Monetary Policies, Blockchain, Future of Money

ÖZ

BANKACILIĞIN DÖNÜŞÜMÜ: NEGATİF FAİZ ORANLARI VE MERKEZ BANKASI DİJİTAL PARA BİRİMİ TASARIM İLKELERİ VE ÖNERİLERİ **MUHAMMET DOĞAN**

Bu tez, nominal faiz oranlarının alt sınırına bir çözüm sağlamak için kağıt paranın tamamen değil, ancak yüksek nominal değerlilerinin aşamalı olarak kaldırılmasının uygulanabilirliğini tartışmaktadır.

Çalışma aynı zamanda nominal faiz oranlarının sıfır alt sınırını ortadan kaldırarak para politikası araçlarındaki olası genişlemeye de ışık tutmaya çalışmaktadır. Bu nedenle, kağıt paranın tamamen değil kısmen de olsa, bir merkez bankasına ait bir dijital para birimi (MBDP) ile değiştirilmesini önermektedir ve MBDP ile ilgili temel faydalar ve zorluklar kısaca tartışılacaktır. Bu tez, MBDP'nin banka mevduatlarının yerini alıp alamayacağını ve banka mevduatlarından MBDP'ne geçişlere neden olup olmayacağını analiz etmeyi hedeflemektedir.

MBDP'nı ve MBDP'nin sebep olabileceği olası banka hucümları ile ilgili olası çözümleri içeren bir para sistemi için dört tasarım ilkesi belirtilmiştir. İlkelerle göre, (I) MBDP değiştirilebilir faiz özelliği taşınmalıdır. (II) MBDP ve rezervler ayrı para formları olmalıdır ve doğrudan dönüştürülebilir olmamalıdır. (III) Mevduatın MBDP'ne dönüştürülebilirliği için herhangi bir garanti verilmemelidir. (IV) MBDP yalnızca uygun menkul kıymetlere karşılık piyasaya çıkarılmalıdır.

Bu çalışma, hem negatif faiz politikaları hem de merkez bankası dijital para birimleri için yararlı bir kaynak olarak hizmet etmeyi amaçlamaktadır. MBDP'nin uygulamaya konulmasıyla beraber, banka hücumları ile ilgili olarak, politikaların etkinliği tasarıma bağlı olsa da, tasarım ilkeleri önem taşımaktadır. Özellikle merkez bankası, ihtiyaç anında talepleri karşılayacak etkili bir mekanizmaya sahip olmak için MBDP'ni bir fiyat kuralı veya miktar kuralı ile kontrol etmelidir.

MBDP'nin potansiyel etkisini tartıřmak iin, bir MBDP rneęinin gerek dnyada nasıl alıřabileceęinin aık bir tanımıyla bařlamak gerekir. Sistem doęal olarak merkez bankasının ykmllęne negatif faiz oranları empoze etmeyi mmkn kıldıęından, alıřma, ncelikle nakit talebini banka mevduatları ve MBDP'ne karřı esnek bir řekilde ele almak iin bir CTC oranı nermektedir. Paranın rollerinin ayrılmasından sonra, MBDP yeni kanuni para olacaęı iin nakit, merkez bankası parasının daha az tercih edilen bir biimi olacaktır. alıřma, merkez bankalarının byle bir sistemi nasıl tasarlayıp iřletebileceęini tartıřıyor ve sisteme dair bazı cevapsız sorular ne srlmektedir.

Anahtar Kelimeler: Merkez Bankası Dijital Para Birimleri, Negatif Faiz Oranı Politikası, Geleneksel Olmayan Para Politikaları, Blokzincir, Paranın Geleceęi



FOREWORD

Following the Great Financial Crisis, many central banks have introduced a new policy called unconventional monetary policies. The new precautions taken by the central banks have pushed the nominal rates to the zero lower bound. As a result of the new policies, monetary policy space in the interest rates is constrained, and that limits the policy options to address future deflationary shocks.

The discussion on the future of cash is escalating in the digital world, which poses new challenges to authorities and central banks worldwide. The discussion is taking place against a backdrop of doubts about financial stability raised by the Great Financial Crisis, the rise of (private) cryptocurrencies, the development of new digital payment methods, and large technology companies' entry into the payment services.

The rise of cryptocurrencies and blockchain technology has produced new opportunities in the issuance and handling of money and inspiring new forms of digital assets and markets over the last decade. Simultaneously, a swiftly growing geopolitical, economic, and social environment has created new expectations and novel necessities for secure, reliable, user-friendly, accessible from all over the world, means of exchange, and digital settlements. Cryptocurrencies that are issued privately and pegged to a somewhat stable asset and some companies' stablecoins, relatively, are the most significant innovations, and the parallel phenomenon of central bank-issued digital currencies, commonly referred to as CBDC, is the subject of this paper.

Central bank digital currencies (CBDCs) has the potential to address both long-standing and new challenges financial inclusion and payment system stability. CBDC diverges from other forms of digital or virtual currencies, including cryptocurrencies such as bitcoin and 'stablecoins,' which are not issued by central banks or typically considered legal tender.

Since 2014 research regarding CBDC has increased. Lately, various central banks have joined this research of CBDC. The motives for CBDC differ among nations, as does its significance and potential for generating value.

In the recent BIS report, it is stated that more than %70 of central banks are working on the blockchain to explore the central bank digital currencies, and the Bank of Canada stated that they have started to build their CBDC. CBDCs can offer a range of advantages. CBDC can give the central banks more effective, future-oriented tools to implement monetary policy in more direct and innovative ways and keep pace with technological change.

Working on such subjects during the global pandemic was both concerned and hopeful because we live in the dawn of a new era that will diminish hand-to-hand transactions. The subject of the CBDC can help with the sovereignty matter to the central banks, as the cash disappears. That is why I found particularly important this subject.

I would like to thank my advisor, who never doubted me, and his guidance was utmost illuminating. Also, I would like to thank my family, especially my sister and brother-in-law helped me during the first part of the thesis, which involves their specialty. Lastly, I would like to thank Satoshi Nakamoto since his vision brought numerous benefits to societies worldwide; even though the name does not belong to one person, the name rather is a representation of a vision. Ironically, digital currencies were created against central bank money. Nevertheless, the DLT, the system of that underlies the cryptocurrencies, has the potential to improve central banks' effectiveness, as mentioned above.

Muhammet DOĞAN

İSTANBUL, 2020

CONTENTS

ABSTRACT	ii
ÖZ.....	iv
FOREWORD.....	vi
CONTENTS.....	viii
LIST OF GRAPHS	xi
LIST OF TABLES	xii
LIST OF FIGURES	xiii
LIST OF PICTURES.....	xiv
ABBREVIATIONS	xv
PROLOGUE.....	1

PART ONE

BRIEF HISTORY OF MONEY AND INTEREST

1.1. Early Times of Money and Interest.....	8
1.2. Money and Interest in Hellenes.....	11
1.3. Money and Interest in Ancient Rome	15
1.4. Money and Interest from the Middle Ages to 20 th Century	19

PART TWO

NEGATIVE INTEREST RATE POLICY

2.1. Theoretical background for Negative Interest Rate Policies.....	30
2.2. Opening up space for second money in the economy: double money system in one economy	40
2.3. Why second money in an economy?.....	46
2.4. Operating Framework of Negative Interest Rates.....	55
2.5. Effectiveness of the policy	62

PART THREE

CENTRAL BANK DIGITAL CURRENCIES

3.1. Blockchain technology in National Currency as Central Bank Digital Currencies.....	66
3.2. The Technology Behind the CBDCs: Blockchain	68
3.3. Benefits of Blockchain.....	69
3.3.1. Decentralization	70
3.3.2. Transparency	70
3.3.3. Greater automation.....	70
3.3.4. Security	71
3.3.5. Increase in speed and efficiency	71
3.3.6. Cost reduction	71
3.4. Possible adaption of the DLT.....	72
3.5. Related works.....	77
3.6. Central Bank Digital Currency.....	85
3.7. Types of CBDC.....	87
3.7.1. Restricted CBDC.....	88
3.7.2. Public CBDC.....	90
3.8. Possible Benefits of CBDC.....	92
3.9. Design Principles	97
3.9.1. Interest Bearing CBDC	97
3.9.2. Coexistence of Restricted and Public CBDC As a Distinct Money	98
3.9.2.1. Arbitrage: Households and Firms	99
3.9.2.1.1. Model for Households and Firms Arbitrage.....	100
3.9.2.2. Arbitrage by Banks	101
3.9.2.2.1. Model for Banks' Arbitrage	101

3.9.2.3. Convertibility of CBDC to Bank Deposits	103
3.9.2.4. Eligible Securities against CBDC.....	104
3.10. Possible Implications of the CBDC	104
CONCLUSION.....	106
REFERENCES.....	109
APPENDIX 1	150
APPENDIX 2	151
APPENDIX 3.....	155

LIST OF GRAPHS

GRAPH 1: RELATIONSHIP OF THE INTEREST RATES WITH NET INTEREST INCOME	3
GRAPH 1.1: US INTEREST RATES AND TOTAL CONSUMER CREDIT 1970 – 2019.....	30
GRAPH 2.1: THE ADJUSTMENT OF MONETARY POLICY INSTRUMENTS AT DANMARKS NATIONALBANK.....	37
GRAPH 2.2: EXCESS RESERVES IN THE USA	42
GRAPH 2.3: EXCESS RESERVES IN JAPAN	42
GRAPH 2.4: EXCESS RESERVES IN THE EURO AREA	43
GRAPH 2.5: REAL INTEREST RATE RATIO IN G20 ECONOMIES.....	47
GRAPH 2.6: CURRENCY IN CIRCULATION AS OF GDP IN THE WORLD	48
GRAPH 2.7: THE VALUE OF ATM WITHDRAWALS (VALUE IN LOCAL CURRENCY).....	49
GRAPH 2.8: SEARCH INTENSITY OF VIRUSES AND CASH USAGE	50
GRAPH 2.9: CASH WITHDRAWAL VALUES IN THE UNITED KINGDOM	53
GRAPH 2.10: CASH TO COIN CONVERSION RATE	57
GRAPH 2.11: DEFLATION AND INTEREST RATE IN JAPAN	60
GRAPH 2.12: PRE AND POST NEGATIVE INTEREST RATE EFFECT TO CREDIT.....	63
GRAPH 2.13: EXCHANGE RATES PRE AND POST NEGATIVE INTEREST RATES.....	64
GRAPH 2.14: TRADE WEIGHTED EXCHANGE RATE OF THE SELECTED CURRENCIES ..	65
GRAPH 3.1: TAXONOMY OF THE DIGITAL CURRENCIES.....	77
GRAPH 3.2: TOKEN ARRANGEMENT MODEL	90
GRAPH 3.3: TOTAL SEIGNIORAGE REVENUES IN THE UK.....	96
GRAPH 3.4: BANK OF ENGLAND’S VIEWS FOR CBDC.....	97
GRAPH 3.5: CONVENIENCE YIELD ON CBDC.....	100

LIST OF TABLES

TABLE 1: NEGATIVE INTEREST RATES OF SELECTED CENTRAL BANKS.....	4
TABLE 1.1: INTEREST RATES IN ANCIENT GREECE CITIES.....	12
TABLE 1.2: THE ROMAN MONEY SYSTEM.....	17
TABLE 1.3: INTEREST RATES IN ANCIENT TIMES.....	20
TABLE 1.4: SELECTED INTEREST RATES DURING THE MIDDLE AGES.....	22
TABLE 1.5: SELECTED EUROPE AND US SHORT TERM INTEREST RATES.....	27
TABLE 1.6: LONG TERM HIGHT GRADE AMERICAN BOND YIELDS	28
TABLE 2.1: ACCOMPANYING POLICIES TO NIRP	45
TABLE 3.1: POSSIBLE APPLICATIONS OF DLT	76
TABLE 3.2: BENEFITS OF CBDC.....	93

LIST OF FIGURES

FIGURE 2.1: CASH CIRCULATION SCHEME	61
FIGURE 2.2: CASH TO COIN RATE IN THE MARKET	62
FIGURE 3.1: CONCEPTUAL FRAMEWORK OF SMART CONTRACTS	70
FIGURE 3.2: FRAMEWORK OF THE PILOT OF E-KRONA.....	79
FIGURE 3.3: ACCOUNT AND TOKEN BASED CBDC WORKFLOW.....	87
FIGURE 3.4: THE MONEY FLOWER.....	88



LIST OF PICTURES

PICTURE 1.1: LYDIAN ELECTRUM COIN.....	11
PICTURE 1.2: SILVER TETRADRACHM OF ATHENS.....	14
PICTURE 1.3: SILVER QUADRIGATUS (TOP) AND SILVER DENARIUS (BOTTOM).....	16
PICTURE 1.4: GOLD COIN FROM BYZANTINE	18
PICTURE 1.5: THE CUMBERSOME COPPERPLATE MONEY.....	23
PICTURE 1.6: A CREDIT NOTE ISSUED BY STOCKHOLMS BANCO	24
PICTURE 1.7: BANK OF ENGLAND £50 BEARER BANKNOTES	25



ABBREVIATIONS

AD	: Anno Domini
AML	: Anti-Money Laundering
BCE	: Before Common Era
BIS	: Bank for International Settlements
BOC	: The Bank of Canada
BOE	: The Bank of England
BOJ	: The Bank of Japan
CBDC	: Central Bank Digital Currency
CBS	: Copenhagen Business School
CDO	: Collateralized Debt Obligation
CFT	: Combating the Financing of Terrorism
CPMI	: Committee on Payments and Market Infrastructures
CTC	: Cash to Coin
CY	: Convenience Yield
DBM	: Digital Base Money
DDR	: Digital Depository Receipt
DLT	: Distributed Ledger Technology
DN	: Danmarks Nationalbank
DOA	: Decentralized Autonomous Organizations
DSGE	: Dynamic Stochastic General Equilibrium
ECB	: The European Central Bank,

ECCB	: The Eastern Caribbean Central Bank
FED	: The Federal Reserve System (The Central Bank of the United States)
FinTech	: Financial Technology
GDP	: Gross Domestic Product
GFC	: Global Financial Crisis
GİB	: Gelir İdaresi Başkanlığı (Revenue Administration of Turkish Republic)
IBM	: International Business Machines
IMF	: International Monetary Fund
IRS	: The Internal Revenue Service
KYC	: Know-Your-Customer
NEF	: New Economics Foundation
NIRP	: Negative Interest Rates Policy
OMFIF	: The Official Monetary and Financial Institutions Forum
PoS	: Proof of Stake
PoW	: Proof of Work
QE	: Quantitative Easing
RegTech	: Regulation Technology
Riksbank	: The Sveriges Riksbank
RTGS	: Real-Time Gross Settlement
SARB	: South African Reserve Bank
SARS-COV-2	: Severe acute respiratory syndrome coronavirus 2
SME	: Small Medium Enterprise

SNB	: The Swiss National Bank
TechFin	: Technology companies that provide financial services
TRY	: Turkish lira
UK	: United Kingdom
US	: United States of America



PROLOGUE

Initially, our societies were small enough to share everything, and there was no need for money; thus, the concept of interest was irrelevant. Since the inception of civilization, both the concept of money and interest essential subjects for people. The initial trade was simply a raw material-based swap transaction (Bilgi, 1997, p. 16); nevertheless, the idea of interest has emerged when commerce needs some space to develop. We have started to shape modern societies like Assyrian Trade Colonies in Anatolia; the money and interest have become crucial for the trade and daily life during the trade colonies' times. The bank-like institutions were the creditor of the traders, and their funding was coming from other merchants (Michel, 2008). However, way before the trade colonies, churches were the credit institutions for the public to personal spendings. Therefore, the concept of the money goes back to ancient times.

In time, we have shaped our societies and adapt ourselves to the dynamic nature of the world. Until the industrial revolution, the pace of the change was rather slow, and the disruptive effect was little to no. However, industrialization stimulated the change, and a century later, we have found the protocol of information exchange through machines; the internet. The innovation effect that comes with the internet was remarkable. The adaption of money to the digital world was quite smooth, nothing like the first trials of paper-based money in China in the 7th century (Glahn & von Glahn, 2016). The first attempt of the fiat money¹ was not quite successful; however, more importantly, it gave the idea of substitution of the commodity money by the government. The money has taken the shape of the government's trust in the fiat form. The emergence of the central banks was to provide stability to the economy by preserving the value of goods and services and establish trust in the system to foster spending rather than holding the money for the future; thus, the new form of money was an innovation that useful to the economy. In 1900, the United States issued an act regarding the paper-based currency, the dollar, and declared the gold will be the reserve of the government-issued paper currency; however, this strict gold standard only last for 33 years (Elwell, 2011). Following the gold standard, Quasi-Gold

¹ A government-issued currency that isn't backed by a commodity such as gold or silver rather backed by government trust.

Standard did not provide the intended aim from the policy, and in 1973 State has abandoned the standard altogether. Thereafter, the fiat form of money has continued to exist with the trust of the people.

Following the Global Financial Crisis (GFC) 2008, the central bank of some countries, namely, the US, England, Japan, and the European Union, had to take new measurements known as unconventional monetary policy. As can be seen in Table 1, these policies involve cutting interest rates to the zero lower bound and implement large-scale asset purchase programs (Bank of England, 2020c; European Central Bank, 2020a; Federal Reserve Bank of New York, 2020). After having these unconventional monetary policy implications, central banks of some countries are suffering from insufficient policy space, and these unconventional monetary policies caused people to lose their trust in the system².

Rosengren (2019), in his speech regarding the constraints on the central banks, summarizes from the Federal Reserve's perspective as:

'In reaction to most recessions, the Federal Reserve's typical reduction of the federal funds rate has been in the range of roughly 5 to 6 percentage points. Therefore, the current low-interest-rate environment gives policymakers very little "room to maneuver" in a hypothetical next recession, at least in the traditional monetary policy mode of reducing short-term rates.'

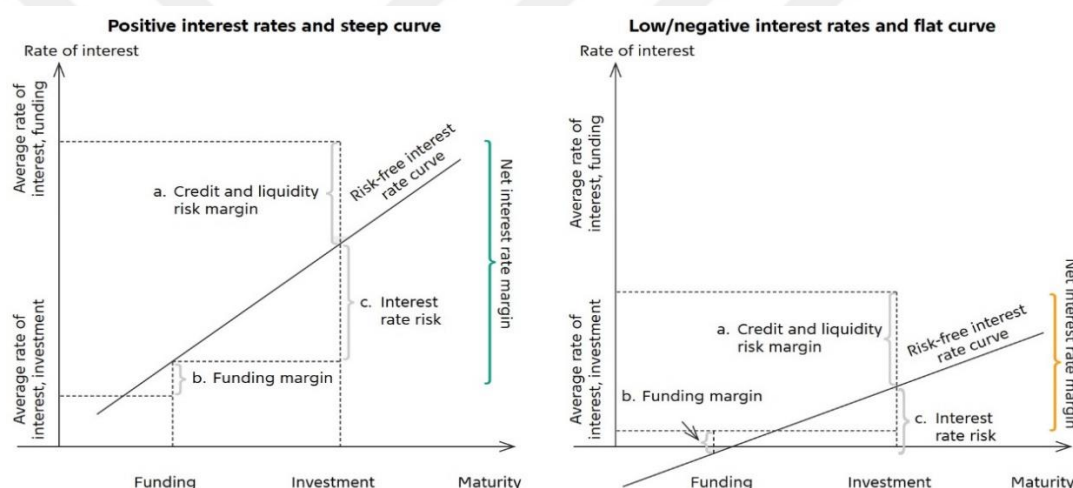
After decreasing the nominal interest rates to the near-zero, the effective lower bound on nominal interest rates have started to argue. The lower bound of nominal interest rates stem from cash due to the nature of printed money, and according to Fisher (1896, p.372), *'any possessor of money or equivalent would hoard it rather than lending it at a loss.'* This lower bound puts the policymakers in a difficult position when they need to manage the market efficiently (in a situation like deflation, increasing unemployment, or downturn of the business cycle). In case a central bank decreases the policy rate below zero, the profitability of the banks would erode because of the closing spread between the rates of lending and deposit. The profitability of the

² See Anti-austerity movement.

banks, thus, seems the most significant concern regarding the negative nominal interest rates (Campos, 2019).

Moreover, if a bank relies on deposit funding rather than capital markets and other resources, this would be more effective for the bank (Danmarks Nationalbank, 2015). Regarding the nominal negative interest rate effects on the banks, much research has been conducted, and the main results show that somewhat smaller banks, having these effects rather strong, namely an increase in risk appetite and loss in the earnings (graph 1).³

Graph 1: Relationship of the interest rates with net interest income



Source:(Danmarks Nationalbank, 2015, p. 52)

Constraints on monetary policy have attracted attention from both academics and policymakers; many solutions have been offered to increase the ability of the monetary board to stimulate the economy when the lower bound faced.⁴ Blanchard et al. (2010) have proposed a possible solution for the lower-bounds on interest rates, which raises the target inflation rate, e.g., a 4% target inflation rate rather than a 2% target rate.

³ See for further details on bank lending in NIRP (Molyneux et al., 2020);(Schepens, 2018);(Boungou, 2020)

⁴ Conducting monetary policy is an important job especially when the nominal interest rates are quite close or equal to zero. Due to this phenomenon academics and policy makers show quite an interest in this area and here are the some of policy options for further read; (Woodford, 2003) (Benhabib et al., 2002) (Blinder, 2000) (Bernanke, 2002) (Clouse et al. 2003)

Table 1: Negative Interest Rates of Selected Central Banks

Central Bank	Main financing rate	Excess Reserve Rate	Aim
The Sveriges Riksbank	-0.10% (Weekly operation rate)	-0.00% (Repo Rate)	to prevent the local currency's appreciation and to solve the low inflation problem
Danmarks Nationalbank	0.05% (lending rate)	-0.75% (7 Day deposit rate)	The bank seeks to prevent appreciation of the local currency.
Swiss National Bank	0.50% (liquidity-shortage financing facility)	-0.75% (rate on sight deposits)	The bank tries to hold the local currency at target levels
European Central Bank	0.00% (primary refinancing operations)	-0.50% (deposit facility rate)	to ensure price stability over the medium term, a measure for low inflation
Bank of Japan	0.10% (basic balance)	-0.10% (policy-rate balance)	The bank fighting against deflation
	0.00% (macro added-on balance)		

Source: Respective National Banks, 2019

Thus, they aim to increase room of monetary policy to resist shocks. For the same problem from another perspective, Williams (2017) proposes a price-level target for this situation, and he suggests that the target of price-level provides clarity for the market in the calculated (e.g., five years price level, ten years price-level) time horizons. Ball et al. (2016), in the report, that they have prepared on the central bank actions regarding the lower bound of the nominal interest rates. According to authors, when facing below-target inflation and relatively low aggregate demand, a central bank, in order to stimulate the economy, can establish a large-scale asset purchase (Quantitative Easing) and impose negative nominal interest rates to accompany large scale asset purchases. According to Eggertsson & Woodford (2003a), constraints that have been created by zero lower bound on nominal interest rates “*lower the welfare*” when comparing with the non-constraint situation. Further, the authors argue that zero

lower bound makes open market operations ineffective even if they are not conventional. Therefore zero lower bound makes any central bank vulnerable to a liquidity trap (Eggertsson & Woodford, 2003b).

For the problem of zero lower bound on nominal interest rates Henry, (1976); Rogoff (1998, 2014, 2017a, 2017b) suggest phasing out the paper currency idea; therefore, without paper money, lower bound vanishes, and that gives required space to monetary policy board to respond possible shocks. Rogoff specifies the followings on the subject of implementing the negative interest rates:

‘Fundamentally, there is no practical obstacle to paying negative (or positive) interest rates on electronic currency, and effective negative rate policy does not require eliminating paper currency.’

In 2008, movements against the central banks had found solid ground with the introduction of the Bitcoin. Over some time, some researchers have proposed that the database, which is introduced with the bitcoin protocol, can be useful for the benefit of the traditional financial systems (Koning, 2014). Before the popularity of private cryptocurrencies, some central banks have studied them (Ali et al., 2014a, 2014b; Mersch, 2015). The potential of the blockchain technology (also known as Distributed Ledger Technology -DLT) has taken the attention of the researches and from the central banks, and the implications of the DLT have been testing since 2015 by various central banks (Kiff et al., 2020). However, the rise of the stablecoins⁵ may pose a threat to the sovereignty of the central bank over the monetary policy. Kiff et al. (2020) states that;

‘In some economies, cash is disappearing as a means of payment, and new digital payment systems are challenging central bank roles. In other countries, the private sector lags in improving financial inclusion and reducing the operational costs and risks associated with the management of physical currency.’

Thereof, central banks should make their money more attractive, and the contingency plan of Bank of Canada and The Bank of England’s CBDC model

⁵ Privately issued rather less volatile cryptocurrencies.

provides an example of such precautions (Bank of Canada, 2020b; Bank of England, 2020a).

The definition of the Central Bank Digital Currency (CBDC) can be challenging since the functions depend on the design of it. However, some features can be laid down to have a scope for the CBDC. For instance,

- CBDC should be widely accessible, not like the reserves.
- CBDC should carry more functionality than banknotes in retail transactions.
- CBDC should be separated from other central bank money forms.
- CBDC should bear interest.

These features allow for exploring the CBDC in monetary policy, whether it can be a second policy tool or not (either with price rule⁶ or a quantity rule⁷). After the introduction of the CBDC, according to central bank money for all scenario if the design principles that mentioned above employs, liquidity of banks and lending function of the banks not necessarily limited. There may be some shrinkage in the deposits. Still, the impact of it would be limited; according to Kumhof & Noone (2018), both banks and the customers would control the effects of switching to CBDC from deposits, and banks would continue accordingly to their intermediary role in the economy.

This thesis is going to discuss the feasibility of phasing out paper currency, not entirely but mostly, to provide a solution to the lower bound of nominal interest rates. The work also attempts to shed light on possible expansion in monetary policy tools by eliminating the zero lower bound of nominal interest rates. Thus, it suggests a substitution, not entirely, of paper currency, which is a digital currency, belongs to a central bank. The main benefits and challenges regarding the CBDC will be briefly discussed. The scope of this thesis to analyze the CBDC, whether it can be displaced bank deposits and to cause runs from bank deposits to CBDC. Also, providing useful

⁶ Central bank specifies the interest rate on CBDC and quantity of CBDC is varying.

⁷ Central bank specifies the quantity of supplied CBDC and interest rate on CBDC is varying.

background material for both negative interest rates policies and the central bank digital currencies.

The possible solutions regarding the design of the CBDC will be explored through these questions;

- The availability of the CBDC will be open to whom/which entities?
- The access to the CBDC will be direct or indirect (through APIs)?
- The anonymity of the CBDC to what degree and to which institute or individuals?
- Will there be a transaction limit(s) in the CBDC?
- What will be the conversion rate of CBDC to other monies, and according to what will it specified?
- Smart contract usage in the ledger of CBDC?
- The lending of the central bank through CBDC and systems settlements.

The rest of this thesis organized as follows; Section 1 consists of a history of Money and the interest's evolution from the inception of civilization until the 21st century. Section 2 is a related literature review for the unconventional monetary policy, negative interest rates and discussed the implications of the negative interest rate policies and the operating framework for the negative interest rate policies. Section 3 consists of the examination of blockchain technology, then an explanation of possible use cases of blockchain as well as national currency with the related literature, that followed by the explanation of the CBDC types and use cases of the CBDC types. Section 4 involves the unanswered question and possible future works and concludes that the CBDC would be beneficial depending on the design options and the preliminary works; however, since the technology still in its infancy, further research is necessary.

PART ONE

BRIEF HISTORY OF MONEY AND INTEREST

1.1.Early Times of Money and Interest

In the paleolithic period,⁸ the traces of early humans all over the world can be observed. However, during the paleolithic age, there is no sign of any trade, and that followed by the Mesolithic period⁹, with a few exceptions of signs of trade. Still, in this period, settlements, even for a specific time frame, have started. During the Neolithic period¹⁰, ancient humans were hunter/gatherer, but some places show us settlements, agriculture, and domesticated animals. When humanity started to urbanization from being hunter/collector, early high civilization have started. During the early high civilization period in Mesopotamia, more specifically in the Uruk¹¹, civilization has flourished. The temples, which arguably caused to settlements of people, claimed their power on the society. The temples worked as both regulators and controllers of life, and that depends mostly on economics. In the Uruk, The Temple of the Eanna¹² was the principal owner of the lands, and they had handmaids and workers who serve them. Nissen (2004) says the following regarding the temple in the Uruk:

'It is the Temple of the Eanna in Uruk, which controls not only agriculture, animal husbandry, and handicrafts, but also trade, and supplies raw materials to these lands, which lack much raw material.'

Further, the temples were in the finance business, they were working as a bank and giving loans¹³ to people with interest, and when the customers cannot pay their debt, they worked as an asset management company. They, to collect their debts, enslave and sell the debtor to collect their debts. The interest rates in the loans here, according to clay tablets, cannot be higher than %33 for cereal and %20 for silver (Yıldız, 1989). After some time, the ruling class starts to give loans to the people like

⁸ ~2.5 million years ago to 10,000 B.C.E.

⁹ ~10,000 B.C.E. to 8,000 B.C.E.

¹⁰ ~ 8,000 B.C.E. to 3,000 B.C.E.

¹¹ Capital city of Sumer

¹² Sumerian: 𒂗𒍪𒀭 É-AN.NA, House of Heavens

¹³ The subject of the agreements were usually trade goods.

the temples, and within times they have become the dominant power; after that, the temples lose their control over money and interest (Oates 2004, as cited in Ildız, 2013, p.16).

Following the Sumer, at the beginning of the second millennium B. C. E., Old Assyrian trade colonies coordinated comprehensive commercial exchange with Anatolia. They brought gold and silver for textiles and tin. The trade volume was tremendous during the trade colonies times, and trade was managed by the merchants rather than the State or military (Larsen, 1974). Roughly the amount of silver traded at those times was 7 tons and 225 kilos for gold. In order to identify the materials, they used labels for the quality of the metals, such as there were ten kinds of gold, eight for silver and copper, and five for iron and tin (Erol, 2019). Since the trade was expanding, that caused systematic bookkeeping¹⁴ and, somehow, the emergency of today's banks bit-karims. The interest rate was specified by Karum authorities to the %30 annually; however, there was a specific transaction record that says %10 interest will be added to the original debt. According to Yıldız (1989), bit-karim was the most significant place of Kanesh-Karum¹⁵. This place was used for trade-courts, congresses, and all the capital accumulation and protection around the kingdom. Besides, merchants debited their money and paid their taxes in this place. Apart from being a deposit bank, bit-karim's were providing credits to the people, and the palace; as well as they offered intermediary service while two merchants were buying and selling their goods. From the historical Kültepe texts, Özgüç (2005) states that:

'If Assyrian merchants could not pay the debt specified in their borrowings on their day, the creditor's addressee would be the chamber of commerce, the guarantor of the merchants because traders had credit accounts in the trading rooms.'

One can observe through history the abuse of the interest usage in any society until the state or ruling class regulates them. One of the oldest law books, the Laws of Eshnunna, in the world was discovered near the city of Baghdad city, Iraq. There are

¹⁴ See for further details in the Assyrian times' trade institutions, partnerships, and commercial treaties (Michel, 2008)

¹⁵ Centre of a complex network of Assyrian trade colonies, the capital of the ancient Kingdom of Kanesh

a total of 60 laws in the Eshnunna lawbook and 13 of them on debt, interest, and trade (Goetze, 1951). In the Eshnunna lawbook, the traces of joint family ownership of real estate goods are more substantial and represent the transition period from a natural economy to a monetary economy (Bilgiç, 1963). The Hittites conquered the trade city of the era Ugarit in the B.C.E. 14th century; following this event, the Uraian¹⁶ traders started to give loans with high-interest rates to the Hittites. This situation has put people in a difficult situation, and many of them lost their property. Therefore, King of Hittite Hattušili III issued a proclamation and forbade Uraian traders to give loans and to own a property.

In Babylon, merchants were known as tamkarum; they were more than just a trader. They were providing loans to the people, and due to this reason, they were accepted as bankers rather than merchants. Some of the families in Babylon made a fortune from their high-interest credits to the people. They have continued to conduct their high-profit banking model until the Hammurabi come to the throne (Klengel, 2006). Therefore, one of the earliest code of laws in the humankind, The Code of Hammurabi, contained a section which related to financial transactions, ownership, and usage of credit; further, the laws included the rates for the loans.¹⁷ Law 88 in the Code of Hammurabi states the interest charges on loans and interest rates on silver have been fixed to 20% (Hammurabi, 1780 B.C.E.). The interest rate for cereals was different from the silver, and since this part of the economy has not been regulated, interest rates on the loans of cereals various; however, the average interest rates correspond to 1/3, which is 33% (Klengel, 2006, p.95). In Babylon, there was some set of rules due to the usage of credits; one few were about the charging debtor when the harvest went terrible. If a farmer cannot make a profit from harvest, then the lender cancels the interest on that loan (Nagarajan, 2011). Following the laws of Mesopotamia, law books started to emerge as a religion to protect the integrity of the laws. For instance, the Old Testament/Torah involves three orders regarding the

¹⁶ The word "Ura" in the language of the Luwians, who live intensely in this region; meant "Big" (Laroche, 1959).

¹⁷ There were two different types of money namely, silver and grain, interest rate for grain was %20 for silver %33. See for the further details (Hammurabi, 1780 B.C.E.).

interest, and it is prohibited to lend relatives and their race with interest while foreigners exempt from this rule¹⁸.

Until the coinage societies used raw materials and variable items to trade, however, according to the findings of Oates (1986), King of Babylon Sennacherib (704-681) stated that; *'I made clay molds, pouring bronze into all of them, like half-shekel pieces, I made the castings flawlessly.'* After that, words spread to communities nearby, then Lydia minted coin from gold and silver mixture in the seventh century.

Picture 1.1: Lydian Electrum coin¹⁹



Source:(Nomos AG, 2020b)

1.2. Money and Interest in Hellenes

Starting from the sixth century, Hellenes were using various type of loans in their daily business, and according to some orators, banking transaction was aphanes²⁰(invisible) side of the economy. Since the trade and financial transactions were enhancing, the law should follow this process to protect the debtor so that system can continue to survive and evolve. In the Hellenes; there were mainly six types of

¹⁸ Exodus 22:25, Deuteronomy 23:19, Deuteronomy 23:20.

¹⁹ Time of Ardys to Alyattes, circa 630s-564/53 BC.

²⁰ During the time of ancient Hellenes, orators distinguish the economy into two a visible (phaneros) one and an invisible (aphanes) one. The credit transactions commonly made in the presence of a witness in the ancient Greece so that the lender can prevent any failure of the loans. Since wealthy people, usually, bankers hide their transaction from the people and without any witness this transaction will be recognized as aphanes.

loans—loans for entrepreneurs, like SMEs credits, loans that require some sort of collateral such as land and house, local government loans, Venture Capital like loans, short term credits like spot credits, and personal credits which has the highest interest rate among the other type of credits. Sea credit types, as a concept, is similar to the insurance working principles. The rate of the interest rates, inasmuch as credit types, have shown variety, and the range for the interest rates starts from 18% to 50% annually and goes to 25% daily. Nevertheless, most of the time, the State borrowed without interest or with minimal rates, such as 1.2%. According to Ildiz, %10 is the average of the interest rates with 3-4 year maturity (Ildiz, 2013).

Table 1.1: Interest Rates in Ancient Greece Cities

Type of Interest	Venue	Time	Rate
Temple loan with a collateral	Delos	B.C.E. 5th - 4th Century	10%
Interest on deposits in private banks	Hellas	B.C.E 4th century	10%
The loan with a city real estate collateral	Athens	B.C.E 4th century	8%
The loan with a countryside / rural area real estate collateral	Athens	B.C.E 4th century	%6-8
Industrial production loan	Athens	B.C.E 4th century	%10-33
Maritime trade loan	Athens	B.C.E 4th century	%20-33
Emergency personal loan	Lydia city Klazomenai	B.C.E 4th century	For Silver %20

Source: (Ildiz, 2013, p.154)

According to Aristotle, Thales made a fortune using his skill to predict the next harvest of olives. Thales, with a small amount of money, buys the future use rights of olive presses in Chios and Miletus, and when the harvest time came, he became wealthy with his futures²¹ (Aristotle, 1999, p.17-18). Aristotle says the following regarding the coinage and the number of coins becoming the wealth indicator;

‘When the use of coin had been discovered, out of the barter of necessary articles arose the other art of wealth-getting, namely, retail trade; which was at first probably a simple matter but became more complicated as soon as men learned

²¹ Financial contracts that obligate the selling party to sell an asset or the buying party to buy an asset, also contracts have a prespecified price and date from the future.

by experience whence and by what exchanges the most significant profit might be made. Originated in the use of coin, the art of getting wealth is generally thought to be chiefly concerned with it, and to be the art which produces riches and wealth, having to consider how they may be accumulated.

Furthermore, it is thought to be concerned with coin; for a coin is the unit of exchange and the measure or limit of it. Moreover, there is no bound to the riches which spring from this art of wealth-getting' (Aristotle, 1999, p.15).

As we can understand from the various types of credits, coinage stimulated the societies the usage of debts and altered the spending habits. It is both increases private spending and state spending. Nevertheless, from the emergence of the coinage and the credit institutions, not only bankers and the temples have benefited, but also usurers have benefited. Due to the layer of the societies'²², Athens citizens who need money cannot easily borrow money from bankers and temples. However, they could meet these needs from specific lenders(usurers) (Finley, 1953). Aristotle says the following on the matter of gaining wealth out of money itself;

'The most hated sort, and with the greatest reason, is usury, which makes a gain out of money itself, and not from the natural object of it. For money as intended to be used in exchange, but not to increase at interest. The interest, which means the birth of money from money, is applied to the breeding of money because the offspring resembles the parent. Wherefore of modes of getting wealth, this is the most unnatural.'

Besides that, Aristotle specifies until Solon's²³ reforms, people were putting their freedom as collateral in loan agreements, and if they fail to pay their debts, they become slaves.

²² See for further details on the class structure during Hellenes; (Ossowski, 1963, p.42)

²³ Solon (Greek: Σόλων Sólōn [só.lɔːn]; born c. 630 BCE—died c. 560 BCE), Athenian statesman, a lawmaker and, a poet; known as one of the Seven Wise Men of Greece (Cadoux, 2020).

Picture 1.2: Silver Tetradrachm of Athens²⁴



Source: (Nomos AG, 2020a)

As can be seen in picture 1.2 first standard shape of coins in Hellen was involves the head of Athens and Holy Owl. However, silver drachma coins in Athens were more like early Anatolian electron coin figures.

In the Hellenes, trapezites²⁵ started their business as a quality checker of the coins since there were various types of coins. In case someone needs to validate whether the coins valuable as they are promised or not, they would go to trapezites. Since their business models are based on trust, people, in time, started to deposit their coins to trapezites so that they can spend it when they need to and somehow avoid the risk of steal. Moreover, whenever someone wants to spend money, they would go their trapezite, and they would send the money through their trapezite. When the Hellenes trapezites, later quality checker means of this trapezite have evolved and turned into a banker, started to lend the deposits of the customers they have initiated a chain of influence and cause to grow the financial sector and the development of monetary economics within societies. The bankers have supported either by the State or other individuals in the banking business, and the agreements have been protected with law. Nevertheless, the effect of the war lead people to collect their deposit, and that followed by the deterioration of the silver value in the newly minted coins. During the

²⁴ Attica Athens. Circa 500/490-485/0 BC.

²⁵ Bankers were called as trapezites (τραπεζίτης) in ancient Greece.

late 3rd century B.C.E., the silver ratio of Drachma down from 1:40 to 1:400+; eventually, they could not avoid experiencing a credit crisis or inflation phenomena (İldiz, 2013).

1.3. Money and Interest in Ancient Rome

Ancient Rome, based on a relatively small city, initially ruled by the kings and then by the republican constitution of an aristocratic ruling class. Coinage started relatively later in ancient Rome because aes rude²⁶ was used as coin until around B.C.E. 300. At the beginning of the republic, they used the traders' coins that brought from Hellas, and there are relatively fewer records on interest rates in ancient Rome. In their first coin, bronze was used by Greeks; to produce coins for Rome following this; the head of Mars can be seen on the coins; thus, the Romans adopted coinage much more. First standard coin of Rome Quadrigatus, the name of the coin comes from the four horses at the back of the coin, as can be seen in picture 1.3. Silver Quadrigatus has been used from B.C.E. 225 until the minting of Denarius in B.C.E. 210. The Denarius is one of the longest-running currencies of Rome (Eagleton & Williams, 2007).

²⁶ The broken bronze piece used in South Italy from the 4th century to the 3rd century BC instead of money is known today as aes rude, which means unprocessed bronze (Eagleton & Williams, 2007, p.44).

Picture 1.3: Silver Quadrigatus (top) and Silver Denarius (bottom)



Source:(American Numismatic Society, 2020b, 2020c)

Following the improvements in the coinage, Rome engaged in regulations to build more integrated and structured regulations. Regarding the financial improvements in Rome, Eagleton & Williams (2007) states the following:

'The Romans began the 3rd-century B.C.E with a relatively underdeveloped coin and a state financing system in which money played a relatively insignificant role. This was enough for the conquest of Italy, but building an overseas empire required more complex and stable regulations. Now the coins had become imperative for the effective administration of the Roman State.'

First interest regulation in Ancient Rome can be found in the *Leges Duodecim Tabularum*²⁷ (Frank & Johnson, 1933, p.5). Homer & Sylla (2005), in their book, specify the followings about the socio-economic situation of the Roman society 'Cato²⁸ said:

"In preference to farming one might seek gain by commerce on the seas, were it not so perilous, and in money lending, if it were honorable... How much worse

²⁷ The Law of the Twelve Tables

²⁸ Marcus Porcius Cato (/ˈkeɪtoʊ/; 234–149 BC)

the money lender was considered by our forefathers than the thief...” Nevertheless, Plutarch says that Cato himself invested in mercantile loans, probably secretly.

This attitude probably explains why so few Roman rates of interest were recorded for posterity.’

Table 1.2: The Roman Money System

		Unit of Measure Value (after 210 BC)	Unit of Measure Value (after 140 BC circa)
Silver	denarius	10 as	16 as
Silver	quinarius	5 as	8 as
Silver	sestertius	2 as	4 as
Bronze	as	1 as	
Bronze	semis	1/2 as	
Bronze	triens	1/3 as	
Bronze	quadrans	1/4 as	
Bronze	sextans	1/6 as	
Bronze	unda	1/12 as	

Source:(Eagleton & Williams, 2007, p.45)

In B.C.E. 443, interest rates became stable within laws which were $8\frac{1}{3}$ (8.33) %. The legal rate of interest remains the same for 96 years and in 347 B.C.E. have reduced to half of the prevailing legal interest rate $4\frac{1}{6}$ (4.16)%. The decrease in the interest rates has brought a moratorium with it, and five years later, interest has forbidden completely; however, that did not take long, and legal interest rates were raised to previous levels (Homer & Sylla, 2005). During the Social War²⁹ in 91 B.C.E., the State has overspent so that, in the end, bankruptcy has become inevitable. Since desperate times require desperate measures, in the year 86 B.C.E, the Valerian law organized all debts of the State to pay only one-fourth of them, and the legal interest rate has been raised to 12% again (Homer & Sylla, 2005). However, according to an incident between Cicero and Brutus, Cicero warns Senator Marcus Junius Brutus to reduce the interest rates on the loans that he gave to the Cyprus city Salamis and the King of Cappadocia, from 48% to 12% (Rostovtzeff, 1930, p.159).

²⁹ See for the further details on Social War; (Gill, 2017)

When the time comes to the common era, interest rates were around 4-6% in Rome. Jesus expands the meaning of interest and forbids usage on Israelites; however, foreigners exempted from this rule as specified in the Torah. Starting from the common era, the interest rate in Rome was volatile between 4% and 12% until the fourth century A.D. Following the Roman Empire, Byzantine, throughout its existence, has shown not higher than the legal limits of Rome, which was around 11%. However, in Maritime credit types (bottomry), the legal interest rate was not applied, and since this is the situation, interest rates were high, as much as 17%. The interest rates document very few in the Byzantine and follow the Roman Empire rate because the church has forbidden the interest in every form. However, this ban of interest usage was not even taken into account by the church following the decrease in the interest rates. The Code of Justinian³⁰ was the sovereign law regarding the interest rate in Byzantine. Although the interest rate was banned from time to time, it was restored to its old version after a while.

Picture 1.4: Gold coin from Byzantine³¹



Source: (American Numismatic Society, 2020c)

During Medieval Europe, the term ‘interest’ has been used in the documents as a loss rather than a profit. According to Noonan (1957), as cited in Homer & Sylla (2005), ‘*Interest was considered the compensation due to a creditor because of a loss which he had incurred through lending.*’ The term *interesse* was generally used in the

³⁰ See for further details regarding the Codex (Justinian I, 1932)

³¹ Gold Solidus of Anastasius I, Constantinople, AD 498 - AD 518

sense of recompense or fine for the loans that cannot be paid when it is due. The interest rates have declined during the Middle Ages and later Renaissance. Regarding this trend in the interest rates, Homer & Sylla (2005) says the followings :

'The earliest short-term rates quoted were somewhat higher than the last and highest of the western Roman legal limits. They were not too different from early Greek rates and were within the range of Babylonian rates, although the credit forms were very different from ancient credit forms. The later Renaissance rates were well within the range of new rates, and the lowest was far below modern rates in periods of credit stringency.'

1.4.Money and Interest from the Middle Ages to 20th Century

In the late eleventh century, Genoa, like Florence and Venice, has emerged as a trade and finance city. Genoa was different because they were holding fairs in the city several times a year. They were called Champagne Fairs, and, in these fairs, merchants from all over Europe took part. The fairs during the 12th and 13th-century financed by Italian bankers. Due to the nature of the fairs, participants were diverse, and that revealed the need for a standard type of payment in different currencies. Roover (1948a) states the following regarding the bill of exchange:

'A medieval bill of exchange, unlike a modern draft, always originated in an exchange contract. A merchant gave a sum in local currency to another merchant and received a bill payable at a future date in another place and in another currency.'

The deposit keeping was important for the Italian merchants also as well as in the Hellas and Rome. The merchants have used this deposit keeping as a type of investment to their business. The merchants offered variable rates for the deposits; if the venture fails, there will be no returning to the investors. If the merchants have profit out of their business, the profit will be distributed regarding the share of the investor (Noonan, 1957, p.171). During these times, banking institutions continue to develop and provide the basis of the modern form of banking.

Table 1.3: Interest Rates in Ancient Times

		Ancient Greek Interest Rates					Roman and Provincial Interest Rates				
		Normal Loans	Real Estate Loans	Loans to Cities	Earning of Endowments	Loans for Commerce and Industry	Rome	Egypt	Asia	Africa	Byzantine
B.C.E.	Sixth Century	16-18	-	-	-	-	-	-	-	-	-
	Fifth Century	10-12%	8-12%	-	-	12-18%	8.33%	-	-	-	-
	Fourth Century	10-12%	8-12%	8.5-12%	-	12-18%	4.16-8.33%	-	-	-	-
	Third Century early	7.14-12%	10%	8.5-12%	-	-	8.33%	24.00%	-	-	-
	Third Century late	6-10%	7%	10%	6-10%	-	8.33%	24.00%	-	-	-
	Second Century early	6-9%	6.67-10%	10%	6.67-10%	-	6-8.33%	5.00%	8-12%	-	-
	Second Century late	6-9%	-	7%	10%	-	6-8.33%	10.00%	8-12%	-	-
	First Century	6-12%	-	8-12%	10%	-	6-12%	12.00%	8-12%	-	-
A.D.	First Century	8-9%	-	-	-	-	4-12%	12.00%	<12%	-	-
	Second Century	-	-	-	-	-	6-12%	12%	<12%	5-12%	-
	Third Century	-	-	-	-	-	12+%	-	-	-	-
	Fourth Century	-	-	-	-	-	12-12.5%	-	-	-	-
	Fifth Century	-	-	-	-	-	12.5-12.5+%	-	-	-	-
	Sixth Century	-	-	-	-	-	-	-	-	-	8%
	Seventh Century	-	-	-	-	-	-	-	-	-	8%
	Eighth Century	-	-	-	-	-	-	-	-	-	8%
	Ninth Century	-	-	-	-	-	-	-	-	-	11.125%
	Tenth Century	-	-	-	-	-	-	-	-	-	11.125%

Source: (Homer & Sylla, 2005, p.40,41,42,56)

Genova city merchants specialized in deposit banking as in Florence. According to Roover (1948), there were four types of credit institutions in Italy during the fifteenth century, namely, *banchi di pegno*, *banchi a minuto*, *banchi in mercato*, and *banchi grossi*.³² The famous banker family Medici's were *banchi grossi* due to the business volume and customer types. Roover (1948) states the following on the matter of banking during the fifteenth century:

'The Florentine bankers were traders as well as bankers. They combined foreign trade and dealings in exchange—not a petty exchange of foreign for domestic coins, but trade in bills of exchange (cambium per literas). To most bankers, it was less important than trade-in commodities. Even the Medici, the most prominent firm of merchant bankers in Florence, emphasized trade rather than banking.'

However, in the fourteenth century, the banks in some parts of Europe were distributing the deposits as credit, and they were generally keeping the reserve ratio around 30% (Roover, 1948a). Nevertheless, according to Lane (1937), banks devoted their assets mainly to investments instead of loans because of the government's attitude towards the loans.

In the Netherlands, in the sixteenth century, princes' have issued perpetual bonds and life annuities; however, the issuing perpetual bonds and life annuities might go a little back, according to Ehrenberg (1928), since even Popes raise money, in 1526, through the sales of mentioned instruments as the Italian cities. Following the escalation of the Netherlands, the city of Antwerp has emerged. Later, Antwerp has become the norm of the financial trade. The city had mainly two-part (Motley, 1856). One of them belonged to the debt instruments, and the other part of the city was the center of the exchange market. In the second part of the city, the market was involved commodity exchange as well as highly speculative bets also such as King's visit to the city or the returning of ships.

During middle age and thereafter, the volatility is high. Most of the volatility occurs due to illegal activities. (Homer & Sylla, 2005) summarises the high volatility and recording challenges as following:

'A new problem for this history arises with the development of the medieval money market and the volatility of the rates on such instruments as the commercial bill. No longer do the data represent principally interest rates on conventional, sluggish "normal" loans, such as the consumer loans which dominated ancient credit. Consumer credit existed in the Middle Ages in volume, but it was largely illicit and probably was often undercover, in part obtained from the pawnshops, in part from the loan sharks, and in part disguised as commercial transactions.'

³² *banchi di pegnos*; pawnshops, *banchi a minuto*; retail bank, *banchi in mercato*; money-changers, *banchi grossi*; great banks

Table 1.4: Selected Interest Rates During the Middle Ages

Century	Spanish Netherlands			Dutch Republic			Italy			France		
	Short Term		Long Term	Short Term		Long Term	Short Term		Long Term	Short Term		Long Term
	Commercial Loans	Deposits	Mortgages, Cencus Annuities	Commercial Loans	Deposits	Mortgages, Cencus Annuities	Commercial Loans	Deposits	Mortgages, Cencus Annuities	Commercial Loans	Deposits	Mortgages, Cencus Annuities
Early 12th	10%	-	-	-	-	-	-	-	-	-	-	-
Late 12th	16%	-	8% - 10%	-	-	-	20%	-	-	-	-	-
Early 13th	10% - 16%	-	8% - 10%	-	-	-	20-25%	10-20%	-	-	-	-
Late 13th	10% - 16%	-	8% - 10%	-	-	-	8-15%	10-20%	6.625% - 8.375%	15-20%	14%	-
Early 14th	10% - 25%	-	8% - 10%	-	-	-	7-15%	5-12%	4.875% - 8.375%	15-20%	-	-
Late 14th	10% - 25%	10%	8% - 10%	-	-	-	5-15%	5-12%	5.25% - 10%+	15-20%	-	-
Early 15th	8% - 17%	5%	8% - 12%	-	-	-	5-15%	5-10%	6% - 10%+	-	10.00%	-
Late 15th	8% - 17%	5%	8% - 12%	-	-	-	5-15%	5-10%	5% - 10%	-	10.00%	-
Early 16th	4% - 13%	4% - 6,25%	4% - 10%	-	-	8,33%	4-13%	4-6%	4-10%	5-12%	8.33%	-
Late 16th	7% - 12%	6,25%	4% - 10%	-	-	6,15% - 8,33%	7-12%	5-6%	4-10%	8-12%	8.33%+	-
Early 17th	-	-	-	6% - 12%	6,15% - 8,33%	5%-8,33%	-	-	-	-	8.33%	-
Late 17th	-	-	-	1,75% - 4,50%	3%-4%	3%-12,5%	-	-	-	-	5% - 8.33%	-

Source: Homer & Sylla, (2005), p.136,137

The interest rates during the middle ages followed a decreasing trend; much of the interest rate trend was either controlled or influenced by Italian bankers. During the mid-17th century, the bancos³³ were evolving to a central authority, and in the year 1668, the world's first central bank has been established by the 4 class of the society.³⁴ This idea emerged from a failure of the Stockholm banco, which failed by a bank run (Rodney et al., 2018, p.1). Following this event, the State issued a law to protect price stability (Wetterberg, 2009). The very first central bank was privately established as a private bank. After the bank fails to pay the deposits of people, the ruling classes come into action and fund the bank to turn into a central authority. They first engaged in coin minting, and the coins had various weights. One of them was around 20kg (picture 1.5).

Picture 1.5: The Cumbersome Copperplate Money



Source:(Wetterberg, 2009, p.29)

Thereafter, they realize the challenges of collecting taxes and transportation of the coins. Thus in 1661, they have produced the paper money (picture 1.6). Even

³³ The name of "Bank" is derived from the Italian word "banco" which is because of the furniture type used in this business.

³⁴ They are the nobility, the clergy, the burghers and the peasants.

though China had already tried paper money in the early seventh century³⁵, the European banknotes made the innovation famous.

Picture 1.6: A Credit Note Issued by Stockholms Banco



Source:(Wetterberg, 2009, p.42)

Following this establishment, central banks have started to emerge in other countries as well, such as England. England, after the revolution of 1688, has changed drastically both politically and financially. Following the Dutch debt principles and Italian banking system England managed to create a new financial center in London. Even though they have no banking and no capital accumulation, London started to emerge as a financial leader in the world shortly after their revolution. The domestic market was evolving quickly, and some intervention to the payments of the interest by the royalties reveal the need for a central authority for the payment system. In the year of 1694, after three years of waiting, the foundation of the bank has been officially under the name of ‘Governor and Company of the Bank of England’ (Macaulay, 1848). The Bank of England started to conduct a banking business under some restrictions. Eventually, the bank accepted deposits from both the government and the people. Bank

³⁵ Tang Dynasty (618-907) issued the very first bank note in the history; however, Song Dynasty (960-1279) after 10th century backed the currency with government force and made it possible of wide spread usage of Huizi paper money (Glahn, 2016, p.261,263)

of England did something already been doing by goldsmiths, which is issuing bearer banknotes (Picture 1.7).

Picture 1.7: Bank of England £50 Bearer Banknotes



Source: (Bank of England, 2020b)

Thus, the initial steps of modern banking have been taken by the Bank of England. Even before the establishment of the Bank of England, there was a corridor of interest rates. The limit for usury was 6%: however, governments were borrowing from 10 to 12 percent. From the late fifteenth century to the late sixteenth-century, interest rates were around 6%. Following England, in 1776, the French government established an institution called Caisse d'Escompte³⁶. This institution was similar to the Bank of England in the way of holding to issue notes payable to bearer and official loan provider for the government from 4% (Clough, 1952). From the seventeenth

³⁶ Discount Office

century to the eighteenth century in France, interest rates were around 5%: however, Dutch interest rates in the same terms were low regarding France's interest rates. From the foundation to the nineteenth century, Riksbank's interest rate also followed a declining path. Even though rates were increased during the mid-eighteenth century, the trend quickly changed its course to lower levels (Table 1.5).

In the UK, in 1717, gold has been accepted as legal tender, which silver had this for a long time. In 1773 the Stock Exchange was written on the sign of a coffee shop and required a membership to get in. One year later, from this event, silver payments were restricted to a £25 limit, and that created an implicit standard for gold (Ashton, 2006, p.177). Even before the 1720s, the government bonds interest rates have been stabilized at a 3% interest rate; however, the stock (bond) of governments sold from different values instead of par, i.e., premium or discount. In 1749, the Chancellor of the Exchequer came up with a solution to merge several bonds into 3% consolidated annuities: the consols.

The American colonies have adopted many traditions since the colonists used to be a part of England. The English usury law brought here also and updated to 6%, and the interest rate in commercial investments perceived normal and moral of trade (Homer & Sylla, 2005, p. 271). American interest rates followed a declining path from even though time to time, due to the wars, increased (Table 1.6). Since in the colonies no minting process of money, specie was scarce. Only small quantities that brought from Europe by colonials (Dewey, 2015, p.8). According to Wright (1941), The total coin supply value in 1700 was around \$1,000,000, and in 1775 was approximately \$12,000,000 (p.167). Officially, the United States, as in the UK, began their money system with silver and gold followed this system.

Table 1.5: Selected Europe and US short term interest rates

		England	France	Holland	Sweden	United States
		Decennial Averages %				
19th Century	1st Decade	5.00	5.32	-	-	-
	2nd Decade	4.90	4.49	3.91	-	-
	3rd Decade	3.95	4.01	3.05	-	-
	4th Decade	3.62	4.00	2.87	-	10.64
	5th Decade	3.57	4.10	3.13	-	7.99
	6th Decade	3.84	4.20	3.06	5.09	8.49
	7th Decade	4.18	3.37	3.79	5.53	7.07
	8th Decade	2.96	3.43	3.31	5.00	6.46
	9th Decade	2.57	2.71	2.72	4.17	5.14
	10th Decade	2.09	2.09	2.40	4.55	4.51
20th Century	1st Decade	3.16	2.47	3.10	5.15	4.72
	2nd Decade	3.82	2.68	3.12	5.44	4.72
	3rd Decade	4.26	4.15	3.67	5.10	5.00
	4th Decade	1.32	2.44	1.26	3.06	1.56
	5th Decade	0.83	1.69	1.51	2.80	0.87
	6th Decade	3.09	3.88	1.72	3.52	2.58
	7th Decade	5.80	4.89	3.36	5.08	4.64
	8th Decade	9.64	8.39	5.36	6.41	7.17
	9th Decade	11.46	10.85	6.90	9.31	9.57

Source:(Clapham, 1945, p. 429,430,431; Hawtrey, 1995, pp. 281-297,302; Homer & Sylla, 2005, p. 205,206; Waldenström, 2014, pp. 283–286)

Table 1.6: Long Term Hight Grade American Bond Yields

Federal Government Bonds Selected Market Yields %					
1799	7.42	1833	-	1867	4.97
1800	6.94	1834	-	1868	4.62
1801	6.44	1835	-	1869	4.07
1802	6.02	1836	-	1870	4.24
1803	6.16	1837	-	1871	4.18
1804	6.29	1838	-	1872	3.70
1805	6.38	1839	-	1873	3.51
1806	6.14	1840	-	1874	3.42
1807	6.08	1841	-	1875	3.30
1808	5.96	1842	6.07	1876	3.66
1809	5.85	1843	5.03	1877	3.81
1810	5.82	1844	4.85	1878	3.97
1811	5.95	1845	5.16	1879	3.96
1812	6.12	1846	5.50	1880	3.63
1813	6.30	1847	5.77	1881	3.13
1814	7.64	1848	5.71	1882	2.91
1815	7.30	1849	5.16	1883	2.88
1816	7.25	1850	4.58	1884	2.76
1817	5.86	1851	4.47	1885	2.68
1818	5.78	1852	4.39	1886	2.43
1819	5.90	1853	4.02	1887	2.32
1820	5.16	1854	4.14	1888	2.27
1821	4.57	1855	4.18	1889	2.13
1822	4.65	1856	4.11	1890	2.37
1823	4.72	1857	4.30	1891	2.58
1824	4.25	1858	4.32	1892	2.73
1825	4.32	1859	4.72	1893	2.96
1826	4.50	1860	5.57	1894	2.72
1827	4.37	1861	6.45	1895	2.82
1828	4.48	1862	6.25	1896	3.06
1829	4.50	1863	6.00	1897	2.57
1830	4.37	1864	5.10	1898	2.50
1831	4.41	1865	5.19	1899	2.22
1832	4.45	1866	5.17	1900	2.00

Source: (Homer & Sylla, 2005, p. 282,283,284)

The first coinage act³⁷ defines the silver proportions in the coins. Gold coins, also defined by this act. The ratio of silver to gold was specified as 15 to 1. Later with some arrangements in the gold proportions in the hard money and gold rush in the US and Australia caused the disappearance of silver coins. Until the year 1863, there were hundreds of banks and thousands of banknotes in circulation. United States securities became a pledge of the banknotes with an act issued in 1863, and none of them was legal tender. In 1863 the U.S. government issued Treasury notes to make official legal tender³⁸. The particular side of this notes either any time in the future or on-demand those were not convertible to gold or any valuable mine. However, the government realize the unwanted side effects of notes and started a strict gold-backed period of banknotes in the year 1879. After the twentieth-century, wave bank runs happened, and many banks failed, and the Fed did not provide sufficient cash for the banks due to its policy. After 'Black Friday' government have taken many steps to enrich the cash in circulation, and the gold standard was creating obstacles for new policies. Thus, in 1933, convertibility into gold restricted, and the gold standard was abandoned. However, the United States continued its gold standard by the Gold Reserve Act of 1934, but it is a partial-gold standard since no citizen can demand gold with the dollar. This Gold Reserve Act continues its existence until 1973; after that, the Fed announced pure trust backed fiat dollar.

During the 1970s in the US, populist policies caused a high inflation rate as well as high-interest rates. Since the effect of interventions on the market is significant, this artificial growth in the interest rate in the late 1970s and many other things that came along with the policies mentioned above caused a saving and loan crisis. Following the 1970s, securitization³⁹ increased, and with the help of both government and credit rating offices derivative world vastly increased. After the invention of the synthetic CDOs, credit conditions eased, and therefore, the system has grown much more extensive (Graph 1.1). The deterioration in the lending standards in the US

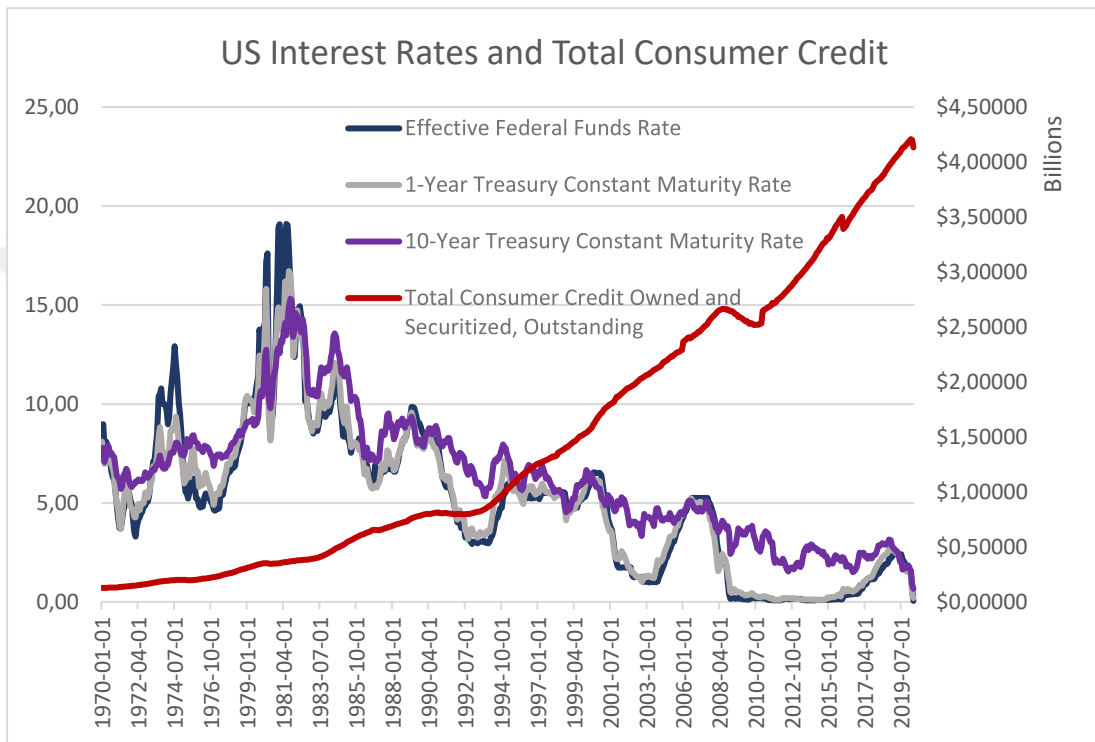
³⁷ U.S. Code (31 USC 5103)

³⁸ 1863 (12 Stat. 709).

³⁹ Securitization is the procedure where an issuer designs a marketable financial instrument by merging or pooling various financial assets into one group. The issuer then sells this group of repackaged assets to investors. Securitization offers opportunities for investors and frees up capital for originators, both of which promote liquidity in the marketplace. See for further details: (Chen, 2019)

caused the 2008 Mortgage crisis, and that caused short-term interest rates to decline to the near-zero bound. Since the short-term rates are close to zero in many developed economies, central banks are in need of policy space.

Graph 1.1: US Interest Rates and Total Consumer Credit 1970 – 2019



PART TWO

NEGATIVE INTEREST RATE POLICY

2.1.Theoretical background for Negative Interest Rate Policies

Central banks intervene in developing or realized events in the market with various instruments in their countries. One of these instruments is policy interest rates, but also known as only interest rates. As the ecosystem's last resort of the money, central banks can lend or borrow money to the market. The interest rate applied to these transactions is also used to influence the market. Central banks tend to control the market, especially during recessions or staginations. Since the demand is limited, to stimulate the economy, in some manner, to revive the economy, Central Bank

lowers the interest rates. Mankiw (2009), in his article, argued that lower interest rates would encourage people to spend on goods and services. Thus, one economy simply can escape from any recession and revive if it is a demand-side shock. In his work on the monetary policy at the zero lower bound Ullersma, (2002) emphasizes the importance of this subject and argues that supply-side shock, trust, and demand would play a crucial role in the interest rates when they are hitting the zero bound.

Arteta et al. (2016), in their work, specified the main issues behind the negative interest rate policy. According to authors, stabilizing inflation expectations, supporting growth, and easing currency pressures are the main reasons why central banks go under zero lower bound. These reasons stem from the need for additional policy space to a central bank when the markets face:

‘Continued growth disappointments, depressed inflation expectations, and declining real equilibrium interest rate... two additional considerations were the narrowing pool of assets eligible for their purchase programs and the possibility of diminishing returns from Q.E.’

The authors emphasize the importance of the adaptation of these policies and advise that such policies should be handled carefully while considering the benefits and possible drawbacks. Since the negative nominal interest rates both eccentric and unfeasible as the nature of money, therefore this concept has attracted interest from both policymakers and academics. On the subject of negative interest rates following works are examined.

To our knowledge, Gesell (1916), in his work⁴⁰, proposed stamps for printed money for every month, and further, he suggested 5.2% interest equivalent dues on money per annum. Keynes (1936) argued that Gesell’s work is incomplete. Further, Keynes adds:

‘Money is not the only item in an ecosystem that hold liquidity premium, and possible implication of Gesell’s proposal would push people to buy other item that hold liquidity premium such as foreign currency, jewelry, and precious metals.’

⁴⁰ Original name of work is that; Die natürliche Wirtschaftsordnung durch Freiland und Freigeld. Originally printed in 1916 in Bern then translated by Philip Pye in 1929 and reproduced in 1958 in London.

Fisher (1933), in his book, defines and argues that this stamp scrip might be useful in such scenarios that recession or stagnation due to the features of this stamp scrip as he defined as:

'Stamp Scrip is, as hitherto used, a temporary substitute for a part of the regular currency which has deserted. It is small in amount and short in duration...The two points about Stamp Scrip are: First: It is like money because it can be banked OR invested OR spent. Second: It is unlike money because IT CAN NOT BE HOARDED...Thus, the stamp is more like a tax on hoarding than a sales tax.'

In his book, he even included a real-life implementation of this Stamp scrip as Gesell proposed an appropriate substitute for money.⁴¹

After a while, Thornton (1999) argued that negative nominal interest rates could exist and in such an environment that individuals and investors would be willing to accept it because holding money in a bank would be cheaper and less risky than transporting and storing by themselves. Summers (1996) suggest that the inflation target should be *modus operandi* for any central banks even in the zero nominal rates, and up to 3 percent inflation target may be enough to decrease the possible risk from recessions. Tetlow & Williams (1998) conclude that the expectation of future inflation, if well managed, can be useful.⁴² Krugman (1998), in his work on liquidity trap, argues when nominal interest rates at or near zero, inflation target can be used to reduce the real interest rate, therefore to have the prior level of output in the economy. Bernanke et al. (2004) have examined the effectiveness of unconventional monetary policies at the zero lower bound in so-called regular times for an economy; particularly, they focused on the U.S. and Japan. They use three policy alternatives to measure the effectiveness, which are: forward guidance, increasing the balance sheet of the central bank, and altering the composition of the balance sheet of the central bank. They find evidence that alternative monetary policy options are capable of affecting future expectations, not just only the interest rates but also the level of future price.

McCallum (2000) argues that a central bank should employ monetary stabilization policy via the foreign exchange market in a situation that zero levels on

⁴¹ See for further details Cohn, H. R. L. (1932, August 10)

⁴² See for further details (Lars E.O. Svensson, 2010)

the nominal interest rates have been faced. On the subject of zero lower bounds, Goodfriend (2000), in his study, he proposed 3 three possible solutions for the zero lower bound of nominal interest rates, which are *'a carry tax on money, open market operations in long bonds, and monetary transfers.'* First of these solutions, imposing a carry tax on the money as Gesell proposed, tax per period or currency, and for the bank reserves at the central bank. Further, he adds on this subject:

'When short-term interest rates are pressed against the cost-of-carry floor, the carry tax would anchor the short end of the yield curve much as the intended federal funds rate does today in the United States. A carry tax on currency could supplement the carry tax on electronic reserves by creating more leeway to make interest rates negative.'

For the second and third solutions, the author suggests quantitative policy and emphasize this policy could promote spending by creating liquidity at the floor of the interest rate. The author also argues that when imposing such policies, the Central bank would require more help from the fiscal side to achieve an effective quantitative monetary policy.

Buiter & Panigirtzoglou (1999), in their work on liquidity traps, they suggest two optimal solutions. First of their solution using expansionary fiscal policy, and the second one, which is the interest of this thesis, lowering the nominal interest rate floor. Their proposal involves the Gesell solution that is imposing a tax on currency. Stamping currency by giving them new marks to circulate again in the economy, creates a relatively negative interest rate. Therefore, with negative nominal interest rates, they argue that the possibility of ending up in a liquidity trap would be reduced. They argue that even if in an economy that in the liquidity trap, imposing such a solution would pull out the economy from where it is.

Buiter & Panigirtzoglou (2003) suggest two models for the problem of zero lower bound on nominal interest rates when they are proposing a solution for the liquidity trap. The first is old-Keynesian, and the second is the New-Keynesian approach. They suggested that removing the zero-lower bound on nominal interest rates in the old-Keynesian approach, as Gesell (1916) proposed, paying negative

nominal interest rates for currency⁴³ and commercial bank reserves at the central bank. In line with Goodfriend (2000), they have concluded that a carry tax much simple for bank reserves complicated and awkward for currency. For their second approach, they specify that the Gesell approach could be more effective rather than *‘a policy of minimising the risk of hitting the zero lower bound by keeping the inflation target and the inflation rate sufficiently high.’*⁴⁴

Fukao (2005), in his work on Japan economic issues, i.e., deflation, argues that because of the zero lower bound of nominal interest rates, the traditional methods are not as effective as they do in the past. Since this is the situation, he says:

‘In order to cope with this unusual situation, a non-traditional monetary policy measure is proposed. A negative nominal interest rate is needed to clear Japanese markets and can be achieved by levying a tax on all the government-guaranteed yen financial assets.’

In order to through the zero-lower bound, he suggests the implementation of a modified version of Gesell’s currency tax as a contemporary case. The author suggests that the Bank of Japan should do open market operations and buy all securities such as exchange-traded mutual funds and real estate investment trusts. The author further suggests that since the open market operation not sufficient enough to solve the deflation problem, there should be levy tax, just above the deflation rate, on all government-backed assets. Also, rather than the stamps, the author suggests taking a fee while changing old banknotes with a new one.

Eisler (1932), in his work, stable money, suggests a double money system. By separating the medium of exchange (legal tender) function of money, means of accumulating capital (store of value), and measure of value. Further, he suggests the store value of money and measure of the value of the money should be undertaken by money banco⁴⁵, and current money (physical cash) can be the legal tender. Also, the author suggests an exchange rate between these monies, which is specified by the cost-

⁴³ Including cash in vaults.

⁴⁴ See also work of Bryant (2000) and Freedman (2000)

⁴⁵ Money, which is not physical, bank money in other terms electronic money or central bank cryptocurrency.

of-living index. By doing so, the stable prices are targeted even in the expansion of credits. The main goal is that stabilizing the general price level and the national purchase power of a currency. The author emphasizes the importance of the international part of this theory '*... there is no way of stabilizing nationally the general price-level or reciprocally the purchase power of a national money*'. Then explain his conditions on the matter;

'The first condition for the stabilisation of the general price-level and of the national purchase power of a currency is the international stabilisation of the exchanges through the parallel, proportionate and synchronic development of production and consumption in the various countries by means of proportional supplementary budgets and the preliminary exchange of mutual stabilisation credits'⁴⁶. If these indispensable conditions are realised by international treaty, the simultaneous application of the tabular standard in each country is the necessary complement of the measures stated. Since all previous experiments with index-currencies cannot be used as an argument against the possibility of organizing an expandable currency of monetary units with stable purchase-power by means of a logical co-ordination of the three above-explained measures.'

Davies (2003), in his work on negative interest rates feasibility, emphasize that Gesell's stamp on money can be implemented, and also author argues that previous proposals enough to achieve costless implementation of negative nominal interest rates

'All that is needed is to break the link between cash and the unit of account: a 1,000-yen note would no longer be worth 1,000 yen. Alternatively, cash can be replaced with electronic legal tender, subject to a negative interest rate.'

The electronic legal tender is here either the bank money or e-money. This can be created to serve for this purpose, according to the author. Davies (2005), in his work, another implementation method for negative nominal interest rates, proposes that separating the means of payment role and account of payment role of money. Further, he suggests that different monies should carry that separated roles. The author's suggestion for the means of payment role money rather unusual; the author here argues that the means of payment role should be on the local currency rather than a national one.

⁴⁶ (Eisler, 1924, as cited in Eisler, 1932, p.213)

Buiter (2005), in his work on comparing two ideas on the matter of negative nominal interest rate breach, one of them is Gesell's carry tax on currencies, and the other one is that Eisler's Parallel Virtual Currency. For Gesell's proposal, the author emphasizes the difficulty of paying, negative or positive, interest on the currency is that negotiable bearer bond. On the other hand, bank balances and central bank reserves would be easy to pay negative or positive interest. The author further suggests that removing the status of the legal tender of "old-currency"⁴⁷ would be not enough per se; according to the author, there must be a fine for the currencies that are not renewed with stamps. Eisler proposes that separating one money's dominance into two in an economy such as creating a new currency which will hold the means of payment and medium of exchange role of the dominant money. The initial money continues to be numeraire and unit of account but now rather electronic than printed. Since it is easy to put negative nominal interest rates to the electronic accounts when compared with the printed money, this method has been proposed. According to Buiter, Gesell's solution '*seems to be preferable*' due to the complication of other methods.

Buiter (2007), in his following work on numeraire, he pointed out that two problems. The first one is numeraire (a measure of value) used in private transactions, whether to determine and define by the monetary authorities. The second one is whether it is an appropriate objective or not using the numeraire in terms of price stability as a monetary policy. Further, the author also discusses the essence of the next step following the numeraire's separation from the currency. Then asks that is the numeraire changing will affect the zero floor of nominal interest rates or not.

Buiter (2009), in his work, proposes three possible methods for eliminating the zero-lower bound on nominal interest rates. First of them is the removal of currency, which is practically bearer instruments rather, using registered instruments so that interest payments could be easily traceable. The second method that the author proposes is an adaptation of the stamp scrip⁴⁸ (taxing currency) idea of today's technology. The last proposal involves decoupling the numéraire function of currency from its medium of exchange function. Therewithal, the author introduces an exchange

⁴⁷ Unstamped or not renewed

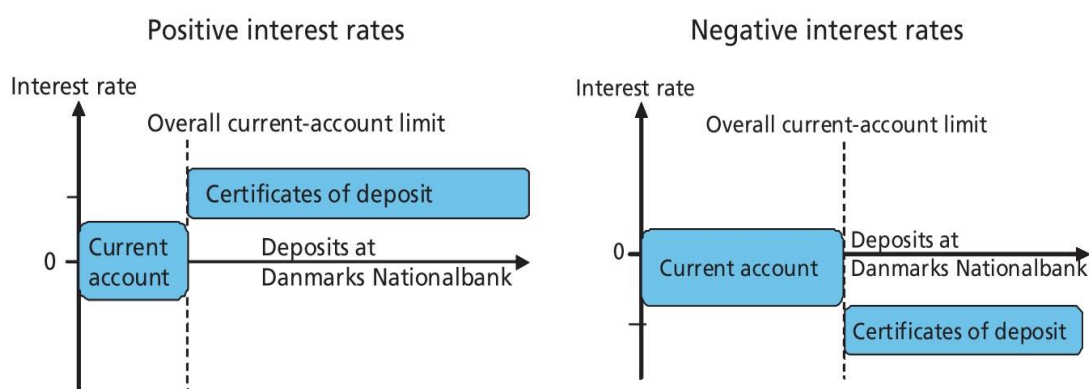
⁴⁸ Introduced by Fisher (1933)

rate between the medium of exchange and numéraire that can be specified by either government or it can be work as market-determined.

Blomquist et al. (2011), in their work they have examined the policy action against the zero lower bound, and rather than the conventional measures, the central banks of selected areas have resorted to new measures, so-called unconventional monetary policies, to provide further stimulus to their territory. These methods involve communication on the expectations about future policy rates and monetary policy and buying and selling securities in the markets. According to the authors, amongst the central banks which have been applying unconventional monetary policies FED and BOE come forward on the success of these policies. However, there are few studies on this subject, as the authors emphasize: *'preliminary findings suggest that they have worked as intended.'*

Jørgensen & Risbjerg (2012), in their work on the Danmarks Nationalbank's negative monetary policy decision, provide valuable insights, and describes the transmission mechanism of the negative nominal interest rates to the market rates. Danmarks Nationalbank uses three instruments to manage its accounts, namely, current accounts, open market operations, and current account limits. Graph (2.1) shows the visualized version of the operations during the first launch of negative interest rates.

Graph 2.1: The Adjustment of Monetary Policy Instruments at Danmarks Nationalbank



Source: (Jørgensen & Risbjerg, 2012)

Summers (2014), in his work on the U.S. Economic Prospects, argues that the problem is not fixing the minor issues; rather, the problem is '*secular stagnation*.' According to the author, the long-run effect of the short-run developments causes this negative anticipation. Besides that, as the negative nominal rates rest on the zero limits, it restrains the policy space. On the problems of the author draws attention, he suggests targeting one problem solution at a time, and for the negative rates author argues reducing the actual rate of interest would provide a necessary stimulus.

Köse et al. (2015), in their work on the possible impact of negative nominal interest rates on the economy of Turkey, they argue that if the Turkish economy goes under zero in terms of interest rates, the country would probably end up losing foreign investors that came for the real return.

Agarwal & Kimball (2015), in their work on zero lower bound on the nominal rates of the interest's, emphasizes that there would be no need for eliminating the paper currency when trying to go under zero. According to the authors, breaking through the lower bound of nominal interest rates to stimulate the economy is parallel to going off from the gold standard after the great depression. In their study, the authors have proposed a solution to breach the lower bound of nominal interest rates and introduced a '*time-varying paper currency deposit fee*' among the central bank and the correspondents. Therefore, a central bank can have a crawling-peg exchange rate among the currencies; it has owned such a rate that can be lowered under zero as well as it can go above zero so that a central bank can have another policy tool to manage the market. In his following work Kimball, (2015) suggests that negative interest rate policy not so different from conventional policies when the policy considers 'real terms.' Thus, the proposal of eliminating the zero lower bound can be applied as his suggested model with a two dollar one is 'electronic,' and the other is cash. The separated roles of one currency go into two distinct electronic and paper currency. The unit of account, numéraire, and legal tender should be represented by electronic money for many reasons⁴⁹. The model suggests changing parity between electronic and cash from time to time, as the policy suggests, and this can be done with cash windows that

⁴⁹ See for further details; (Kimball, 2015)

can be specified by the central bank. The author further advises that policy should be explicated to every counterpart of the negative interest rates.

In their study, Jobst & Lin (2016) examined the effect of negative interest rates policy (NIRP) in the European Central Banks' control areas. Their findings suggest that with the negative interest rate policy, the European Central Bank seems to achieve price stability. Therewithal supported the financial conditions' easing and caused minimal credit expansion. However, the authors emphasize the limits of this policy and warn about any further rate cuts that might turn these positive effects to negative. Another work on the negative interest rate policy from Turk (2016) examines the effect of negative interest rates on Denmark and Sweden. Up until the release date of the author's study, the negative interest rates did not affect bank profitability in the working countries. Nevertheless, the author emphasizes the effects of the negative interest rate policy should be closely monitored. Stroukal & Kadeřábková (2016) argue that negative interest rates have led to the housing bubble in the countries that have been applying the negative interest rate policy. Bech & Malkhozov (2016) states that, from the beginning of the NIRP, there is not any critical negativity caused by the negative interest rates; policymaker, however, should watch out for the behavior of individuals and institutions for further negative rates or the time passed in the negative territory.

In their paper, Assenmacher & Krogstrup (2018), on the subject of negative interest rate, argue the practical feasibility of *'decoupling cash from electronic money to achieve a negative yield on cash.'* The main goal of the paper getting rid of the lower bound on the nominal interest rates. In their proposed system, there is no need to remove the cash from circulation, and it does not require significant changes in the current operating system of the central banks. Therefore, in any circumstances, it can be fully reversible. This proposal includes an introduction of electronic money alongside cash. Then some functions of cash should undertake by new electronic money, i.e., unit of account. In order to imply this proposal, cash cannot be a unit of account since it is affecting the behaviors of consumers, and legal tender should be given to electronic money rather than cash. Therefore, the cash reserve conversation rate can be applied. This rate is a basic conversation rate electronic money to cash

specified by the central bank. With this new instrument, Central banks can control the negative territory can, at the same time, prevent the transitions to cash.

2.2. Opening up space for second money in the economy: double money system in one economy

‘The existence of physical cash establishes an “effective lower bound” for interest rates which may compress intermediation margins and hinder the transmission mechanism.’ IMF, 2017

Developed economies have entered a recession and even a crisis after some bank fails in the U.S. in 2008; this event also caused a worldwide crisis. When traditional monetary policy instruments were insufficient to provide a way out, large-scale asset purchases, which we had previously seen only in Japan (Kimura et al., 2002) and thought to be specific to there, were preferred. Along with the large-scale asset purchases, interest rates are reduced to the lower limits.

In this period, short-term nominal interest rates were mostly lowered by central banks in response to the 2008 crisis. However, the decline in long-term real interest rates also existed before this. Globally, rapidly increasing savings combined with the timidity of investments, as well as the reduction of low-risk fixed-income assets, led to real interest rates being pulled down for adequate economic growth (L. H. Summers, 2014). In fact, in the last 30 years, global long-term real interest rates have declined by 450 basis points (Rachel & Smith, 2015).

Prior to the 2008 crisis, it was thought that policy rates should not exceed the zero lower-bound even if they were close to zero, and the lower limit was considered to be the zero band. In the first instance, with the introduction of zero interest rates in 1999 by the Bank of Japan⁵⁰, it was estimated that the lower level could be pulled down beyond zero levels. After adding this event to the literature, other countries acted more

⁵⁰ Central Bank of Japan

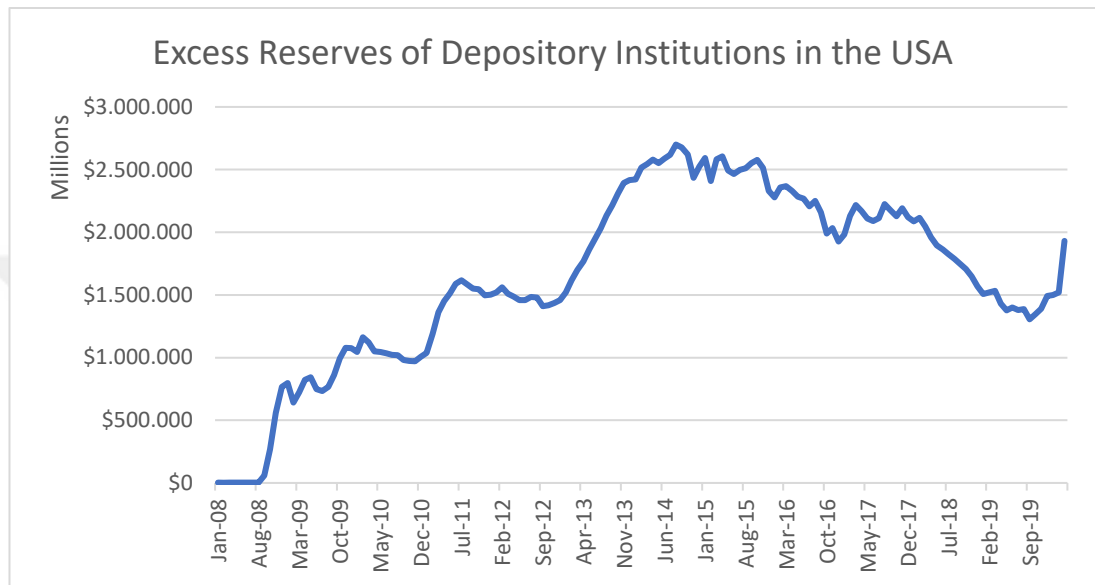
bravely to go beyond the zero lower bound when the financial conditions require that kind of intervene. After the 2008 Crisis, policy rates were brought closer to the zero-lower bound as a solution, and for the first time in July 2009, Riksbank⁵¹ introduced negative nominal interest rates. Following the Riksbank, the European Central Bank (ECB), Danmarks Nationalbank (D.N.), the Swiss National Bank (SNB), and the Bank of Japan (BOJ), due to the expanding area of intervention in the financial markets of their own countries and due to the falling inflation expectations following negative growth expectations, they introduced negative nominal interest rates between 2014 and 2016 (Current rates of these central banks can be seen in Table 1). However, in 1970 the Swiss National Bank, for the first time in history, started to apply the negative interest rate to foreign accounts. In fact, in the late 1970s, negative interests of up to 40% could be observed in Switzerland (Meggyesi, 2010). Since the main purpose here is not to expand the policy area in order to solve any financial crisis rather, the primary purpose is to protect the value of the Swiss franc and prevent the flow of money from outside. Due to the implementation method, this was not considered as a policy expansion for central banks. Nevertheless, they stated in the press statement that: “Negative interest makes Swiss franc investments less attractive,” and that shows us this phenomenon in Switzerland has not lost its effect even these days (Swiss National Bank, 2016). However, it is emphasized that in some quarters, the effective lower limit of interest rates is the zero lower bound. This situation is based on the argument that the central bank keeps the nominal interest rates very close to zero. However, the negative levels can be seen by decreasing the interest rates in real terms by affecting the expected inflation rate (Blomquist et al., 2011).

When central banks announced their decision about the negative interest rate policy, since the policy requires precise attention, we have seen that their reasons for implementation changes amongst the peers. Because in some quarters, negative rates seem like a tax for the cash holders. Therefore, negative interest rates labeled as ‘*wolf in sheep wool*’ since it is not directly taxing and only applied to the excess reserves. In some manner, to push the money into the real economy, it is required. Considering the vast amount of savings in some areas after the Great Financial Crisis, the Quantitative

⁵¹ The Riksbank (Sveriges Riksbank) is Sweden's central bank.

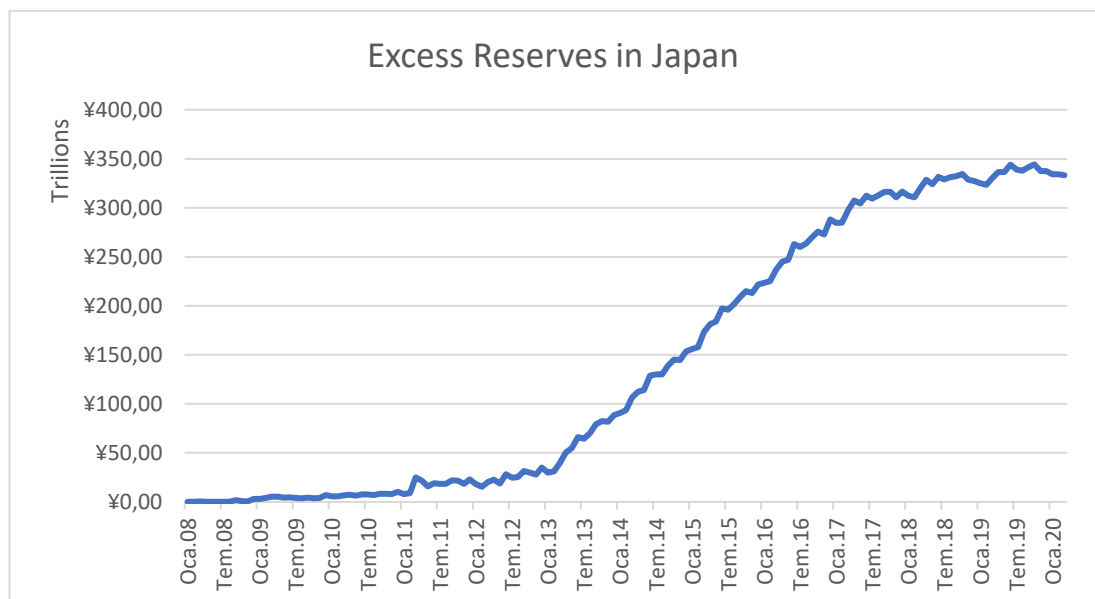
Easing of some central banks contributed to that situation. Excess reserves for the USA, Japan, and the Euro area can be seen in graph 2.2, graph 2.3, and graph 2.4, respectively.

Graph 2.2: Excess Reserves in the USA



Source: (Federal Reserve Bank of St. Louis, 2020)

Graph 2.3: Excess Reserves in Japan



Source: (Bank of Japan, 2020); Author's Calculations

Graph 2.4: Excess Reserves in the Euro Area



Source: (European Central Bank, 2020b)

In the process of implication, negative interest rate policy, low demand, and below the mentioned target inflation as well as protection of domestic currency level considered to act on it, and yet these are not the only reason for the negative interest rate policy implication. Nevertheless, among the reasons for implementing a negative interest policy, supporting the growth takes the lead along with the stabilisation of inflation expectations. On the other hand, as seen in table 2.1, a negative interest rate policy can be accompanied by other measures as facilitating financing conditions and promoting economic activity. Since the policy has an adverse effect on banks' earnings⁵² (Danmarks Nationalbank, 2015), a negative interest rate policy can be used with accompanying policies. However, with the implication of NIRP, a central bank can cause excess reserves⁵³ to be spent on relatively more risky instruments/investments. Demiralp et al. (2017) they study the reaction of euro area banks with a large sample to the negative interest rates through three channels: government bonds, lending, and wholesale funding. Their result shows that banks tend

⁵² See for further details on banks' profits in negative interest rates (Schepens, 2018); (Boungou, 2020)

⁵³ An amount that is more than the minimum reserves that specified by the Central Banks.

to expand their credits, increasing foreign government bonds, and less demand for wholesale funding. In their following study, Demiralp et al. (2019) argue that under negative interest rate policy, banks working differently. According to 252 confidential bank data set in the Eurozone, such as primarily funded by deposits and holding excess loans, remarkably expand their loans to the non-financial private sector when comparing pre-NIRP terms. Indeed, their exclusive work supports the idea that NIRP can be used as an effective accompanying policy for quantitative easing. Table 2.1 exhibits the outline of accompanying policies to NIRP in the Central Banks.



Table 2.1: Accompanying policies to NIRP

Central Bank (policy rate)	Date	Rate	Complementary Policies Announced
European Central Bank	June-2014	-0,10	Targeted Longer-Term Refinancing Operations program with 2- year maturity. Announced preparations for an Asset-Backed Securities Purchase Program
(Overnight deposit facility rate)	September-2014	-0,20	Asset-Backed Securities Purchase Program initiated
	December-2015	-0,30	6-month extension of asset purchase programs. An expanded pool of available assets for purchase, no increase in a monthly amount
	March-2016	-0,40	Expanded size of Quantitative Easing program from €60 billion to €80 billion per month until March 2017, added non-financial corporate bonds to list of assets eligible for purchase, new Targeted Longer-term Refinance Operations program with a four-year maturity
Riksbank (One-week repo rate)	February-2015	-0,10	Forward guidance, SEK 10 billion of government bond purchases
	March-2015	-0,25	Expanded bond purchases to SEK 30 billion
	July-2015	-0,35	Expanded bond purchases to SEK 75 billion
	February-2016	-0,50	Reinvested maturing bonds and coupons from the Q.E. program
Danmarks Nationalbank (One week certificate of deposit rate)	July-2012	-0,20	
	September-2014	-0,05	
	January-2015	-0,20	
	January-2015	-0,35	
	January-2015	-0,50	Suspension of new bond issuance
	February-2015	-0,75	
Swiss National Bank (Overnight sight deposit rate)	December-2014	-0,25	The minimum exchange rate reaffirmed
	January-2015	-0,75	Franc floor abandoned as overall "overvaluation has decreased," if necessary, promises currency intervention in the future
Bank of Japan (Current account deposit rate)	January-2016	-0,10	No changes to existing Qualitative and Quantitative Easing program
Central Bank of Hungary (Overnight deposit rate)	March-2016	-0,05	

Source: Respective National Banks

2.3. Why second money in an economy?

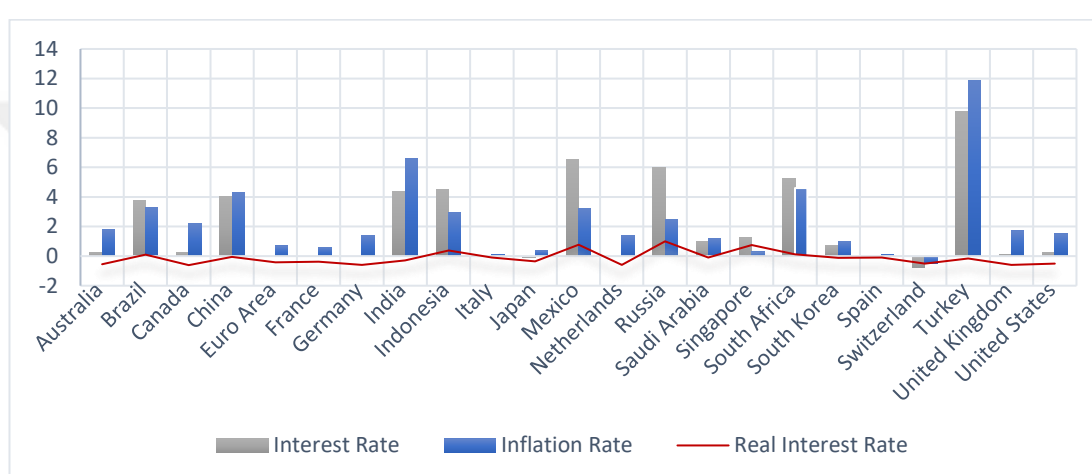
The application of negative interest within the monetary transmission mechanisms confronts possible constraints. For example, the negative interest that should be applied to loans or deposits of commercial or individual accounts can cause a loss of profit on the banks' side, and banks demand additional fees, which may push depositors to return to cash. Negative interests can be prevented by holding cash in this way. However, keeping cash in hand will create a high-security requirement, which means that making and transferring payments with cash brings many risks. In international payments, the cash transfer of money from one continent to another continent will be both perilous and costly. Rostagno et al. (2016) argue that holding money as cash can cost between 0.2 and 1.3 percent depending on the size of the banknotes. Rogoff (2014), in his study, argued that with the abolition of cash money, the lower limit would be removed in nominal interests, and monetary policy could intervene in cyclical changes without restriction. Another aspect that the author emphasizes is that cash is open to abuse for tax evasion; therefore, it is necessary to remove cash from circulation in proactive progress. However, societies may face some difficulties in giving up cash completely. Cash is still of great importance in trade in many countries. In a period when digital payment instruments do not reach universal dimensions, the complete removal of cash will cause considerable damage to the trade. Research on payment methods by the Swiss National Bank in 2017 suggested that there were regional differences in cash use even in Europe (SNB, 2017).

In his study Kimball, (2015) stated that applications should be applied diligently for switching from cash to digital money. He advocates that digital money and cash should not be at the same level (par) in order to accelerate the transition process and to avoid escape from negative interests. He advocates that central banks can be implemented from time to time with the application of a cash window and that this balance can be used effectively in a financial settlement. The author also argues that if institutions clearly understand the negative interest rates, the application of negative interest is rather conventional.

From another aspect of conventionalism of the negative nominal interest rates, in many country nominal interest rates tries to catch up with inflation; if one can simply

put this situation in real terms, it would look like negative interest rates are already in place. If we look at the real interests of countries (Graph 2.5), we would see that the situation, in reality, is not different from what the current proposals are related to negative interest rates. Further, since this is the case, this might cause a ‘Money Illusion.’⁵⁴ Nevertheless, a central bank should undertake the financial inclusion duty and support full transparency.

Graph 2.5: Real Interest Rate Ratio in G20 Economies



Source: Respective Central Banks, Author’s calculation

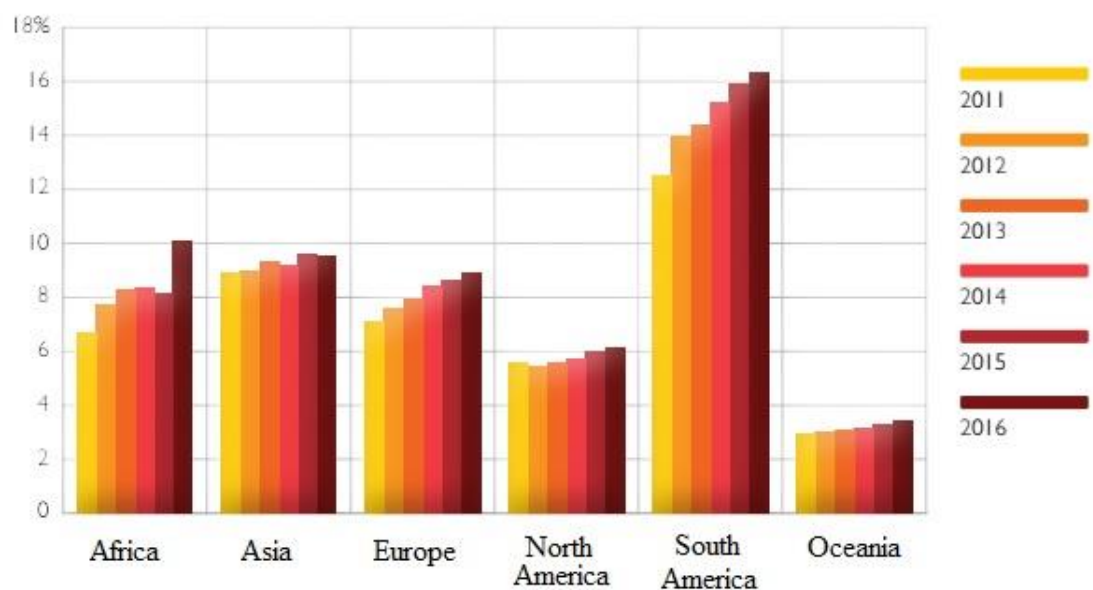
In their study, Bech et al. (2018) stated that demand for cash has increased in developed economies since the 2008 financial crisis. They add this demand for cash stems from ‘*lower opportunity cost of holding cash.*’ Also, they emphasized that only a few societies can live without cash. According to Popovska-Kamnjar (2014), the existence of electronic money in developed countries is confirmed by statistical evidence since they have prior access to all technological advancement. They also specify the current situation of electronic money;

‘Now, the influence is not significant - central banks are recording a very low decrease of currency in circulation as a result of an increase of e-money. But still, having in mind that any innovation takes time to be accepted on the market, in the future central banks and experts need to follow the developments surrounding e-money more closely and more carefully.’

⁵⁴ The term “money illusion” refers to a tendency to think in terms of nominal rather than real monetary values. See for further details; (Shafir et al., 1997)

Digital Money Index, which belongs to Citi and Imperial College London, showed that Finland, in 2019, as the readiest country to use digital money among 84 countries in the world (Citibank, 2019). In the research, the mentioned countries have experienced a 5% improvement in the preparation of digital money in the past five years. In the Global Fintech Report published by C.B. Insights research firm as of the 3rd quarter of 2019, it is stated that financial technology companies that mediated these technologies received an investment of \$24.6 billion as of the 3rd quarter of 2019. Even though those number only represents the cumulative up to the 3rd quarter, it was stated that it exceeded all financial technology investments made in 2017 (C.B. Insights, 2019). Even though technological progress has become widespread and these developments are the substitution of cash in financial payments, the percentiles of cash in total money in the world are still at a considerable level (Graph 2.6).

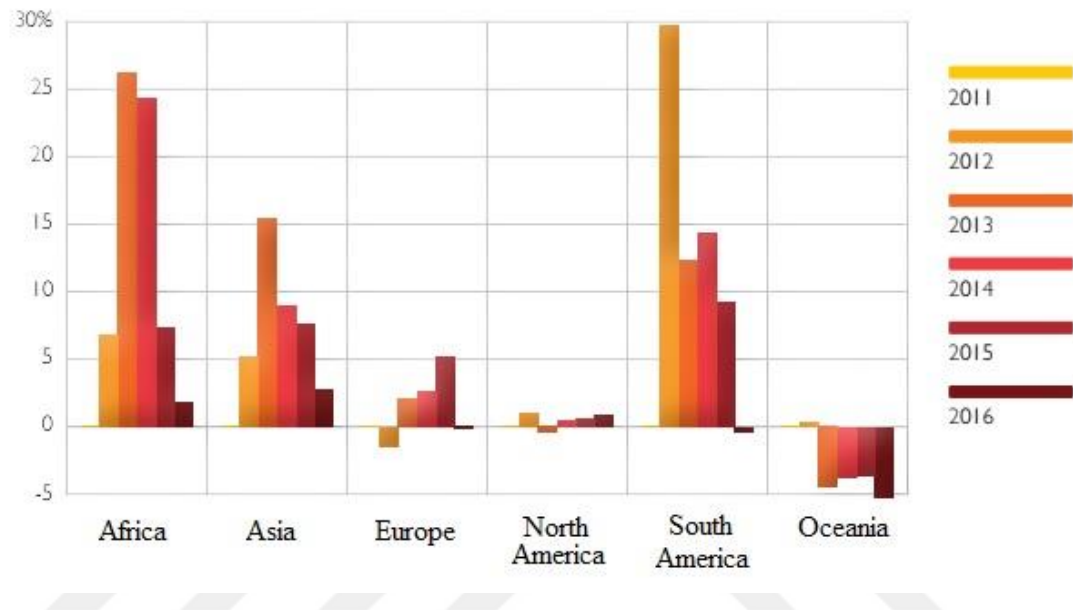
Graph 2.6: Currency in Circulation as of GDP in the World



Source: Boesenach, Knaap, & Vries, (2018)

Another finding of Boesenach et al. (2018) report on world cash shows that withdrawals from ATMs experienced a weighted average positive growth rate (Graph 2.7).

Graph 2.7: The value of ATM withdrawals (value in local currency)

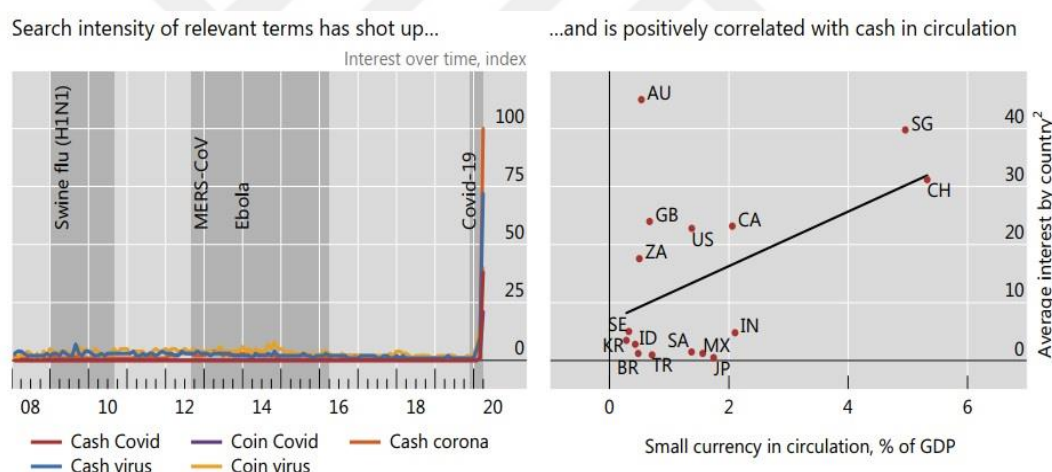


Source: Boesenach, Knaap, & Vries, (2018)

Besides, in some countries, cash payments are used to protect their privacy, although there is sufficient infrastructure to go cashless society. Cash has another feature, which is entirely independent of digital systems. Even if there is a power cut in the whole country, one can continue to live with cash, and it can prevent the trade from stopping altogether. In their study De Almeida, et al. (2018) identified possible problems that may be encountered by cashless societies under four categories. In addition to problems such as infrastructure problems, the collapse of payment systems, overcoming power supply interruptions have been identified as one of the biggest problems. According to the authors, '*electricity production and supply infrastructure is the most vulnerable*' any harm to electricity production and supply causes significant damage to all infrastructure. Transformation to the cashless system, therefore, requires both natural and supernatural precautions. In his study, Cheney (2006) states that before hurricane Katrina, over 70 million dollars of cash were sent to the region by the FED in order to keep financial needs intact.

In late 2019 the world has witnessed a novel virus that named as SARS-COV-2⁵⁵ that causes Covid-19 disease. The Covid-19 pandemic has created enormous panic among the people, and a crisis has occurred stimulated by the SARS-COV-2 virus. In order to prevent the contamination of the virus, countries from all over the globe applied quarantine. After these rough measures, economic slowdown or sudden stops would follow⁵⁶. After that, governments take economic responses to limit the effects of the crisis caused by the virus. IMF has created a tracker for the policies initiated by the governments to combat the global Covid-19 disease crisis (IMF, 2020). This pandemic has also led to society's concerns about the transmission of the virus through cash. In their work, Auer et al. (2020) have shown the public interest in search engine data (Graph 2.8).

Graph 2.8: Search Intensity of Viruses and Cash Usage



Source: (Auer et al., 2020)

The search intensities during the time of recent pandemics have shown on the left side. When compared with the Covid-19 epidemic with the other pandemics, Covid-19 indisputably caused people to search more than ever. Cash and COVID duo have created a bad image in society; due to this reason, people would likely search

⁵⁵ Severe acute respiratory syndrome coronavirus 2

⁵⁶ This chapter written in May of 2020.

more. On the right-hand side of the graph, the countries in question show more search intensity on this subject if the daily transactions are based mostly on cash because of the concerns about the virus.

According to recent research by Kampf et al. (2020), '*coronaviruses can remain infectious on inanimate surfaces for up to 9 days,*' and on paper, this can go up to 5 days. In many countries, central banks are putting efforts to mitigate these effects of the crisis and have announced several precautions. Bank of Canada (2020) has announced '*Safe handling*' related to cash and suggested to clean the polymer banknotes with soap. Central Bank of Kuwait (2020) announced that used banknotes will be stored for four weeks before going to circulation again. National Bank Of Georgia (2020) suggests that after contact with cash, hands should wash adequately, and if possible, non-cash, contactless, and mobile payments should be used. Oesterreichische Nationalbank (2020) states that there is no evidence that cash spreads the virus; however, 5 and 10 euro banknotes are coated with a protective varnish to prevent contamination. People's Bank of China (2020) announced that to provide clean cash from the virus, the bank will sterilize the money before putting into circulation again. Reserve Bank of India (2020) stated that people should avoid using cash and use non-cash digital payment options. After the pandemic influence on the public, The Reserve Bank of New Zealand (2020) states that '*businesses are not obliged to accept cash, but declining it may end up disadvantaging people who rely on its use.*' South African Reserve Bank (2020) states that currently, no evidence shows that the Sars-Cov-2 virus is transmitted via banknotes and coins. However, the bank encourages people to wash their hands often. Bank of Korea (2020) stated that when the notes arrive at the central bank, they put them into a process to sterilize as well as the bank will keep the banknotes for two weeks before putting them into circulation again. Nederlandse Vereniging van Banken (2020) increased the contactless payment limit of the card users from 50 euros to 100 euros. The bank also states that these measurements will be beneficial for both sides of the trade. Cseresnyés (2020) stated that billions worth of banknotes are being taken out from circulation each day by the Bank of Hungary, and the bank keeps the banknotes for two weeks prior to putting

into circulation. Bank Indonesia (2020), encouraging the use of non-cash payment. Banco de Portugal (2020), have taken measures to promote card-based payments.

According to one study conducted by the Bundesbank, payment behavior changes amongst the people, and contactless payments become the new norm (Deutsche Bundesbank, 2020). In a recent blog post of Fabio Panetta⁵⁷, he specified that European customers want more secure, lower cost, and user-friendly systems more than ever. The author also says that the ECB endeavor to supply electronic payment infrastructure to fortify its influence on the markets. Following these, the author adds the followings:

'The ECB is also exploring possible future avenues by assessing the case for issuing a "digital euro." A high-level task force is currently examining the pros and cons of introducing a digital currency, which could be used by intermediaries or even by citizens through their electronic devices (such as smartphones or tablets) for their day-to-day spending needs.'

Even though the ECB is exploring a central bank digital currency, it is still early phase, and according to the author, they will be inclusive on this matter (Panetta, 2020).

During the time of crisis, the demand for U.S. currency often increased as the U.S. currency perceived as a reserve currency (Judson, 2012). Regardless of scientific evidence on banknotes being a medium of transfer of viruses, the effect of this ongoing crisis on people may alter the attitude towards cash. Besides that, the current crisis can cause the storage of banknotes owing to they have cleaned⁵⁸. Further, the crisis will have an impact on people's payment habits⁵⁹; eventually, societies will modify their daily practices of payment relating to cash. To such an event like moving away from cash, central banks should be prepared because abandoning cash can cause significant risk. Since the cash is inclusive, and even the people who do not have a bank account can hold the cash, this may harm the unbanked people. According to data from the U.K., the transition may have begun (Graph 2.9), and people may have gotten used to

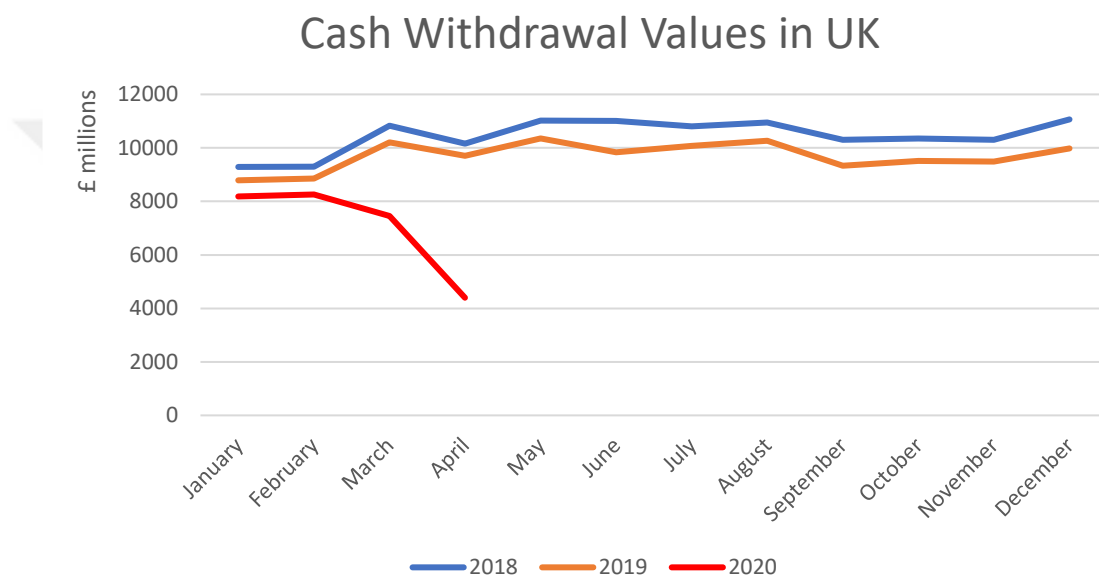
⁵⁷ Member of the Executive Board of the ECB

⁵⁸ See for the people's reaction to dirt banknotes; (Lomsadze, 2020), (Hall, 2020)

⁵⁹ See for further information from the very first country that trying to go normalise; The implications of this pandemic in China, and paths to recovery; (Huang, et al. 2020)

this situation (Hearing, 2020). Before the current crisis in 2019, The Riksbank made an announcement about the legal tender concept. As cash usage decreased in Sweden and the general concern is that this situation can eventually affect the efficiency of the payment system. The Riksbank proposed a committee that will gather to review the concept of legal tender (Sveriges Riksbank, 2019).

Graph 2.9: Cash Withdrawal Values in the United Kingdom



Source: (Link, 2020)

Regarding emerging situations all over the globe, one central bank cannot dismiss the advancement that comes with disruptive innovation⁶⁰. Since the first coinage, cash became undeniably a part of our lives. As the coins excel over the other materials that are used to make the trade, the future seems to dominate the cash. By the time, cash will evolve to a digital version of itself. Therefore, the Central Bank Digital Currency can be the initial step of this evolution. Since the global money transfer system goes into a blockchain base⁶¹, denial of this situation may harm or do not contribute to the progress of the country. Regarding this situation, it will be much more convenient to switch to a dual currency system rather than giving up cash entirely

⁶⁰ As it can be creative destruction, this situation can be related to psychological egoism too since most people act in the best interest of themselves.

⁶¹ A company who provide infrastructure services to companies as American Express, Money Gram; Ripple <https://ripple.com/customers>

because it will be challenging to put it into circulation for any reason after the cash is eliminated.

Further, even if we decide to remove cash starkly, we need to do it with tiers due to the daily habits of societies. Such as Rogoff's proposal involves removing large banknotes from circulation (e.g., \$100 note). As specified in Agarwal and Kimball (2015), '*a transition to a cashless monetary system could easily take decades.*' ECB, in a press release, announced the discontinue production of €500 in the Europa series⁶². The reasons for the termination of the large denomination as follows:

'It has decided to permanently stop producing the €500 banknote and to exclude it from the Europa series, taking into account concerns that this banknote could facilitate illicit activities.'

Considering the cash transaction limits, one can reach this restriction payment in cash with one banknote in Greece. The limits range from €500 to €15000 in some countries in the E.U. (Centre for European Policy Studies & Ecorys, 2017), and this limit in cash transaction in the USA is \$10000 (IRS, 2020), and in Turkey, it is ₺7000 (G.İ.B. 2015). Regarding the restrictions, we should not have any large denominations since they make it easier to elude from these restrictions.

Beginning of the negative interest rate policy and enabling the CBDC, the central bank must ensure that currency in circulation is shortened. Since large denominations can be used to store money and in the underground economy, there are too many illegal activities such as bribes, drug trafficking, hiring hitman-hacker, and money laundering. Besides the people who are in a part of the underground economy somehow, companies and ordinary people use this situation for their benefit with tax evasion. For instance, companies hire people without any contract, especially immigrants who do not have any visas to work in the country, or some transactions can be done in cash without an invoice from two sides. When the matter comes to individuals, almost every purchase is open to tax evasion, from the local grocery store to the babysitter of the family or the cab payments. Elimination of cash as can create

⁶² The Europa series is the second series of euro banknotes, which is being introduced gradually, starting with the €5 in 2013 and followed by the €10 and €20 in 2014 and 2015, respectively.

many cultural problems as well as during troubled times such as storms or earthquakes, everyone needs some amount of cash.

2.4. Operating Framework of Negative Interest Rates

The system that involves both cash and electronic money may exist with some modifications of our conventional system. In this section, we are going to discuss the system with negative interest rates and try to demonstrate how it would work. In one economy, a double money system may create questions regarding regulation and banking act; however, these issues will not be addressed here due to the scope of this thesis.⁶³

Without eliminating the cash, the government can create second money to expand its control over financial stability because the abolition of cash can cause many problems that we tried to cover above. Besides the issues that we have mentioned, people can try to hide cash and create a black market for it. Up until now, we have seen some of the illegal works carried out with cash, and the abolition of cash can cause many unwanted problems in an economy. Rather than eliminating the cash all along, governments can discourage to use of cash; as we discussed above, many proposals have been suggested on this subject. Such as Gesell (1916) suggested regularly stamped the money and that stamps can be bought from government offices. Fisher (1933) suggested temporary money as a stamp scrip during troubled times. Goodfriend (2000) proposed a carry tax on cash so that the central bank can imply a negative interest rate. Mankiw, G, (2009) mentioned a proposal from one of his lectures' student: *'while banks are applying negative rates to the reserves, FED announces some series and all currency within that serial number would no longer be legal tender'* which involves lottery scheme. In the work of Eisler's (1932) stable money book, the author suggests a double money system by dividing the functions of money into two. By creating paper currency and bank money (electronic money) and with the bank money as a unit of account makes it possible for depreciation of paper currency compared to bank money. Buiter (2007,2009) revitalized the proposal of

⁶³ See for the system that involves more money than one; Blanc (2018) ; See for further details of legal issues in cryptocurrencies and monetary system Sapovadia (2015); For Virtual Currencies legal frameworks Part 3 of Kotane (2018) can be read;

Eisler (1932) by suggesting a more streamlined proposal that involves a negative cost on cash. Agarwal & Kimball (2015) proposed a system that can work with two money. Assenmacher & Krogstrup (2018) went further on the current proposals and suggested some practical issues. As emphasized in Assenmacher & Krogstrup (2018), negative interest on the digital accounts can be set equal to the negative yield on cash with the CTC conversion rate;

$$i_t = [360 * (CTC_{t+d} - CTC_t)] / (d * CTC_t)$$

Where the i_t denotes annualized yield on cash, and d is the time units of adjustments between the CTC rates.

A central bank would have two monetary bases to control the market, one of them for cash, and the other one is for digital money (Coin). Once a central bank has two money in its system, it is much easier to enable negative interest rates. Let us say a central bank wants to enable the negative interest rates to stimulate spending when defending the demand shock. Since the coins⁶⁴ are all electronic, when the central bank announces negative interest rates on coins, let us say -1% per year fixed rate, starting from the first day of the announcement, cash to coin conversion rate will begin with par. The CTC rate initially starts from par, which $CTC_0 = 1$; thereafter, the central bank can announce that the yield on cash will be equal to the negative rates on accounts. The first day's CTC ratio can be calculated as;

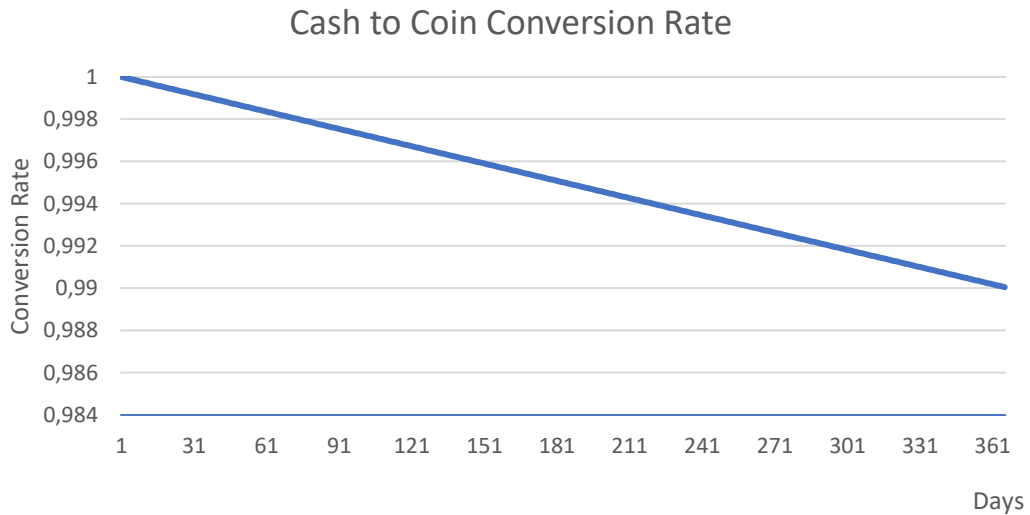
$$CTC_1 = \frac{1}{\sqrt[360]{1-0,01}} = 1.00002. \quad ^{65}$$

As the days pass by, the cash to coin conversion rate will decrease, and after one year from the announcement, one TRY (Turkish lira) would be converted to 0,99 Coin. However, this process will be gradual, and once the conversion rate is applied, it will be effective immediately. For instance, after a month from the beginning of negative interest rates, it will be equal to 1,0008; when a bank needs cash, it applies to a central bank to meet the demand of its own, the bank will give 1000 coins to the central bank, and in return, it will take roughly 999.2TRY from the central bank.

⁶⁴ Represent all the electronic money in the system.

⁶⁵ Year days taken as 360.

Graph 2.10: Cash to Coin Conversion Rate



Source: Authors own elaboration

In an economy, if there will be two money, the legal tender should be pre-specified since, from tax payments to lease contracts, uses the legal tender. The change in the legal tender requires some alteration in the money act and banking acts to have an effective policy result. These changes depend on the country's structure of the legal base, institutional, and cultural substructure. To establish such a system requires to separate the functions of money. Money has three main functions; first, money serves as a medium of exchange⁶⁶, the second store of value⁶⁷, and lastly, the unit of account⁶⁸. Coin (digital currency) should undertake the medium of exchange and the unit of account functions of money. Since these functions are crucial in an economy, if we do not separate the functions, cash will dominate the digital coin even if we increase the CTC conversion rate. Therefore, it would be ideal when the coin is the measure of goods and services. Since the unit of account function affects people's behavior, even

⁶⁶ Money acts as an intermediary to make it easier to purchase things rather than barter with something you have. The supplier takes money in exchange for a good or service. Herewith, a medium of exchange function of money emerges.

⁶⁷ When people gave up spending today and hold the money of their own, they save a value. A value that buys goods or services when they need to.

⁶⁸ As a unit of account, money makes measurable so many things in life such as the price of an island or a good spa in exotic places, and thanks to this function, we can keep precise financial records.

in thinking to save and spend, that will contribute to the policy. From lease contracts to price tags in the markets, people should see the coin's sign to ensure the system will work properly.

The CTC conversion rate will apply whenever one wants to convert cash to foreign currency so that any arbitrage from the market of foreign currency would be prevented. Therefore, there will be no need to restrict cash access or to ban the usage of cash when converting to foreign currency. As we know from history, in the economy, goods or services cannot limit or prohibit; it just forces that to alter the market, and so the same products or services go to the black market/underground economy (Goldberg & Karimov, 1997). Black markets would respond to the situation of cash⁶⁹⁷⁰ immediately since they cannot resist any opportunities from illicit works (Kabir Hassan et al. 1995).

Negative yields on the coins should be equal to the cash to coin conversion rate so that there will be no trading opportunity. Besides that, the central bank can increase/decrease this conversion rate according to the market movements, if at the beginning, CTC would be set slightly above from negative rates, which would prevent hoarding of cash. One suggestion was the annually announced cash to coin conversion rate, as we mentioned above, and almost equal to the negative yields on the digital currencies. In the market, the central bank should ensure that the demand elasticity of cost⁷¹ stays elastic form rather than inelastic. In other words, a central bank can use pre-announced rates as well as can alter the cash to coin conversion rate according to the demand. To combat with hoardings, the central bank intervenes in the cash market, and rather than restrict access to cash; the central bank can increase the cost of cash. By doing so, the central bank can effectively respond to market demand and controls the market. After abandoning the '*gold standard*'⁷² in the monetary system, everything became related to the reputation of a central bank. The reputation of a bank stems from

⁶⁹ See for one example of this restricts; (Reuters, 2020)

⁷⁰ See for further readings on black market history; (Winton, 2018)

⁷¹ Since holding cash is not to bring '*naturally*' zero nominal return.

⁷² A gold standard uses gold directly or indirectly as money. In this passage, the gold standard represents indirect use rather than direct use of gold in transactions. In the monetary system, the gold standard means that use representations (banknotes, bills, etc.) of gold are used in exchange.

the trustiness of the same bank. Without a clear communication channel and transparency, a central bank cannot be trusted entirely. It is essential that understand the nexus between the financial system and trust, therefore, act regarding this situation since trust establishes the fundamental of the financial system.

In such a system, if the community participates in this policy with full understanding, assuming country-level financial literacy is high⁷³, the in-question policy will be much more effective. Enactment of negative interest rates might cause panic and hoarding at the beginning, and it is easy to understand societies tends to panic when they have come across something they do not know. If the central bank announces the annual conversion rate, that establishes trustiness in the society because people will know what will be the conversion rate one year hence or one month hence. Therefore, even if there are any panic transactions, which eventually can become bank run⁷⁴, based on this uncertainty of negative rates, these panic movements would be prevented with a clear communication channel that is established onto the negative interest rates.

In his work on the monetary system, Borio (2019) stated that:

'The (monetary) system hinges on trust. It cannot survive without it, just as we cannot survive without the oxygen we breathe'.

If the fundamental of the system cannot achieve by the central bank, that may lead the society to hoard some valuable assets, therefore, can cause severe damage to the financial system. This situation may require some precautions as the U.S. did in 1933, forbidding gold to the public in all manners⁷⁵. However, this is the opposite of the expected outcome of the policy. We have seen substitution in the payment means during the high inflation times in some countries. Also, in some states, it was observed that foreign currency was used as a sovereign store of value. Nonetheless, according

⁷³ If this is not the case, the central bank needs to ensure that policy clearly understood by most of the society before enabling the negative interest rates.

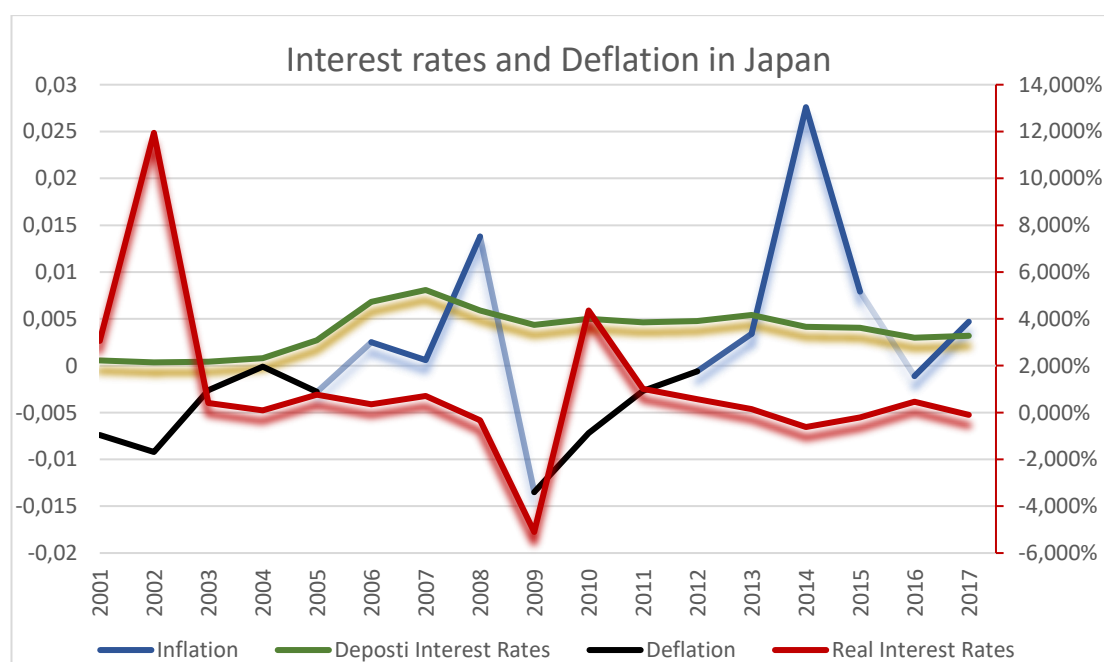
⁷⁴ A bank run occurs when a flood of depositors withdraws funds from a bank within a short time frame (Merriam-Webster., n.d.).

⁷⁵ See the repeal of this presidential executive order by the president of the period Gerald Ford; (93rd Congress, 1974)

to Borensztein & Berg (2000), ‘Countries are likely to be reluctant to abandon their currencies, symbols of their nationhood, particularly in favor of those of other nations.’ We even see the same reluctance in countries that joined to Euro union in 2002. In 2004 European Commission conducted a survey, and results show that %25 of the participants are using national currencies during the daily transactions. Therefore, it would be hard to leave the local currency all of a sudden. If the central bank established a clear communication channel, the effect of which will be prevented (European Central Bank, 2005; Mastrobuoni, 2004).

The system that we try to cover here is not that much differs from the conventional policies. Such as today's world, if one economy experiencing depression, even if the interest rates are negative, one can still make a profit in real terms. For instance, in an economy that is shrinking and experiencing deflation by 2 percent, if the interest rates are at the 1 percent negative level, one can earn 1.02 percent in real terms, as shown in graph 2.11, Japan’s historical evidence support what has been arguing. Therefore, the negative rates are can be the option when the system is required to take action.

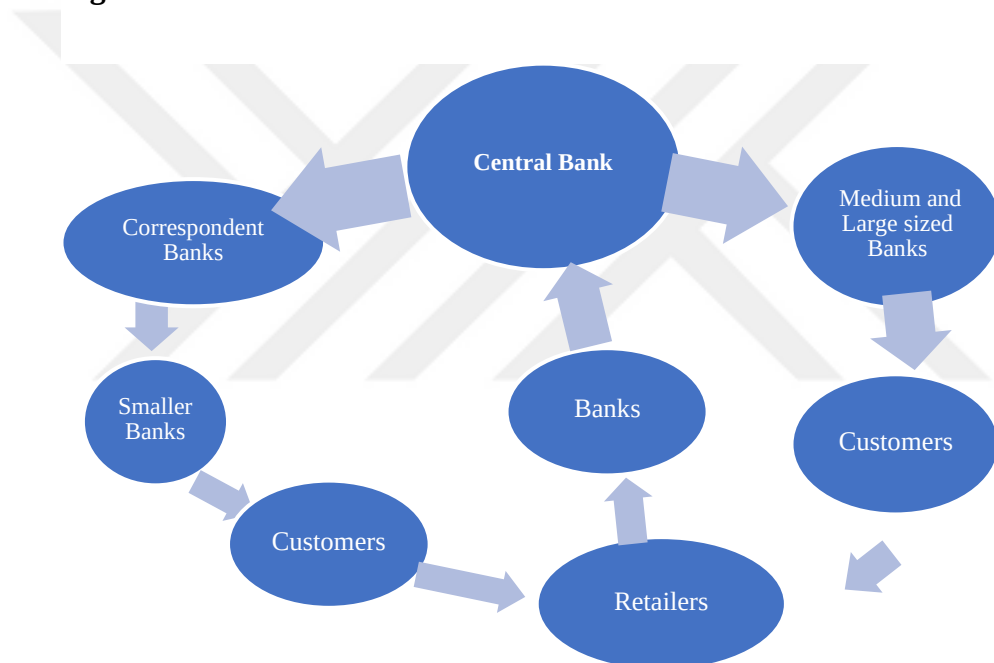
Graph 2.11: Deflation and Interest Rate in Japan



Source: IMF, Bank of Japan, and Author’s Calculations

During regular times, cash circulation in an economy changes according to the seasonality or the day of the months. As can be seen in figure 2.1, to meet the variable demand, Banks get cash from the central bank, and banks pay for the cash from their reserve accounts in the central bank. Some smaller banks cannot get cash directly from the central bank yet; in this case, they can get the cash through the '*Correspondent banks*' with a fee, and when the demand for cash decreases, banks deposits back these extra amounts of cash in the central bank.

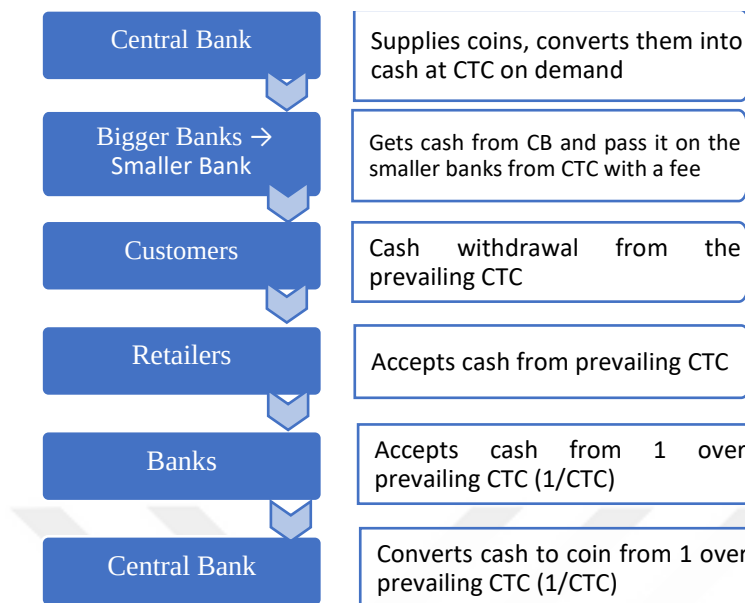
Figure 2.1: Cash Circulation Scheme



When the central bank initiated the negative interest rates policy, this scheme will be a bit different. As can be seen in figure 2.2, the central bank supplies cash and provides to the banks from the prevailing CTC rate. Customers get the cash from the branches of the banks or the ATM's⁷⁶ from the prevailing CTC then use their cash to receive goods or services in the retailers. Then the cash circles back to the central bank from the 1/CTC (current rate).

⁷⁶ Automated Teller Machines

Figure 2.2: Cash to Coin Rate in the Market



2.5. Effectiveness of the policy

After the introduction of the negative interest rates, one of the main issues discussed mainly was the effectiveness of the policy. The initial findings of the countries that have experienced negative interest rates are promising. The negative interest rate policy indicates, in general, positive effect via interest rate and credit channel, asset valuation and portfolio channel, and the exchange rate channel (Blanke & Krogstrup, 2016; Jobst & Lin, 2016; Viñals et al., 2016). In a blog post, Ben Bernanke emphasized that the real interest rates are already negative in the U.S., and that causes misleading in the economy. The author adds, *‘Overall, as a tool of monetary policy, negative interest rates appear to have both modest benefits and manageable costs’* (Bernanke, 2016). According to Tokic (2017), *‘Central Banks are forced to lower the short-term interest rate to a certain level below the long-term interest rate to create a highly accommodative yield curve spread during recessions.’* The author also suggests that at least a 2.5 percent yield curve is required against the recessionary stress. In a press conference Mario Draghi (2016), President of the ECB at that time stated that:

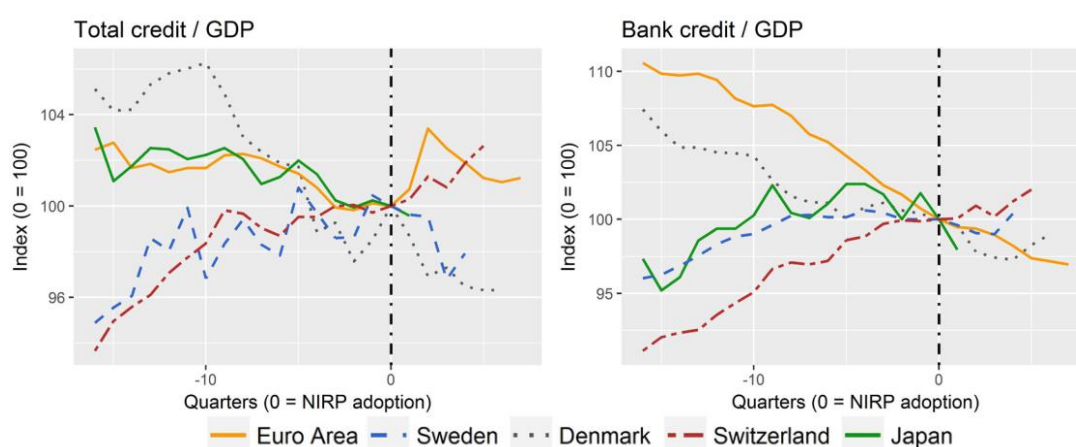
‘I should say that the experience [of the negative interest rates] has been broadly positive for the ECB... We have no evidence that it hampered the transmission of monetary policy, and when we look at bank profitability, we see that 2015, the first full year with negative interest rates has not affected, or has not caused

negative interest income, net interest income going down. As a matter of fact, it went up.'

According to Burenin (2016), after the introduction of negative interest rates in some countries, so far, no significant effects have been observed in the respective countries' money markets. Danthine (2017), in his study on swiss banks where negative interest rates have been applied for nine years, states that *'The introduction of negative rates has not left an identifiable mark on the profits of the banks.'* According to a report from the economist, Denmark's experience has been positive. The Nationalbank is not only using the negative rates, but they also used accommodative monetary policies. So far, they have been successful in achieving the main targets of the bank (Economist Intelligence Unit, 2017).

In case domestic interest rates decrease compared to foreign interest rates, the local currency depreciates to balance real returns on obligations such as loans and bonds. Therefore, this may disincentivize foreign capital flows as well as this can ease the credit conditions and support domestic growth. All in all, if management can use this side effect in their favor, this can create pressure on imports and helps to exports. Graph 2.12 shows 10 quarters before and after the negative interest rate application.

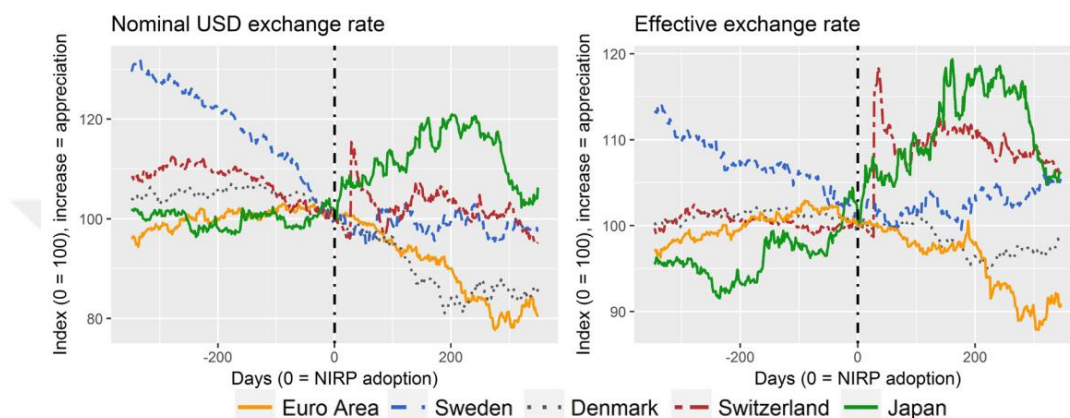
Graph 2.12: Pre and Post Negative Interest Rate effect on Credit



Source: (Angrick & Nemoto, 2017)

Following the credit effect, the exchange rate effect of negative interest rates has been shown as 200 days before and 200 days after the introduction of the policy in graph 2.13.

Graph 2.13: Exchange Rates Pre and Post Negative Interest Rates



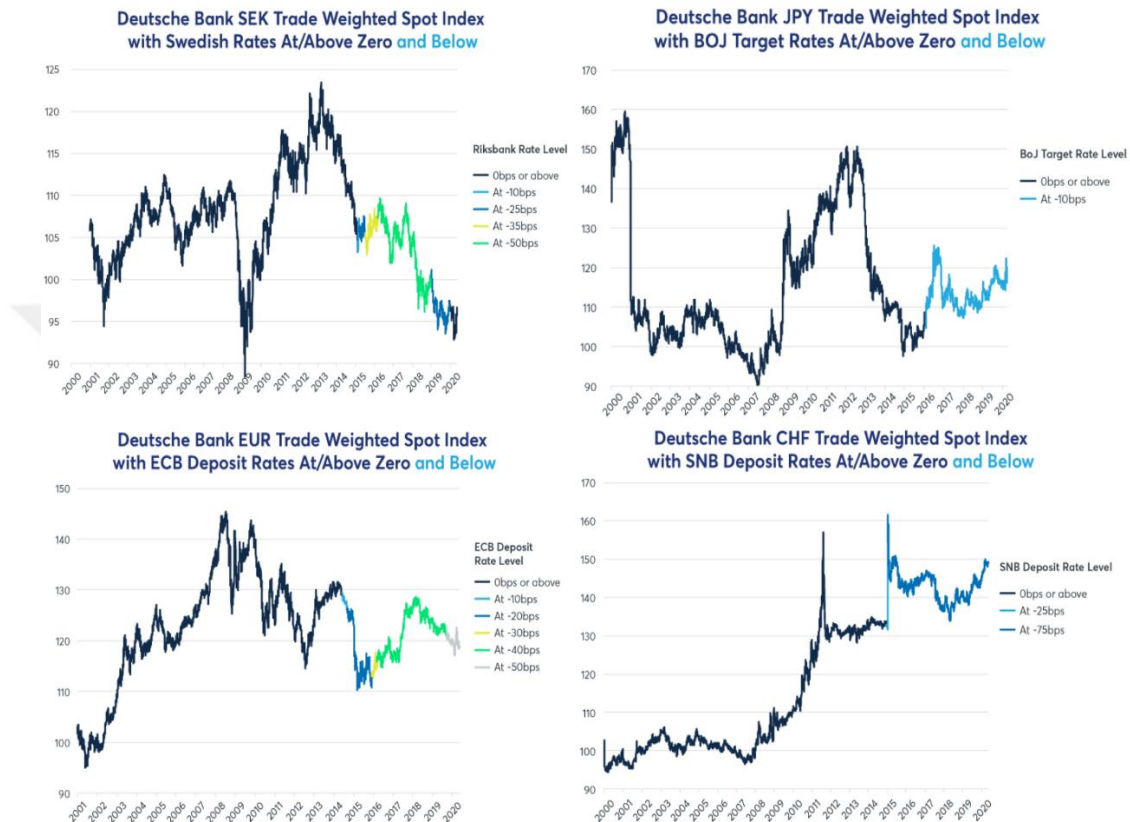
Source: (Angrick & Nemoto, 2017)

As mentioned above, negative interest rates can accompany various policies. In Sweden, the negative interest rates have been used to support export by decreasing the exchange rate relative to foreign currencies. However, in Japan, after the introduction of the negative rates, Yen strengthened as the bank targeted, and Switzerland experienced the same event. ECB has experienced a decrease after the introduction of the negative rates; however, since they are not using any target policy in exchange rates, the level of the Euro fluctuates in the market. The trend of the mentioned currencies, even today still the same, as can be seen in graph 2.14. These data from in question countries have shown that the effectiveness of the policy.

On the other side of the debate, Stiglitz (2016) emphasizes the importance of the credit channel easing and states that credits should cover all SMEs that cannot reach the credits before. An inherited behavior from the 2008 crisis on the financial market can lead to creating another bubble in the financial markets due to the low/negative interest rates and may cause to disappear of rationality. Therefore, as stated out in the work of Goodhart et al. (2016), policymakers should carefully watch the operation of the banks and financial institutions. Financial institutions such as life

insurers and defined-benefit pension funds generally work with longer-term return guarantees.

Graph 2.14: Trade Weighted Exchange Rate of the Selected Currencies



Source: Norland (2020)

Following the negative interest rates enactment, markets may seek guaranteed returns in the long-term securities and, this could dispose of the business models that work with the traditional guaranteed-return (European Systemic Risk Board, 2016). According to Cœuré (2016), monetary policy should not be the only policy in force. There is a need for accommodative policies, both fiscal and structural, to support aggregate demand and help possible future shocks that affect the aggregate demand. The transmission of the policy, therefore, is essential. Negative interest rate policies can provide additional stimulus to the policies; nevertheless, the policy should be handled with precision to secure the benefits while mitigating the risk.

PART THREE

CENTRAL BANK DIGITAL CURRENCIES

3.1. Blockchain technology in National Currency as Central Bank Digital Currencies

Financial technology (FinTech) is generally accepted as financial innovation that provides new solutions to the traditional systems with the help of technology. One such recent development in technology had a positive impact on the day-to-day business environment in our world. Especially in financial services, now we have more secure, cheap, and fast systems to make transactions all over the world, i.e., Ripple⁷⁷. The rising of the digital currencies⁷⁸ and the technology behind them “blockchain” draws quite much attention in many implication areas (Mattila, 2016, p10-16). In the finance area, one of the many possible implications has been argued for some time now. Investor firms, like venture capitals and financial institutions, mostly banks, are investing heavily in blockchain projects. Either for new financial solutions or to make more efficient traditional ones. Central bankers and academics both working on disruptive implications of this Blockchain technology for banking, payments, and financial systems (Andolfatto, 2015; Bank of France, 2016; Broadbent, 2016; Chiu & Koeppl, 2017, 2019; Elasrag, 2019; Güleç, 2018; Klarin, 2019; Raskin & Yermack, 2016; Szostek, 2019; Üzer, 2017).

When the collapse of financial institutions realized, people lost their trust in the financial system. Therefore, following the 2008 crisis, the gold rush⁷⁹ started again, but this time in a different manner, as in history, this technology invented by individuals⁸⁰, and nowadays, some countries exploring possible adaption ways to their

⁷⁷ <https://ripple.com/company>

⁷⁸ The very first proposal come from Chaum (1983) and it was digital cash after that; The European Monetary Institute (EMI), the predecessor of the European Central Bank, published its report (THE EMI, 1994) about electronic purse.

⁷⁹ A situation in which a lot of people try to take advantage of an opportunity because they have heard that they might make a lot of money see for further details Andrist, (2015); Reeves et al., (2010)

⁸⁰ Money, as in printed way, first appeared among individuals and then the ruling class came in and took the control see for further details: Ziebarth, (1924), p.42; Wetterberg, (2009), p.43-44

country's infrastructure⁸¹. One method specifically considered: Digital Currency. Recently, many national central banks made an announcement regarding their interest in the central bank digital currency (CBDC). Bank of England (2020) says the followings on the subject of CBDC:

'At the moment, the public can hold money issued by the Bank of England ("central bank money") in the form of banknotes, but only banks and certain other financial institutions can hold electronic central bank money, in the form of "reserves". A Central Bank Digital Currency (CBDC) would be an electronic form of central bank money that could be used by households and businesses to make payments and store value. This wider access to central bank money could create new opportunities for payments and the way the Bank maintains monetary and financial stability.'

In late 2018, BIS conducted a survey on CBDC to understand the perception of the local central banks to the CBDC concept. 70% of participants stated their interest regarding the CBDC, and they are conducting CBDC projects. However, only 8% of the participants running pilot projects. Nevertheless, pilot projects are just to explore more comprehensively the CBDCs, and the participants stated that they do not plan to issue CBDC after the pilot tests (BIS, 2019, p. 7,8).

In essence, CBDC is basically digitally stored monetary value, and that can be used in transactions and, the Central Bank liabilities include the CBDC same as cash. The central bank-issued digital currency is a complicated concept and raises various doubts regarding the engineering process. Since the CBDC will be the new form of money, and that affects all economic agents, that is something to consider meticulously. How to design such currency will depend on various subjects such as politics, infrastructure, and culture. This part of the thesis will provide how to design a CBDC question, and we provide an overview of the CBDC and discuss the possible motivations and challenges, thus explore the possible implications. Rather than technically, we explore the implications in a theoretical way. However, we start this topic by exploring blockchain technology; thereafter, possible application methods of CBDCs will be explored.

⁸¹ Namely, China, Japan, United Kingdom, United States, Denmark, Singapore, Australia, India see for further details; (Pawczuk et al., 2019); (OECD, 2019).

3.2.The Technology Behind the CBDCs: Blockchain

The Blockchain technology has become popular recently, but the first time we compactly saw this technology⁸² in 2008 within the white paper of Bitcoin: a peer to peer electronic cash system (Nakamoto, 2008). Nakamoto⁸³ introduced a trustless system for electronic transactions, which also prevents double-spending. According to Nakamoto (2008), the system *'allows for online payments to be sent directly from one party to another without going through a financial institution.'* The Bitcoin system is an open, decentralized ledger. Anyone with an internet connection can be a part of this system and make bitcoin transactions. It also keeps the record of the whole network transactions in every node (part of this community); due to this reason, the system is called trustless. Bitcoin protocol on the blockchain system has many rules, such as only 21M bitcoin will be issued; after that system will not continue to produce new bitcoin, and because of that system creates an inherent resistance to inflation. The system also has weaknesses, and yet it evolves day by day with the community of honest nodes as well as the academics who works in this area (Klarin, 2019). To ensure the security of the system, incentives have been provided for the nodes that hold every transaction in their host, and the system will be secure as long as the honest nodes are the majority part of the community. Hawlitschek et al. (2018) emphasize the trust concept of blockchain in their study, and they consider blockchain technology as a means of trust platform to some degree. They specify that trustless systems mostly rely on the development of blockchain-based interfaces.

Blockchain technology initially did not receive the attention that it receives nowadays. The Bitcoin effect initially undermined the power of blockchain and raised many questions regarding the prevailing financial system and the economy. Hereby, many central banks, private banks, and technology firms are concentrated on their project regarding the blockchain. To understand the implications of this technology, firstly, we must understand the technology behind all these innovations. Even though we saw this technology first in Bitcoin protocol, Distributed Ledger Technology

⁸² Prior to Satoshi's white paper, we separately knew these systems but with Satoshi's bitcoin protocol we have witnessed the first compact application. See Nakamoto (2008) for further information.

⁸³ It is most likely a pseudonym. See for further details: Dovbnya (2019)

(DLT)⁸⁴ as known as Blockchain, is not a novel technology. Chaum (1983) introduced '*Blind Signatures for Untraceable Payments*'; eventually, he founded Digicash company. Digicash is the first instant of its kind, which is a digital currency. In the year 1998, Digicash filed for bankruptcy because the project could not overcome the double-spend problem, and internet usage was not quite popular during those times. Merkle (1988) introduced the Merkle root⁸⁵. In 1991, Haber & Stornetta introduced a cryptographically timestamped chain of blocks. Szabo (1998) introduced his work on decentralized digital currency, which was accepted as a precursor to Bitcoin (Tschorsch & Scheuermann, 2016). Dai (1998) published a paper that outlines the 'cryptocurrencies' framework, including Bitcoin.

Blockchain, in essence, decentralized and trustless method of collectively maintained a reliable database. By using cryptography nodes, create blocks on this scheme. The name of blockchain came from here and called initially with separate words block and chain (Nakamoto, 2008). Every block in the system includes all of the data of transactions. The system uses the digital fingerprint to validate the information, thus connect with the next block with the newly created fingerprint. The block system linear; each block contains hash cryptography of the previous block. Blockchain is one type of distributed ledger technology, which is time-stamped series that immutable and traceable. According to a report from the CB Institute (2018), the blockchain system can be explained as follows:

'Blockchain technology offers a way for untrusted parties to reach agreement (consensus) on a common digital history. A common digital history is important because digital assets and transactions are, in theory, easily faked and/or duplicated. Blockchain technology solves this problem without using a trusted intermediary.'

3.3.Benefits of Blockchain

Distributed ledger technology seems promising in many application areas, primarily finance; however, the DLT cannot apply in all areas of our world. Though

⁸⁴ See for further details on DLT technology appendix 2.

⁸⁵ Merkle roots are used in cryptocurrency to make sure data blocks passed between peers on a peer-to-peer network are whole, undamaged, and unaltered.

with the correct application and sector, DLT potentially provides various advantages. Since DLT is a novel concept and there is no generally accepted business model, generalization for DLT is tough. However, the potential advantages of DLT as follow;

3.3.1. Decentralization

Since DLT allows users to transfer value in digital form that eliminates the central authority to control the transactions and ledger, this can provide faster transactions for trade and low costs.

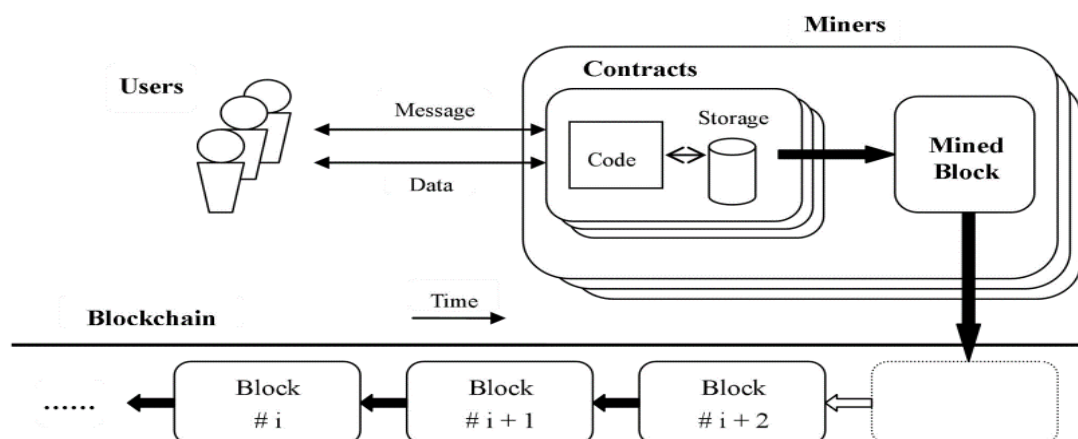
3.3.2. Transparency

All participants of the network can access all the data stored in the network, which is a full copy of the ledger. Any change on the network depends on a consensus of the participants; thus, a trusted central party role is distributed to the nodes of the network. This feature has the potential of the decrease of fraud risk and, within legal frameworks, can reduce or remove the reconciliation cost.

3.3.3. Greater automation

In the DLT '*smart contracts*',⁸⁶ can be set to execute on some certain orders which are pre-agreed, to execute the order smart contracts, and do not wait for any approval after the conditions hold.

Figure 3.1: Conceptual Framework of Smart Contracts



Source: (Tian, 2018)

⁸⁶ See appendix 2.

3.3.4. Security

DLT provides immutability, which is after the data entered into the system that cannot be changed or modified. Since the system works as a chain of blocks, each block is the way of protecting the integrity of the data in the network. However, the administer of the network can access the blocks and alter the blocks. A more resilient system can be achieved in the DLT than the traditional system offers. That also removes the single point attacks due to the distributed nature of the system.

3.3.5. Increase in speed and efficiency

In traditional systems, even in the same country, send some amount of currency can take up to 15 minutes during the working days, and that transaction from one institution to another cannot be taken place in the holidays. In the DLT, even cross border payments can be executed in less than 10 minutes. Also, the lack of correspondent institutions while the payment transfer takes place to increase the efficiency that also helps clearing and settlement processes.

3.3.6. Cost reduction

In DLT, there is no need for intermediaries that offer significant cost reduction. In essence, the system shares the aggregate network data that causes the elimination of reconciliation. According to Belinky et al. (2015), in the financial industry, DLT could save \$15 to \$20 billion annually.

DL Technology is still in the developing phase; although DLT has various advantages, certain risks can potentially endanger the network. Since DLT offers an alteration of the traditional system, to provide sustainability to the ecosystem, central authorities should be in cooperation while phasing from conventional to DLT. Some of the DLT protocols like Bitcoin, cause to emerge some issues regarding scalability and transaction speed when comparing with the traditional one. After some calibration, both scalability and transaction speed increased in few DLT protocols, but there is still a place to go. IBM, Microsoft, Visa, and MasterCard are working on DLT projects to provide better solutions, and with their research, not just only these companies, DLT evolves. In many places in the world, both local central banks and private companies are currently developing DLT systems to increase efficiency in their region. Due to the

lack of the central authority or a base network to provide interoperability or the connection of the networks from one another, local DLTs are stands as solely systems. However, few private companies work on these issues to develop a product such as r3 Corda or Ripple. Each country has its law about the financial sector and the market operations; if local central banks provide their region's financial payment system with the consensus of the other central banks in the world, various potential issues can become achievable with the help of the regulators. Such characteristics in the DLT can help the compliance officers regarding the issues of Know-Your-Customer (KYC), Anti-Money Laundering (AML), and Combating the Financing of Terrorism (CFT). There are also concerns about the DLT systems' privacy and power consumption of the infrastructure that stems from 'proof-of-work' (PoW), which requires a significant amount of processing power of the computers. Nevertheless, the local central bank involvement can make the privacy of both the corporation and individuals secure, and 'proof-of-stake' can be used instead of PoW since one trusted institution will manage the network.

3.4.Possible adaption of the DLT

DLT has potential beyond cryptocurrencies in many areas, as well as finance. Mainly two types of DLT application can be seen as: Fintech firms that are developing blockchain infrastructure for various applications, particularly in the financial sector; and Joint ventures that bring governments and many firms together to research and provide industry-specific solutions.

Especially in the finance sector, many banks are working on DLT to provide efficiency. The innovative effect of the DLT will have much influence on the payment systems rather than the money system itself. R3 Corda is one of the many enterprises that provide solutions with DLT, and firms have around 300 customers from various places of the world, Ripple as R3 has more than 300 firms across more than 40 countries in the world. Also, Ripple recently opened RippleNet that is a network for the across country payments (Ripple, 2020).

Along with the banks, stock exchange markets are too investigating possible adaption of the DLT (Coindesk, 2016). As a disruptive innovation, DLT may alter the

traditional way of issuing stocks and trading them. Regarding the DLT adoption of the capital markets, Lee (2018) emphasizes that the current form promises benefits such as lowering the cost of trading and increasing the participation rate of the markets. The author adds a current form of the DLT needs to improve to provide better solutions than today. However, the author suggests that DLT can be useful in today's world to the capital markets as a Regulation Technology (RegTech), which utilize smart contracts to watch legal compliance. Capital markets are, in essence, places for the traders, sellers (issuers), and buyers; the elimination of the common place may not bring the intended benefits. Various studies show the consensus on the DLTs premising features and the technology still requires further research (Lundström, 2016; Piccolo, 2017; Surujnath, 2017).

According to a report from The World Bank (2017), 1.1 million people are living without a legal identity, and this creates obstacles to their access to vital services. The current trend of digitalization might help this situation, and furthermore, with blockchain technology, we might benefit from a decrease in costs and an increase in efficiency. Syed (2019) emphasizes one potential benefit of the DLT identity system as follows: *'The advantages of blockchain digital identity provide incredible benefits to migrant refugees and victims of trafficking.'* In their study, Aydar et al. (2019) emphasize the inefficiencies of the traditional identity systems and suggest a blockchain-based framework for the digital identity system. In the literature of the digital identity, there is a consensus of the cost reduction of the DL technology as well as this technology provides better management of the data.⁸⁷

To gain more efficiency and more robust systems, energy companies investigating possible adaptations of the DLT in their sector. O'Donovan & O'Sullivan (2019), in their research, examine 131 energy blockchain initiatives, and the author found that the initiatives are increasing rapidly, and systems become more resilient and robust. For the benefits of the implementation, the authors say the followings:

'The most obvious benefit of real-world energy blockchains is the democratization of energy transactions, whereby blockchain technology may be used to remove intermediaries from the energy value chain and enable

⁸⁷ See for the further reading on this topic; (Karahan & TÜFEKÇİ, 2019; Konashevych, 2020; Grüner et al., 2018; Panait et al., 2020; van Bokkem et al., 2019; Zwitter et al., 2020)

communities to execute transactions independently. These independent two-way markets should provide market participants (e.g., customers) with sufficient transaction transparency, security, and reliability, which can be satisfied using the blockchain's immutable and decentralized architecture. Additionally, energy blockchains can reduce transaction costs and settlement times, substitute intermediaries with consensus models, and increase profitability and minimize costs for participants using sophisticated market intelligence (e.g., machine learning).'

DLT research in the energy sector is still in the early phase, and studies on this area are growing exponentially.⁸⁸

On the governmental side, blockchain can help with various services. DLT is the best fit for modern notary services. Since the ledger is distributed, these kinds of operations can swiftly occur at less cost. As in the notary services, in the registry of property, DLT could offer better solutions in a fast and cheap way. Eder (2019) states that *'Property rights and blockchain have moved from vision to reality in different environments with different focus points.'* As the author pointed out, different types of applications are in business now.⁸⁹

As can be seen in table 3.1, DLT can provide various solutions to enhance efficiency. Nevertheless, there are still some people that cannot access the financial system. Regarding the financial inclusion matter, DLT could offer an expansion of the limits of the financial systems. If the DLT applications successfully adapt to the financial system, not initially, but in the mid-term, the technology is promising for financial inclusion. To do so, DLT should offer cheap financial services, provide better infrastructure for the payments, both domestic and international, and the credit channel. Financial inclusion and access to the systems can be increased by providing some essential solutions for the people outside the current financial system, such as Digital Identity, Asset registry, Digital Currencies, and Cross-border Payments.

⁸⁸ See for further reading DLT in the energy sector; (Andoni et al., 2019; Hukkinen et al., 2017; Hwang et al., 2017; Y. Li et al., 2019; Mengelkamp et al., 2018; Pieroni et al., 2018; Tan et al., 2019; Wang et al., 2019)

⁸⁹ See for further detail on Government initiatives in DLT; (Benbunan-Fich & Castellanos, 2018; Smart Dubai, 2020; The Malta Independent, 2019)

Digital currencies have a special place for the DLT since the technology initially started by cryptocurrency applications. CPMI (2015) identified there a feature of the digital currencies as (I) They have zero intrinsic value and their value determined by demand and supply; (II) The transfer of the value is peer-to-peer based via utilizing distributed ledgers, and there is not trusted intermediaries; (III) The institutional arrangements of the digital currencies as different as possible, since in a traditional systems money issuer, network operators, and other back support transactions are being made by the institution that provides the money. However, in the digital currency scheme, each role of the system is distributed to the network participants and the network itself. Thus, the system continues to exist on its own.

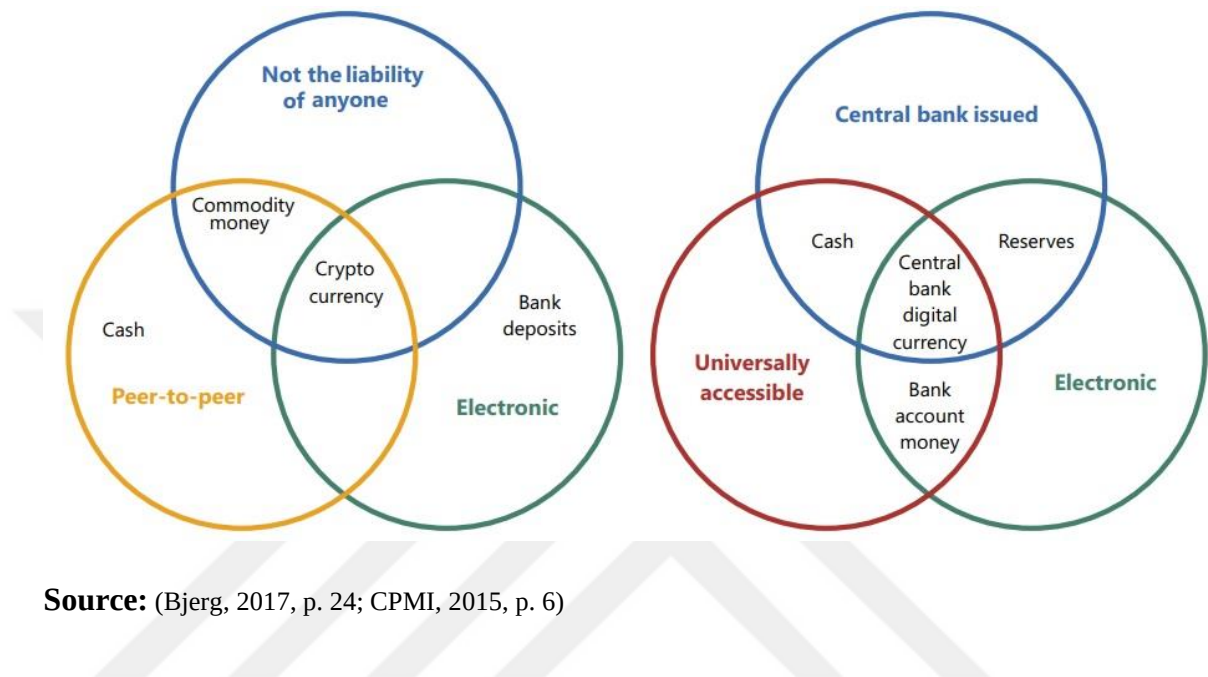
Table 3.1: Possible Applications of DLT

Money & Payments	Digital currencies	Identity	Digital identity platforms
	Payment authorization, clearance & settlement		Storing personal records: birth, marriage & death certificates
	International remittances and cross-border payments (alternative to correspondent banking)	Trade & Commerce	Supply chain management (management of inventory and disputes)
	Foreign exchange		Product provenance & authenticity (e.g., artworks, pharmaceuticals, diamonds)
Micropayments	Trade finance		
Capital markets: digital issuance, trading & settlements of securities	Post-trade processing		
Commodities trading	Rewards & loyalty programs		
Notarization services (e.g., for mortgages)	Invoice management		
Collateral registries	Intellectual property registration		
Financial Services & Infrastructure (beyond payments)	Movable asset registries		Agriculture
	Syndicated loans	Crop finance and warehouse receipts and crop insurance	
	Crowdfunding (as initial coin offerings)	The provenance of cash crops	
	Insurance (in combination with smart contracts)	Safety net programs related to the delivery of seeds, fertilizers, and other agricultural inputs	
Collateral registries and ownership registers	Land registries, property titles & other collateral registries	Governance	Government record-keeping, e.g., criminal records, land property
Internal systems of financial service providers	Replacing internal ledgers maintained by large, multinational financial service providers that record information across different departments, subsidiaries, or geographies		E-Residence
			E-voting systems
			Reducing fraud and error in government payments
			Reducing tax fraud
Healthcare	Electronic medical records	Humanitarian & Aid	Protection of critical infrastructure against cyberattacks
			Tracking delivery & distribution of food, vaccinations, medications, etc.
			Tracking distribution and expenditure of aid money

Source: Compiled from Natarajan et al., (2017)

In graph 3.1, the cryptocurrency scheme and the Central bank digital currency have been shown to provide understanding for the currencies.

Graph 3.1: Taxonomy of the Digital Currencies



Source: (Bjerg, 2017, p. 24; CPML, 2015, p. 6)

3.5.Related works

The subject of the national cryptocurrency gains significant attention due to the possible benefits of the system, as mentioned in section 3.3. Many theoretical monetary systems have been proposed recently; however, Tobin (1985) proposed deposited currency that is a form of government money but not like cryptocurrency. BIS (1996) suggested an e-money that can be stored in the debit cards and spend at any point of sale. That would be a possible response to the loss of seigniorage revenue and the weakening control of monetary policy. However, central banks indicated to stay cautious and only monitor the evolution of the e-money.

Regarding the proposals of the national cryptocurrency Koning, (2014) proposed ‘Fedcoin’ somewhat similar to bitcoin. The author suggests a solution to the volatility problem by pegging cryptocurrency to the Dollar of the US. Following Koning’s proposal, the Bank of England has issued two working papers on the

cryptocurrencies. One of them was investigating the economics of the cryptocurrencies and their results as following '*Digital currencies do not currently pose a material risk to monetary or financial stability in the United Kingdom.*' The second work of BoE was about financial system innovation from the perspective of digital currencies. In their study, DLT was labeled as a '*significant innovation*' and their conclusion on DLT as follows '*The distributed ledger is a genuine technological innovation which demonstrates that digital records can be held securely without any central authority.*'

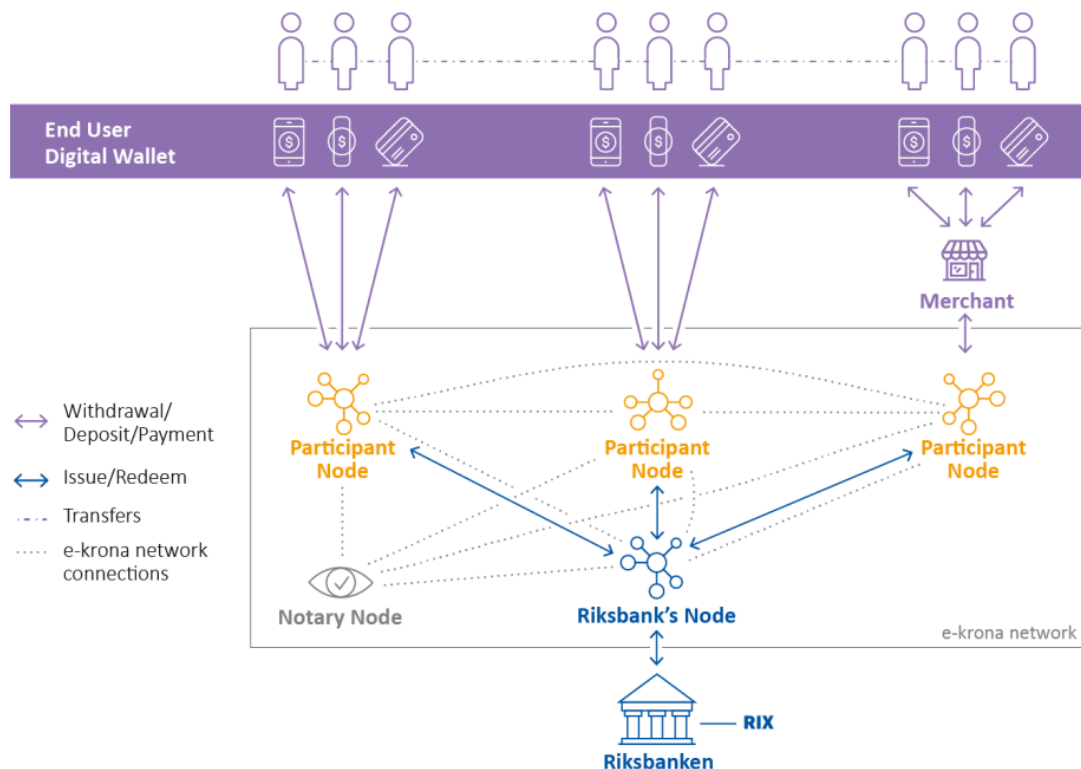
Danezis & Meiklejohn (2016) proposed a cryptocurrency framework that relies on distributed authorities. The centralization in the network prevents the scalability issue and maintains the anti-double spending feature of the system. Hayes (2016), starting from the Bitcoin protocol itself, suggested a nationwide application of the cryptocurrency framework. Such a framework involves *decentralized autonomous organizations* (DOA) that utilize smart contracts; therefore, the system aims to provide stability and efficiency in the market.

Barrdear & Kumhof (2016) have studied the macroeconomics of the CBDCs, with a dynamic stochastic general equilibrium (DSGE) model; they found that CBDC issuance with %30 of GDP can increase the GDP up to %3. According to the authors, this increase can be done with a reduction in real interest rates, transaction costs, and distortionary taxes. The authors also suggest that CBDC could improve the central bank's capability to manage the business cycle.

According to Skingsley (2016), The Riksbank should issue e-krona regarding the needs for access to the central bank money from the non-bank institutions and the people. Also, another concern is that the cash usage decrease in Sweden to %1.5 of GDP, that makes the central bank more inefficient in monetary policy due to the limited effect on the market. The author suggests an accommodative model of e-krona to cash. The Riksbank (2017), in the first report of the e-krona work, described why the bank researching e-krona, possible functions of e-krona, a possible model, and the possible impacts of e-krona on the financial stability and monetary policy. The Riksbank (2018), in the second report of the e-krona project, emphasizes the needs for the e-krona, as mentioned in the first report, in which cash usage diminishing broadly

in Sweden. Even if the cash marginalization will not decrease, the bank has the plan to step in to provide state-backed means of payment to the public. In the action plan published by The Riksbank in 2017, specifies the aims of building CBDC as soon as 2019 (The Riksbank, 2017b). The Riksbank (2020) has announced that the bank has initiated a pilot project for the e-krona due to the recent sharp decrease in cash usage. The CBDC designed to complement the cash. The bank has employed DLT in the design of e-krona, as can be seen in figure 3.2.

Figure 3.2: Framework of the Pilot of E-Krona



Source:(The Riksbank, 2020a)

Dyson & Hodgson (2016) suggested that everyone must have an account at the central bank; however, usage of the account can be manageable by the regulators such as direct access or indirect access via financial institutions and adds this would increase the competition in the payment services.

Bank of Canada has announced the DLT investigation project series beginning from 2016; the first step of their research was a platform for central bank-issued digital receipts for deposited funds (Bank of Canada, 2016). The second step of the research of DLT Bank of Canada employed a *notary node*⁹⁰ consensus model to increase efficiency in the domestic inter-bank payment system; furthermore, the bank's results show that the DLT can provide a cross border digital currency exchange system (Payments Canada et al., 2017). In the third phase of the research Bank of Canada utilize the DLT to provide efficiency in the clearing and settlement system for securities (Bank of Canada, 2018). As a next phase, the Bank of Canada and Monetary Authority of Singapore work jointly on the cross border transfers in DLT. The result of their work stated as following: *'The team successfully demonstrated a cross-border, cross-currency, cross-platform atomic transaction without the need for a third party that is trusted by both jurisdictions'* (Bank of Canada & Monetary Authority of Singapore, 2019, p. 7). Engert & Fung (2017) have proposed two options for the CBDC; first, a benchmark CBDC and second, an I-CBDC, which later bears interest and eliminates the anonymity, and the authors suggest central banks should not supply reserves only selected institutions. Following the developments in the DLT technology and the prevailing financial systems, the Bank of Canada has announced that they have started to build a retail cash-like CBDC as a contingency plan; when the need for CBDC arises, they will be able to intervene immediately. According to the bank's possible CBDC implementation scenarios, there are two scenarios, one is related to the significant decrease in cash usage, and the other is the possible domination of private cryptocurrency. According to BOC, the bank must maintain the safety, universal accessibility, privacy, resilience of the monetary system. If any of the private currency became a dominant payment method, BOC must gain monetary sovereignty by issuing its own digital currency (Bank of Canada, 2020b).

According to Bjerg (2017), central banks should issue CBDCs to manage the risk and instabilities that brought with the invention of electronic money. The author

⁹⁰ A notary node is a protocol that can be used to make to reach consensus easier and faster. *'The notary service of the Corda platform provides a uniqueness and/or validating consensus by attesting to the finality of the transactions. A notary may be a single network node, a cluster of mutually trusting nodes, or a cluster of mutually distrusting nodes'* (Bank of Canada, 2018).

suggests three scenarios for the implementation of CBDC Money User, Money Manager, and Money Maker, respectively. The author states that the purpose of the CBDC is to make a reform in the new age for the central bank to gain its monopoly on the prevailing money as in the paper money.

Mersch (2017), in a speech on the CBDCs but referred to as Digital Base Money (DBM), argued whether the ECB should provide a broader range for DBM or not and DLT implications in the DBM services. Mersch specified four principles of DBM as follows: *‘technological safety, efficiency, technological neutrality, and freedom of choice’* and concluded with the cash importance and freedom of choice.

Bordo & Levin (2017) suggest that central banks should start to work on CBDC due to the transformative effect of the system. According to the authors, macroeconomic instability, loss of monetary control, systemic risks, and the susceptibility to severe downturns can be prevented with the introduction of CBDC.

Accenture (2017), in a report on (r)evolution of money, stated the following regarding the central bank-issued cryptocurrencies;

‘A central bank can bring market participants together and create a governance structure in which cryptocurrencies can thrive and gain much wider acceptance. With central bank support, there are also a myriad of other advantages for the economy. Cryptocurrencies are borderless, and central banks that act now increase the attractiveness of their fiat currency as a medium of exchange in payments, clearing and settlement.’

In their study, Gouveia et al. (2017) have identified four possible scenarios for the implementation of the CBDC, and they suggest as most likely scenario a wholesale non-interest-bearing CBDC, which only the banks can participate. The authors suggest that this possible implementation would increase the efficiency of the payment system between banks and the central bank.

According to Mancini-Griffoli et al. (2018), central bank-issued cryptocurrency *‘could be the next milestone in the evolution of money... CBDC could strengthen the benefits and reduce some of the costs and risks to the payment system and could help encourage financial inclusion.’* The authors state the various

perspective regarding the implication of the CBDC. Due to the various needs and aims for the CBDC policy, the authors emphasize that: *'appropriate design and policies should help mitigate ensuing risks.'* Meaning et al. (2018) states the importance of designing CBDC according to the needs of the region and emphasize that current monetary policy does not need to change if the central bank issue universally accessible an account-based digital currency.

CPMI (2018) has published an analysis of CBDCs and examine the potential implication. According to the report, CBDCs can provide an alternative policy tool to the central bank. If any central bank decides to issue digital currency, different outcomes come with the design of the currency, wholesale CBDC would provide efficiency in the payment system between banks, and retail CBDC would reduce credit and liquidity risks in the payments system and increase resilience. Also, the authors emphasize the implications of not issuing CBDC, which is harmful to the central bank's monopoly power on the monetary authority due to the private tokens.

According to a report from the Bank of Israel (2018) on CBDC, the Israeli economy does not suffer from cash usage decrease and motivation for the CBDC, making the payment system more efficient. If the CBDC bears interest, that can create an additional tool for the central bank. However, the Bank of Israel does not consider issuing CBDC in the near future, but the bank examines and studies on the DLT systems to be prepared for future engagements.

Norges Bank (2018) stated that in the case of evaluation CBDC, the first target should be secure the confidence in the monetary system. On the role of the central bank with the CBDC, the bank says the following:

'It is not Norges Bank's ambition to take over credit provision from banks. A premise underlying this work is that the existence and scope of a CBDC must not impair the ability of banks and other financial institutions to provide credit.'

Also, the bank emphasizes the challenges regarding the CBDC and states that CBDC is not a short term project.

Bascand (2018), in his speech on behalf of the Reserve Bank of New Zealand on CBDC, stated that transaction fees and settlement speed could improve with the application of the system. The author emphasizes the benefits and the challenges of the CBDC and points out that the central bank should mitigate the pros and cons to enhance efficiency in the monetary system.

Agur et al. (2018) have stated the followings after a conference on CBDC:

'The value attached to the privacy of the individual versus state power was maybe THE central distinguishing feature between advocates and adversaries of CBDC. The issue of robustness to cyber-attacks, electric outages, and natural catastrophes was highlighted as a weakness, and the solutions offered ranged from ensuring that a CBDC would have to be designed in a way to also operate without the internet, at least for a while, to the recommendation that the central bank should for contingencies always hold a stock of paper cash.'

South African Reserve Bank (SARB) (2018) has initiated a project that January 2018 that lasts for 14 weeks. In this project, SARB has tested a wholesale payments system which is DLT based, and the followings have stated regarding the results and the future of the project:

'The results show that the typical daily volume of the South African payments system could be processed in less than two hours with full confidentiality of transactions and settlement finality... There are many issues to consider before the decision to take a DLT-based system into production can be taken. Some of these issues relate to the practicalities of implementation, but also to legal and regulatory factors and to the broader economic impact. The future direction will also be influenced by further development of the technology and by central banks and other regulators globally continuing to contribute to this field of knowledge.'

IBM Blockchain & OMFIF (2018) have published a report on central bank digital currencies; in the report, it is suggested that for relatively small central banks, wait and see approach would be useful due to the high cost of adopting this novel technology with unknown features. On the other hand, relatively larger banks should allocate resources for the research and development of the technology as some of the trials meets the demand and exceed the expectations. The report emphasizes the collaboration of the regulatory forces' involvement in both domestic and international levels due to cybersecurity concerns.

Lagarde (2018), during her speech at the Singapore Fintech Festival, emphasize the changing nature of money and suggests that central banks should embrace the new form of digital money, which is CBDC. According to Lagarde, CBDC can help with public policies such as financial inclusion, consumer protection and security, and privacy in payments.

From the legal aspect of the CBDC in the European Union, Fonseca (2019) emphasizes the Euro system's central banks' adoption of the legal changes regarding the issuance of the CBDC. Nabilou (2019) addition to Fonseca, emphasizes the legal challenges that could distort financial stability and create oppositions for the monetary policy. The authors conclude that CBDC may cause to alteration of the Treaty on the Functioning of the European Union. Khiaonarong & Humphrey (2019) emphasize the peril of the other payment methods (other than cash like private cryptocurrencies) dominance within the changing environment of the daily transaction; thus, the authors suggest that CBDC should introduce without losing any time. Juškaitė et al. (2019), the introduction of the CBDC would be beneficial for policy implications. However, the authors also state that the CBDCs are uncharted waters; therefore, the joint analysis is required. As stated in BIS (2019), *'Caution and collaboration will reduce the likelihood of unintended consequences.'*

Ney & Xuan-Yi Zhang (2019), on their research regarding the CBDC, concluded that the credit market would deteriorate with the introduction of CBDC. However, this effect will ameliorate as financial stability improves in the following years. Bindseil (2019) states that within the business cycles or with the structural changes (like crises), CBDC disintermediates the banking system. Nevertheless, Chiu et al. (2019) have to build a model in the banking sector regarding the issuance of the CBDC, and they have concluded that CBDC can increase the lending rate around %7, thus increase output by %1. According to Alfarano (2019), consumers' perceptions regarding the payment system and the banking sector competitiveness are essential factors for CBDC to work effectively. Qian (2019) states that a proper design of the CBDC may help the function of the forward guidance and countercyclical currency controls.

Nevertheless, Danmarks Nationalbank (2017), in a report, stated that:

'It is unclear what central bank digital currency would be able to contribute that is not already covered by the current payment solutions. Denmark has a secure and effective payments infrastructure...'

They have thus argued that CBDC only would increase financial instability and pose a significant threat to the country's economy. From the Bank of Finland Kortelainen, (2017) argued that banks should proceed with caution towards DLT and suggests an analysis of the implications of electronic central bank money. Grym et al. (2018) labeled CBDC as '*a fallacy*' and argues that CBDC can only be the reserves at the central bank. Pfister (2017) stated as follows regarding the central bank issuance of digital currency: '*The decision to embark into such a scenario (Public CBDC) project would be highly political and would not necessarily be accepted by the public.*' Cecchetti & Schoenholtz (2017) suggest that CBDC should be investigated, and central banks must secure the seignorage; however, the authors also emphasize the risk of bank runs and the changing role of the central bank with CBDC.

3.6. Central Bank Digital Currency

The discussion around the central bank's digital currencies goes back to the first sovereign currency. Central banking is undoubtedly a complicated duty; from macroeconomic to microeconomic functions (such as the operation of discretionary monetary policy and lender of last resort assistance), various types of policy have been conducting ever since the foundation of the central banks. As the technology evolves around the core duties of the central bank, new solutions have flourished on the traditional methods. The decrease in cash usage and the detachment of the nexus between the central bank and the people are some of the main arguments. The central bank money currently consists of two types as physical and digital. The latter is the reserves of the financial institutions that are held in the central bank. The cash is the only representative of the sovereign currency in one country, the other than reserves privately issued money.

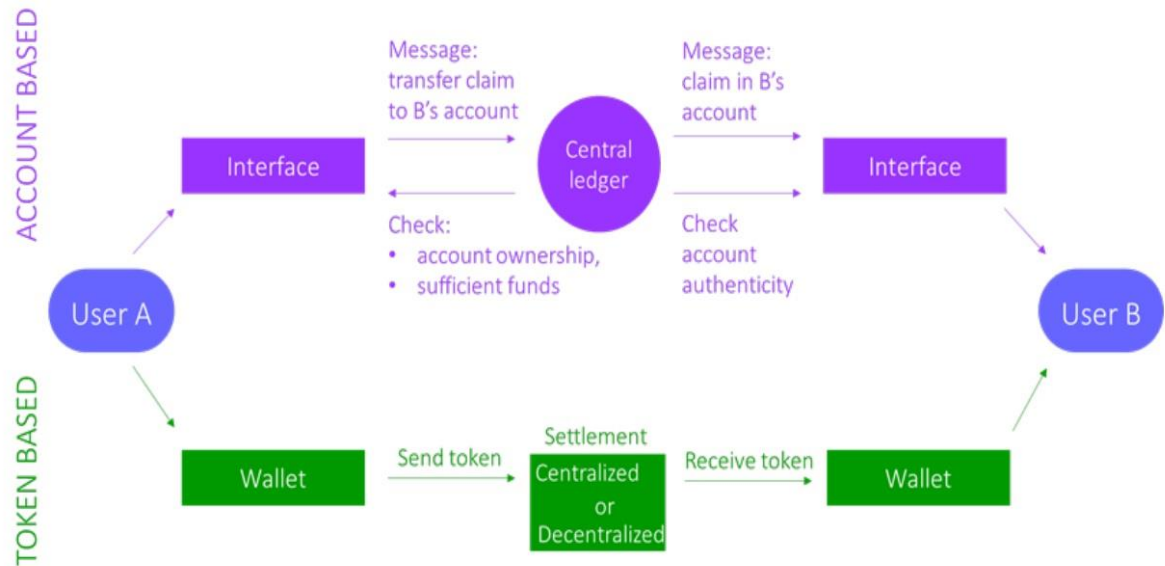
Central bank digital currency could be a new form of sovereign currency. Due to this feature, CBDC is a trending topic among the central bankers and academics, in which they analyze the merits and the perils of issuance of CBDC. According to the Bank of England (2020),

‘A Central Bank Digital Currency (CBDC) would be an electronic form of central bank money that could be used by households and businesses to make payments and store value. This wider access to central bank money could create new opportunities for payments and the way the Bank maintains monetary and financial stability.’

Kiff et al. (2020) define CBDC as *‘a digital representation of a sovereign currency issued by and as a liability of a jurisdiction’s central bank or other monetary authority.’* CPMI (2018) emphasizes the challenges while making the definition for the new mixed type of money; however, the definition of CBDC provided as *‘CBDC is a digital form of central bank money that is different from balances in traditional reserve or settlement accounts.’* Yanagawa & Yamaoka (2019) defines the term of CBDC as *‘digitalized instruments for payments and settlements issued by central banks as their liabilities (central bank money).’* Meaning et al. (2018) define the central bank digital currency as *‘an electronic, fiat liability of a central bank that can be used to settle payments or as a store of value or, in essence, “narrow” money.’*

Generally, two kinds of CBDC have been discussed, a token-based and an account-based CBDC (figure 3.3). Cash, as we know it, is a representation of token-based money as well as many private cryptocurrencies and reserves, and the bank money is account-based. Here we focus on four features regarding the money: an issuer, a form of money, accessibility, and the technology behind the transfer mechanism. To see clearly where this new type of money stands in other money forms, the Venn-diagram has been employed. In the money flower, we can see the positions of the two types of CBDC among the other types of money (graph 3.4).

Figure 3.3: Account and Token Based CBDC workflow

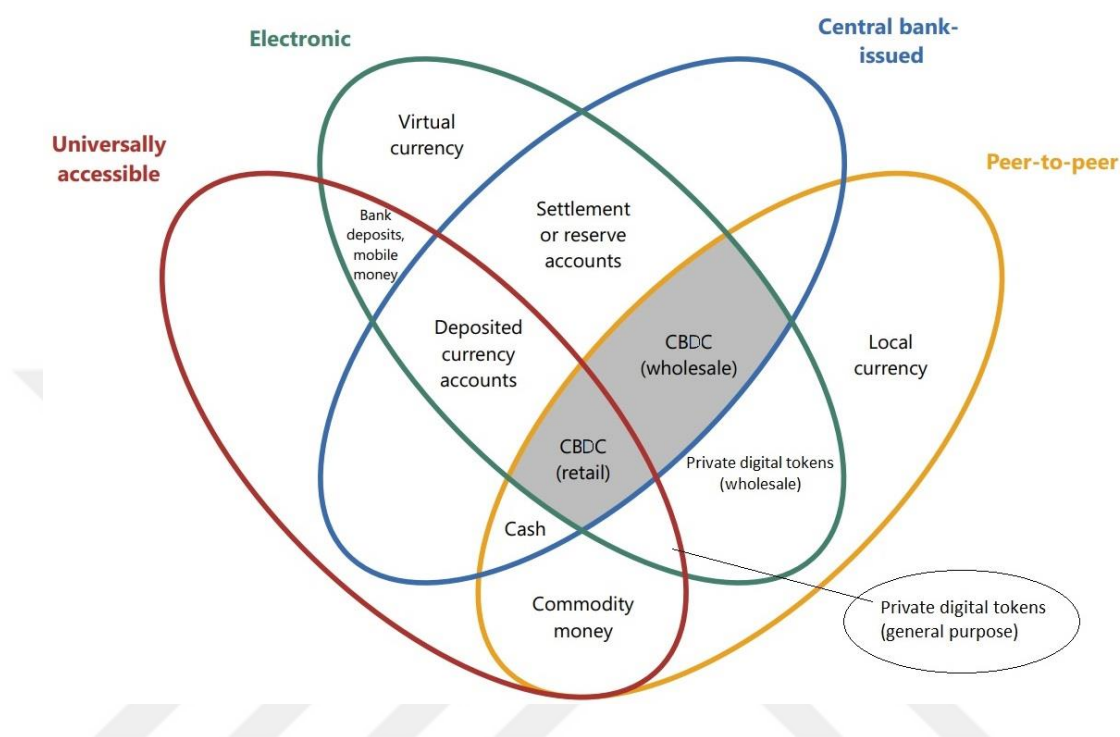


Source: (Mancini-Griffoli et al., 2018, p. 8)

3.7.Types of CBDC

To start an initiative regarding the CBDC, a central bank should decide what will be the primary purpose of issuance? Thereafter, the design option will emerge to provide a solution to the purposes of the central bank. In essence, there are two different kinds of central bank digital currency, and one has two subsections. The first option to use for CBDC is restricted CBDC (a.k.a. wholesale CBDC, only available to financial institutions), and the second one is public CBDC (retail CBDC).

Figure 3.4: The Money Flower



Source: (Bech & Garratt, 2017, p.60; CPMI, 2018, p.5)

The latter option is the best fit for many central banks that have been practicing on CBDC. However, in the pilot tests, we see only restricted CBDC due to the nature of implementation since there are limited participants in the restricted CBDC, which makes the system easily testable and adaptable.

3.7.1. Restricted CBDC

Many central banks conducted DLT experiments that provide information regarding the potential benefits and challenges. As well as the Central banks, private undertakings have conducted tests to investigate market opportunities and deficiencies in the current infrastructure (Appendix 1). A central bank could issue CBDC restricted use of only to financial institutions to use in settlements and transfer of securities. The restricted CBDC system gets the name from the access of the participants; these kinds of systems usually design as permissioned network instead of permissionless. Since

the whole participants are known to the manager of the network, the burden of the proof of work can be eliminated by the notary node (i.e., a central bank).

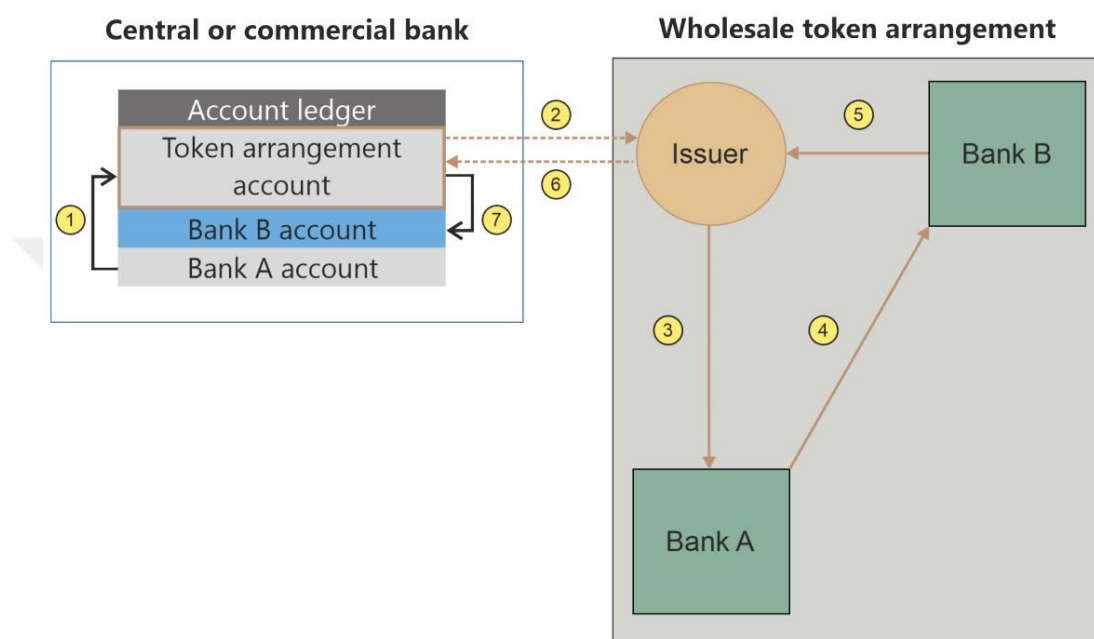
The Monetary Authority of Singapore (2017), with project Ubin, Payments Canada et al. (2017), with project Jasper, Hong Kong Monetary Authority (2016) have tested the real-time gross settlement (RTGS) systems on the DLT, and Hong Kong management went further just to test in RTGS and provide an example of Proof-of-Concept in Mortgage loans, Trade finance, and identity management. The primary challenge of the DLT implementation in the wholesale system was the '*how to transfer value*' in project Jasper; they have employed Digital Depository Receipt (DDR) concept to represent the Bank of Canada's deposits. Like project Jasper, Ubin has employed the same method and proved that transformation could be settled in real-time. Both projects are promising; however, the respective central banks are still in the developing phase. Most of the developing economies' systems of the interbank settlements may not be sufficient enough to provide what DLT can offer today's research level, such as SARB (2018) Khokha project.

Digital tokens on the DLT platform have the potential to be used as a settlement asset; also, these transactions do not require '*a central third party*' to complete the transaction. Since the tokens have their own representation value, a transaction can be completed in peer to peer. However, that does not necessarily mean that there is no need for the central authority; in the validation part, a third party can be the manager of the market.

CPMI (2019), in their report on the wholesale digital tokens, has proposed '*a stylized model*' for token arrangements (graph 3.2). In graph 3.2, an instance of the workflow has been pictured. Various actors can be part of this system, such as validators or controllers. According to Lannquist (2020), '*wholesale CBDC, beyond interbank payments, could be applied in various countries to interbank securities transactions or financial market infrastructure applications (domestic or cross-border).*' CPMI (2019) emphasizes the inherent risks that can be incurred regarding the design of the system. Therefore, before the application, the system

should be tested tightly to understand the risks and the limits of the system; also, the legal requirements should be fulfilled.

Graph 3.2: Token Arrangement Model



Source: (CPMI, 2019, p. 5)

3.7.2. Public CBDC

Public CBDC, like the restricted one, has tested in a few countries⁹¹ (Banco de la República Oriental del Uruguay, 2017; Central Bank of The Bahamas, 2019; Gang, 2020; National Bank of Ukraine, 2019; The Eastern Caribbean Central Bank (ECCB), 2019; The Riksbank, 2020b). The public in CBDC refers to the openness to every agent in the economy. In the restricted CBDC, the design purpose was to replace or enhance the payment system between some banks and the central bank; however, public CBDC can serve different design purposes. After assuring the public interest, we should be able to answer such questions regarding the CBDC; Interest-bearing

⁹¹ See for the updated list of the Public CBDC experiments all around the globe: (Kiff, 2020)

feature, amount of the CBDC, direct access or indirect access, and account or token-based CBDC. Each feature has a significant return in the design of CBDC.

In the public CBDC, the central bank can choose between two forms of currency; one is the token-based currency the other is account-based currency (Figure 3.3). While the token-based approach provides anonymity to the customers, the account-based approach can provide more room to control illicit activities. Since the central banks' duty is not providing anonymity directly to the customers, the token-based approach, therefore not useful. The account-based approach, according to Berentsen & Schär (2018), provides simplicity and low administrative effort while protecting against money laundering and other illicit transactions.

In the Public CBDC, there is no need for the central bank to involve each transaction to check their compliance. ECB (2019) has shown proof of the concept of anonymity between users to some degree. That proof of concept hides the customers' low-value transactions and still covering the AML/CFT regulations in the high-value transactions. Anonymity in the lower transactions could be useful when purchasing from a central market that stores the data of the purchasing history of users. In the compliance section, smart contracts can be useful, such as if one wallet receives a significant amount of money from different accounts, that wallet can be locked down automatically.

The smart contracts can be adapt to various places as well as in central bank payments in different ledgers. However, smart contracts would require more processing power on the ledger, and with the unnecessary burden, the system potentially can slow down. Therefore, doubts would arise regarding the sustainability of the system and the energy consumption. Nevertheless, smart contracts can be separated onto another module so that the primary ledger would have less burden; also, this separated module can be co-governed with another body of government alongside with the central bank.

CBDC should be inclusive and offer an account to every member of the society, and temporary accounts should be defined to the tourists or foreigners. However, the central bank may not want to involve in the loan sector; thus, credit allocation can be

left to the banks again. An account-based system should be provided by the central bank and the other bodies of the government. Since most of the problems in cryptocurrencies have occurred in the market infrastructure and the wallets, in the CBDC, these systems should be secure and resilient. Leaving the bank money as it is should be the choice of the central bank as it may create instability.

Today each country has a cash transaction limit because authorities cannot trace clearly the transactions; thus, the limits are required; however, in the CBDC, there may no transaction limits since the traceability will allow the central bank to check the compliance. A central bank should design the CBDC as interest-bearing and can enable when the rates are down below zero. A central bank would not necessarily pay interest on CBDC, but imposing negative rates may be the solution for the complex problem. Providing interest to CBDC can pose an unnecessary burden to the central bank and may create instability in the financial sector; thus, it would trigger to shift in CBDC from bank money, and that may end up with many unwanted outcomes.

As explained in section 2. 4, CBDC should be convertible directly to cash with the CTC ratio since this policy tool will improve the central banks' effect on the market; the CTC ratio could potentially provide a reliable tool in a time of crisis or a bank run. On the bank money side, CBDC should be convertible to commercial banks' money at par to make the system sustainable.

3.8.Possible Benefits of CBDC

As already specified in section 3. 5, many central banks are exploring the CBDC and considering issuing their digital currency. Rather than a trend, CBDC can be beneficial for the following ways (Table 3.2).

Since the design of the DLT based on valuable asset exchange rather than the internet, which is based on information exchange, delivery versus payment can provide infrastructure for simultaneous payments. However, the technology is still in the developing phase transaction per second can be much less when compared with the traditional systems.⁹²

⁹² See for further details (K. Li, 2019)

CBDC could help with financial inclusion, maybe not in the developed economies, but in countries that have most of the population in peripheries. The infrastructure for cash distribution can be costly and inefficient. Some of the examples of this can be given in the e-form of money such as PayTm⁹³ or M-pesa⁹⁴. However, financial inclusion is not a simple task to fulfill, and CBDC can be a solution with good communications infrastructure, not just by itself is a solution.

Table 3.2: Benefits of CBDC

Efficient retail payments
Making available efficient, secure, and modern central bank money to everyone
Strengthening the resilience, availability, and contestability of retail payments
Overcome the use of banknotes for illicit payment and store of value
Better control of illicit payment and saving activities, money laundering, and terrorist financing
Avoiding the risks of new forms of private money creation
Strengthen monetary policy
Allows overcoming the ZLB as negative interest rates can be applied to CBDC
Interest rates on CBDC provide for additional monetary policy instruments, independently of ZLB
More effortless ability to provide helicopter money
Sovereign money related
Improve financial stability and reduce the moral hazard of banks by downscaling the role of the banking system in money creation
More considerable seignorage income to the state (and citizens) as the state takes back money creation from banks.
Reduce aggregate risk and improve financial stability
Promote financial inclusion

Source:(Engert & Fung, 2017; European Central Bank, 2020c)

The cost of issuing cash can be decreased with CBDC. Álveza et al. (2019) studied the cost of using cash in Uruguay and found that the private cost of handling cash was 0.61% of Uruguay's GDP. Kosse et al. (2017) have found that total resource costs of cash in Canada 0.35% of GDP and the same rate in the European Union 0.49% of GDP. Banks mostly cover these costs rather than firms and individuals. After the

⁹³ India's leading financial services company.

⁹⁴ M-Pesa is a mobile phone-based money transfer service in Kenya.

introduction of CBDC, the central bank will have new fixed costs and variable costs; however, these costs likely to be less than the cash costs, as mentioned above. Also, considering some proportion of cash will stay in the economy, the aforementioned cost will likely to stay.

CBDC can open up a new space for the monetary policy, not just only the elimination of the lower bound but also provides additional monetary policy instruments. As already mentioned above, the removal of the zero lower bound will give a powerful tool to the central banks in a financial crisis. Nevertheless, there are also critics about the negative rates, and the main argument is that the deep negative rates can undermine the trust of the central bank (Mersch, 2020). Besides the zero-lower bound, various authors suggested that CBDC will expand the policy options; Barrdear & Kumhof (2016, p. 3) argues this suggestion as follow:

‘A CBDC regime can contribute to the stabilization of the business cycle, by giving policymakers access to a second policy instrument that controls either the quantity or the price of CBDC in a countercyclical fashion. This second policy instrument becomes especially effective in response to shocks to private money demand and private money creation, and if the substitutability between CBDC balances and bank deposits in the production of monetary transaction services is low.’

CBDC interest rate offers a way to reinforce the transmission of monetary policy through a transparent monetary policy rate (Bordo & Levin, 2017).

CBDC means that each member of society will have an account at the central bank; this will give the central bank another feature that can be used to stimulate the economy in a time of demand or financial crisis by *‘Helicopter Money’*⁹⁵ (Meaning et al., 2018, p. 29). CBDC accounts can also help in a time of emergency; according to Rutkowski et al. (2020), due to the recent unprecedented crisis:

⁹⁵ The term of ‘helicopter money’ coined by Friedman, (1969) in his book the optimum quantity of money, said in a parable as follows: *‘Let us suppose now that one day a helicopter flies over this community and drops an additional \$1,000 in bills from the sky, which is, of course, hastily collected by members of the community. Let us suppose further that everyone is convinced that this is a unique event which will never be repeated.’*

'In Argentina, Pakistan, and Peru, announced new programs that cover one-third of their populations; in the Philippines, more than 70 percent of households will receive emergency transfers.'

CBDC issuance can unearth new opportunities regarding the seigniorage revenue and currency sovereignty. Some FinTech⁹⁶ or TechFin⁹⁷ companies have announced to issue or already issued a cryptocurrency. If they would gain significant attention, their existence might be a threat to the central bank sovereignty. Therefore, they would cause the substitution of the local currency like dollarization. Thus they would threaten financial stability (Diez de Los Rios & Zhu, 2020; Financial Stability Board, 2020). The argument around the sovereign money suggests that CBDC can be a new tool to prevent credit creation in commercial banks (Benes & Kumhof, 2012; Gross & Siebenbrunner, 2019). That can cause problems to the banks' working system as they are working under the credit creation⁹⁸; thus, they might be forced to operate under fractional banking again.

Nevertheless, this idea can be eliminated by leaving bank money as it is or allowing banks to create their '*bank exclusive currencies*⁹⁹', and CBDC can be exchanged with bank money at par. According to Huber (2019, p. 80), the existence of sovereign money and bank money may not pose a problem as it is thought to be and explains as follows:

'Sovereign money and bankmoney have coexisted for over three hundred years, at first in the form of precious metal coins coexisting with private banknotes, and subsequently in the form of central-bank cash (notes and coins) coexisting with bankmoney (deposit money). What would overall be different if this problem-ridden coexistence were to continue with DC used side by side with bankmoney?'

On the fiscal advantages of the CBDC regarding the sovereign money, CBDC can help to capture a significant proportion of the seigniorage revenue. Mayer & Huber

⁹⁶ Fintech is a term used to describe financial technology, an industry encompassing any kind of technology in financial services - from businesses to consumers (Sraders, 2020).

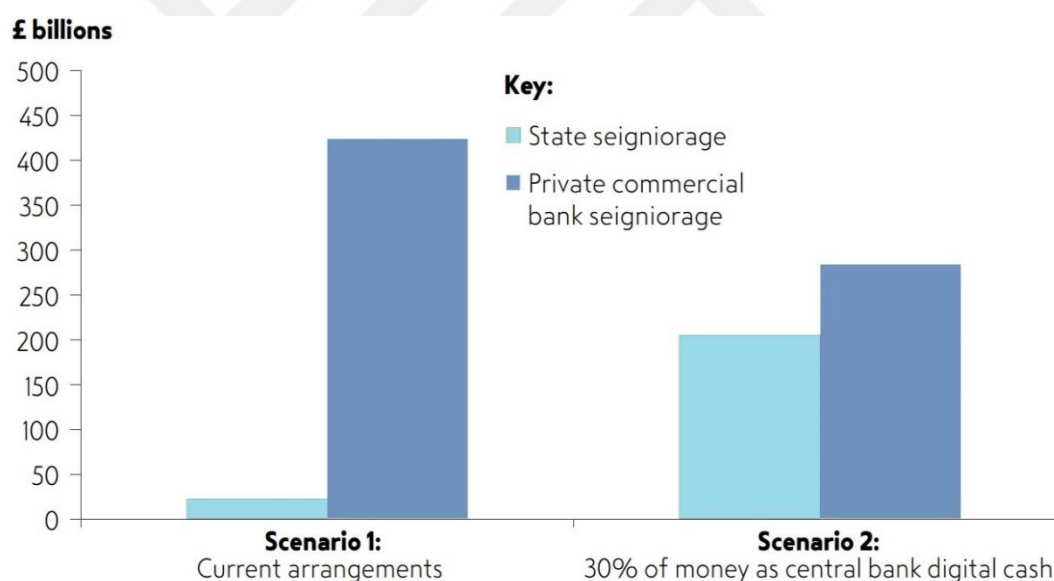
⁹⁷ Technology companies that provide financial services with a more customer and technology centric approach.

⁹⁸ See for further details regarding the credit creation theory; (Werner, 2014b; Xing et al., 2020)

⁹⁹ Allowing private banks to create their own currency can enable banks to do business as usual, and also infrastructural causes can lead this idea.

2014 (as cited in Bindseil, 2019, p. 307) estimated that in the eurozone, seignorage revenue would be more than €100 billion according to the pre-2008 interest rate level. This revenue might be less today considering the interest rate levels; however, today, banks almost all over the world control 97% of the money supply through CBDC that can transfer to the central banks (McLeay et al., 2014b, 2014a; Werner, 2014a). In the report of the NEF and CBS (2017) on the seignorage revenues, they have constructed a historical model in the UK during the 1998-2016 period, which is based on 30% of the money supply held in CBDC instead of bank deposits. They found that total revenue, on average, was equal to 1.8% of each year's government expenditures. During the same period in their model, commercial banks' income had fallen from £424 billion to £284 billion (Graph 3.3).

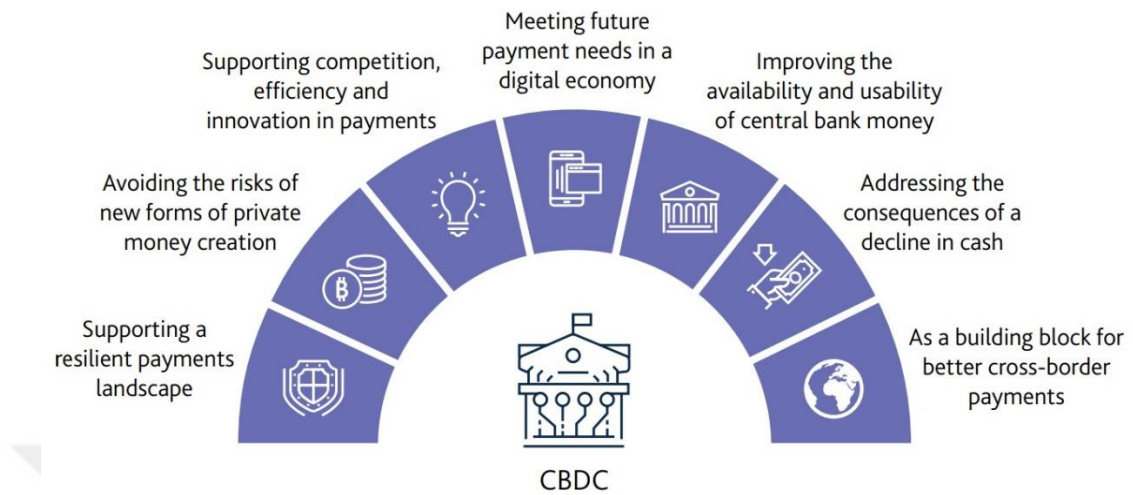
Graph 3.3: Total Seignorage Revenues in the UK



Source: (NEF & CBS, 2017)

BoE (2020), in a report on the CBDC, stated that '*CBDC could support the Bank's objectives to maintain monetary and financial stability, through the provision of a new form of money and a new payments infrastructure.*' In graph 3.4, the Bank of England has argued the potential roles of CBDC in financial stability and monetary policy.

Graph 3.4: Bank of England's Views for CBDC



Source: (Bank of England, 2020a, p. 16)

Each feature has the potential to provide benefits to society; there is a need for further research and experiment to understand the benefits and drawbacks to get the desired outcome. After all, a drop we know, and an ocean we do not.

3.9.Design Principles

3.9.1. Interest Bearing CBDC

CBDC should pay a variable and adjustable interest for many significant reasons. The interest rates play a crucial role in financial stability, price stability, monetary policy design, and the conversion rate between the bank money.

Price stability, as well as the parity between the CBDC, are perhaps the most significant factors of the interest rate policy. Equilibrium requires a price balance between demand and supply for CBDC in the market. If CBDC pays zero nominal interest rate as in the case of cash, and in case of an oversupply of CBDC, to get the level of the market clearance, two possible methods can be applied. First, the depreciation of the CBDC according to other monies, in other words, devaluation. Second, if parity remains fixed, CBDC will lose its real value and balances the real market demand, and that causes inflationary results. Indeed, this is an example of the printing of money.

3.9.2. Coexistence of Restricted and Public CBDC As a Distinct Money

Reserves should be in the form of tokenized restricted CBDC, as mentioned above in the restricted CBDC, and the Public CBDC should be in an account form distinct from the restricted one. These two forms of money should design as not convertible into each other on-demand. Thus, two main objectives can be achieved.

Firstly, if depositors attempt to switch to large numbers of CBDC, it helps to protect financial stability. In such a situation, any bank's willingness to exchange deposits against CBDC can pose a threat to financial stability. Kumhof & Noone (2018) specifies this direct conversion matter between CBDC and reserves as follows:

'When these reserves are convertible into CBDC on-demand at the central bank, the single bank can use its newly acquired reserves to acquire CBDC, in order to then pay out to the depositors that came to it for that purpose. This would lead to a destruction of deposits and facilitate a system-wide, near-instantaneous bank run. Similarly, if reserves and CBDC are not distinct, but instead one and the same, a run via the RTGS¹⁰⁰ system could occur in the same way.'

Secondly, the separation of the reserves and the CBDC allows the central bank to employ another policy instrument, the interest rate on CBDC, or the quantity of CBDC. Interest rates on CBDC can be used for financial stability, or it can add another tool for the monetary policy while the central banks sustain its control over the reserves. Regarding the role of the reserves, Kumhof & Noone (2018) says the followings:

'Retaining control over reserves allows the central bank to continue to influence the risk-free interest rate in the economy, the key rate for real investment decisions, and intertemporal allocation decisions.'

However, in the literature, some authors argue that even with a distinct form of reserves and CBDC because of the arbitrage, the additional monetary policy tool cannot exist. This is because arbitrage will bring convergency to the rates on reserves and the CBDC (Bordo & Levin, 2017; Engert & Fung, 2017). This conclusion of the

¹⁰⁰ Real-time gross settlement (RTGS) is the continuous process of settling interbank payments on an individual order basis across the books of a central bank.

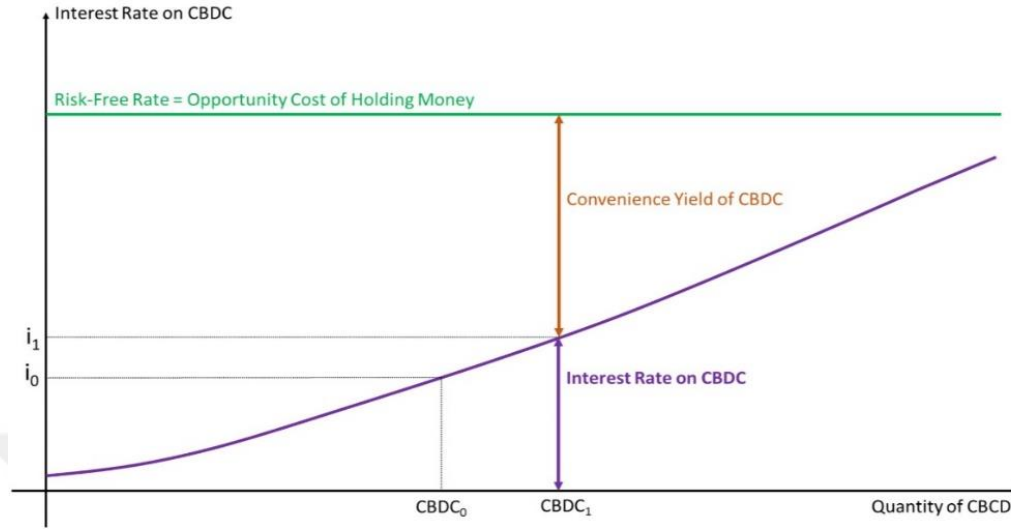
authors stems from an assumption of the same utility provided in two forms of money. Here in this study's assumption, the CBDC is a medium of retails payments; on the other hand, reserves are a medium of interbank settlements. Therefore, we argue the possibility of a new policy instrument, and the risk-free rate continues to be determined by the traditional policy, thus preventing the financial stability issues that could arise from the merge of reserves and CBDC, which mentioned above.

3.9.2.1. Arbitrage: Households and Firms

Currently, two forms of money belong to the central bank; cash and reserves. Cash bears, naturally, zero nominal interest rate; on the other hand, the nominal interest rate on reserves either the same as or almost equal to arbitrage, to the risk-free nominal interest rate of the economy, which is an interest rate on the government bills¹⁰¹ which is a pure store of value asset. CBDC's nominal interest rate risk-free too, however, government bills are only for the store of value, but CBDC will be used as a medium of exchange. The total financial return and the functionality of a medium of exchange specifies its return, which is referred to as the convenience yield (cy) in monetary economics. At the margin, ceteris paribus, the cy is diminishing as the quantity of CBDC increases, and the CBDC demand curve slopes upward at the rate of interest paid to CBDC (Figure 3.5).

¹⁰¹ Government bills are short dated securities which the government use to finance its public debt.

Graph 3.5: Convenience Yield on CBDC



Source: (Kumhof & Noone, 2018)

3.9.2.1.1. Model for Households and Firms Arbitrage

When the CBDC supply becomes short relative to the bank money supply, the cy will be large. The model that employed to prevent arbitrage as emphasized in Kumhof & Noone (2018):

$$rf = ic + cy_{hf}^{cbdc}(CBDC)$$

rf denoted the risk-free rate, ic refers to the interest paid to the CBDC, and the convenience yield will be a function of the stock of CBDC $cy_{hf}^{cbdc} = cy_{hf}^{cbdc}(CBDC)$ because it can be painful for a policymaker to know the size of its due to the variation in the cost technology of transactions. Where ic can be calculated as emphasized in Barrdear & Kumhof (2016):

$$i_t = (i_{t-1})^{i_i} \left[\frac{x \bar{\pi}^\rho (1 + \phi_b (b_t^{rat} - \bar{b}^{rat}))}{\beta_u} \right]^{(1-i_i)} \left(\frac{\pi_{4,t+3}^\rho}{(\bar{\pi}^\rho)^4} \right)^{\frac{(1-i_i)i_{\pi\rho}}{4}}$$

'The model follows a conventional inflation forecast-based interest rate rule, with interest rate smoothing and a countercyclical response to deviations of three-quarters-ahead annual inflation from the inflation target.'

The steady-state nominal interest rate is placed as the second term in the model, in which any increase in the debt-to-GDP ratio finds repercussions in the steady-state real interest rate. The response to the inflation placed as the third term, where $\pi_{4,t}^\rho = \pi_t^\rho \pi_{t-1}^\rho \pi_{t-2}^\rho \pi_{t-3}^\rho$.

Under the CBDC price rule assumption of Barrdear & Kumhof (2016):

$$i_{m,t} = \frac{i_t}{sp} \left(\frac{\pi_{4,t+3}^\rho}{(\bar{\pi}^\rho)^4} \right)^{-i_{\pi}^m}$$

The policy controls both the risk-free rate through reserves and the interest rate on the CBDC by the market.

Under the CBDC quantity rule assumption of Barrdear & Kumhof (2016):

$$m_t^{rat} = \overline{m^{rat}} S_t^{ms} - 100 m_{\pi^\rho} E_t \ln \left(\frac{\pi_{4,t+3}^\rho}{(\bar{\pi}^\rho)^4} \right)$$

The policy controls risk-free interest rate and the quantity of the CBDC, and the market determines the interest rate on CBDC, i_t . In order to adjust to satisfy the conditions of the arbitrage. In either price rule or quantity rule, another policy instrument will be available for the central bank to employ by the introduction of the CBDC. The central bank would have the option to control both the quantity or the price of the CBDC and the real risk-free interest rate. The risk-free interest rate on the only store of value asset is crucial for the real investments and decisions of intertemporal allocation.

3.9.2.2. Arbitrage by Banks

The role of non-bank users of CBDC indirectly determines the CBDC interest rate; since they are absorbing CBDC's marginal unit, thus determine the convenience yield, thereby determines the CBDC interest rate. However, without the role of the banks in the market for CBDC, the analysis would be incomplete.

3.9.2.2.1. Model for Banks' Arbitrage

According to Kumhof & Noone (2018), regarding the role of banks in the CBDC economy, two insights can be acquirable:

'Banks will not tend to hold much CBDC.'

Arbitrage by banks will not cause rf and ic to converge in a world where reserves and CBDC are distinct.'

First, banks would be the same as the household and firms regarding the risk-free interest rate and the convenience yield, rf and $cy_{hf}^{cbdc}(CBDC)$. Since the risk-free interest rate applies to every agent in the economy and in the CBDC market, the convenience yield is determined via a marginal holder. The marginal holder, households, and firms, who gain significant benefits from the CBDC; on the other hand, banks are not gaining that much benefits from holding CBDC over reserves or gilts. Since the opportunity cost would push banks, they would not hold any significant amount of CBDC. As emphasized in Kumhof & Noone (2018), a possible solution for the portfolio problem of banks:

$$rf = ic + cy_b^{cbdc}(CBDC_b)$$

Convenience yield for banks denoted as cy_b^{cbdc} and the quantity of CBDC that held by banks $CBDC_b$. As in the cash holding decision, the solution offers the same, which is sufficient enough to meet customer demands.

Second, banks can obtain CBDC like any other security; however, they have to pay for CBDC since it is an outside asset through the created deposits. Banks cannot borrow from ic , the CBDC, and invest the CBDC from rf to reserves. To satisfy their liquidity demands, households and firms decide on among CBDC and deposits. No arbitrage condition by the banks as emphasizing in Kumhof & Noone (2018):

$$rd = ic - cy_{hf}^{cbdc}(CBDC) - cy_{hf}^{dep} + s = rf - cy_{hf}^{cbdc}(DEP) + s$$

The interest rate on the deposits denoted as rd , cy_{hf}^{cbdc} refers to the convenience yield on deposits, and s refers to the spread that covers the credit risk of holding deposits at the commercial banks. The marginal holders of CBDC would be unconcerned about among CBDC and deposits from the prevailing rates of interests and endogenic stocks of CBDC and deposits. Thus, they only sell their CBDC if only bank deposits offer equal or higher interest rates. As stated in the above formula, the

convenience yield existence makes rf and ic not equal to each other in such equilibrium that has no arbitrage.

The central bank has the power as the only provider of distinct two forms of money, reserves and CBDC, to control fluctuations in the risk-free rate and the interest rate on CBDC or the quantity of CBDC.

3.9.2.3. Convertibility of CBDC to Bank Deposits

Some authors suggested that the convertibility of the CBDC to bank deposits should not be a problem whenever the depositors want to convert and how much ever they want to convert (e.g., Meaning et al., (2018)). This should not be a binding feature for the CBDC, and for some reason, this can be dangerous and redundant.¹⁰²

The peril of the convertibility guarantee does not show itself during regular times, but since there is an obligation to convert deposits to CBDC, in a time of stress, the central bank must accept deposit against CBDC rather than eligible assets. This can cause to run from bank deposits to CBDC, and this would not run from a single bank; rather, it would be a run from the banking system. In the case of a bank run, the central bank can adapt the CTC ratio to the bank deposit to CBDC to discourage switching. In that much a big move, the ratios would be significantly negative, and this can find a lousy response in the politics.

On the other hand, in case of the convertibility not compulsory between the CBDC and the deposits, the depositors can still obtain CBDC with their deposits. Removing the guarantee from the convertibility of deposits into CBDC does not mean that the depositors will not obtain CBDC; on the contrary, CBDC can still be obtainable from the market with the eligible assets. In this way, the complete banking system run is eliminated.

However, the depositors can still try to cash-out all their deposits in such a situation; the central bank would employ the CTC ratio, changing the CBDC in the formula with deposits temporarily, to prevent the banking system run to cash.

¹⁰² Even in some country, there is no obligation for deposit convertibility to the banknote, as in the UK (Kumhof & Noone, 2018). Nevertheless, banks usually pays paper-based money on demand.

On the subject of the stable exchange rate (1:1) among the deposits and the CBDC, Kumhof & Noone (2018) states that parity can be maintained, providing that the following conditions:

'The central bank allows the adjustment of the interest rate on CBDC (under a CBDC quantity rule) or of the quantity of CBDC via exchanges of non-deposit eligible assets against CBDC (under a CBDC price rule) such that private sector agents expect the parity condition to hold. That is, the central bank consistently and credibly acts to match the quantities of CBDC demanded and supplied at the targeted quantities or prices.

There is a functioning and liquid market for CBDC eligible securities.

There is at least one private-sector agent (such as a bank or other financial institution) that can accept/issue a payment from bank deposits and is active in both the market for CBDC and in the market for CBDC eligible securities.'

As the authors specified, a market that is sufficient enough liquid and significant for the marginal holders of deposits and CBDC to trade their assets freely would be reasonable under these conditions. This market would be more reliable, even with a few agents that can access to additional CBDC with eligible securities, than the reliance on the guaranteed convertibility of bank deposits into CBDC.

3.9.2.4. Eligible Securities against CBDC

The last principle of the CBDC is that the central bank issues and exchanges the CBDC for eligible securities like securities of government. That does not apply for reserves and bank deposits. Therefore, the central bank can mitigate the risks that can stem from issuing CBDC, as in the banknotes and the reserves. Further, the rule for exchanging CBDC eliminates, mostly, the risk of the banking sector run. This crisis can stem from one bank when reserves can be freely tradeable with CBDC, or when the CBDC can be changeable directly with deposits that can cause aggregate run from the banking system.

3.10. Possible Implications of the CBDC

There are concerns about the CBDC regarding the disruptive effects over the current market bodies. Various models have been tested by both academicians and central bankers to have a better understanding of the implications of CBDC.

Andolfatto (2019), in his work, investigated the interest-bearing CBDC effects on the banking sector. The authors' results show no detrimental effect on the private banks' lending; even in some cases, the introduction of CBDC could be beneficial. However, the author emphasizes that monopolistic profit would likely decrease, and he specifies that properly designed CBDC unlikely to threaten financial stability. In case of proper design of CBDC, financial stability is not like to be threatened.

Davoodalhosseini (2018) argued that cash and CBDC mutual existence would lower the welfare of society and suggest that the introduction of the CBDC would increase welfare in Canada by 0.64%. Williamson (2019) studied the effects of CBDC on the monetary policy and found three reasons that increase welfare. One, the substitution of the physical currency limits the illicit activities; second, interest-bearing CBDC would add another policy instrument to the central bank's toolkit; third, mitigate incentive problems of private banking.

Keister & Sanches (2019) study the effects of CBDC on interest rates, economic activity level, and welfare. According to the authors, this innovation in the monetary policy can promote efficiency in exchange; however, it causes a shift from bank deposits, and therefore, funding costs of banks would increase. They suggest that, even with adverse effects on banks, the introduction of CBDC will increase overall welfare. According to Kumhof & Noone (2018), in the model they have built, CBDC does not affect the balance sheets of the banks and does not necessarily decrease the financing level of banks.

CONCLUSION

Central banks have various roles just than printing money; BOJ provided an excellent example for the roles of the central banks over society¹⁰³. As Kiff et al. (2020) specified, *'In addition to monetary and financial stability roles, central banks play a core public sector role in the economy to provide a safe, efficient, and inclusive payment system.'* Moreover, as technology evolves, payment systems have to follow to provide more efficiency. Some countries are experiencing a significant decrease in their cash usage; this poses a threat to the central bank role in the payments. Some central banks are now working pro-actively to address the challenges that come with technological enhancement. As in the negative interest rate policies, the well-studied policy would end up fruitfully; as stated in Demiralp et al. (2019), negative rate policy can be used as an empowerment tool for central banks' other monetary policies.

The database, DLT that created for digital money offers potentially better solutions for today's scenarios. The adaption of the DLT in the central bank money system is the most argued subject regarding the societal role of the DLT. In this regard, a new form of money has been proposed as Central Bank Digital Currency (CBDC), that liability to the central bank. Since the money itself is programmable, design features are crucial; well-designed CBDC could improve the financial stability and the payment system; on the other side, the unelaborated design of CBDC would most likely undermine financial stability.

Central bank digital currencies (CBDCs) give rise to numerous questions on the design and operation of the monetary and financial system. Therefore, many financial institutions and the central banks are exploring digital currencies, and the technology lies behind that, distributed ledger technology. Since the technology potentially offers improvement in the traditional system, in the ways of resiliency, cost reduction, security, and increase in speed and efficiency. However, to study the macroeconomic effects of the CBDC would be practically impossible since there is no experience regarding the CBDC and also lack empirical work data. The approach has, therefore, based on a theoretical model.

¹⁰³ See for the detailed explanation (Werner, 2003).

In order to argue CBDC's potential impact, it is necessary, to begin with, an explicit designation of the real-world example of a CBDC and how it might operate. Since the system naturally enables to impose of negative interest rates on the liability of the central bank, which is CBDC, the works propose first a CTC ratio to handle the cash demand elastically. After the separation of the roles of the money, cash will be a less preferred form of the central bank money since the CBDC will be the new legal tender.

Four design principles have stated for a monetary system that includes CBDC and possible solutions regarding the digital bank run. According to the principles;

1. CBDC should bear interest, adjustably.
2. CBDC and reserves should be separated and not directly convertible.
3. There should be no guarantee for the convertibility of deposits to CBDC.
4. CBDC should only be issued for eligible securities.

Nevertheless, under the fractional reserve theory, bank runs cannot wholly eliminate; only the possibility of the bank run can be minimized. Under the quantity rule of CBDC, CBDC's interest rate might decrease profoundly, and that can cause a political risk.

Under the price rule of CBDC, since the CBDC obtainable with the eligible assets, the market can have an eligible asset crisis, even with the vast prevailing amount of debt of the governments.

As stated in the prologue, this study intended to serve as useful background material for both negative interest rates policies and the central bank digital currencies. Regarding the bank runs with the introduction of the CBDC, although the effectiveness of the policies will depend on the design, the design principles stated here are important. In particular, CBDC should control with either price rule or the quantity rule to have an effective mechanism to meet the demands in a time of need.

Some issues regarding the CBDC remain unanswered or requires further investigation, possibly with live experiments; these are:

In rural areas, if the internet connection is lost in that case, will the CBDC application operate, or up to what amount will it operate offline? Some areas might have a problem with the electricity due to the infrastructure problems, will there be a plan to cover that kind of scenarios? In addition to this, if the CBDC becomes the unit of account, will the central bank premise provide infrastructure to make it available to every member of the society, e.g., smartphones, the internet connection.

- Will the design of the CBDC improve the payment system and support resiliency?
- After the introduction of the CBDC, what will be the demand and the system contribute to financial stability?
- Will CBDC cause to disintermediation of the banking system, and if it will, to what extend?
- What will be done to public acceptance of the CBDC?
- Which precautions have been taken to make the system robust and provide personal security?
- The problem of substitutability among the CBDC and the bank deposits.

Paper-based money seems not likely to be usable in the future; nevertheless, CBDC can be the answer. However, the DLT is a novel technology and requires more research to provide a solid ground to central banks.

REFERENCES

93rd Congress.: 1974	Senate bill / 02665. https://www.congress.gov/bill/93rd-congress/senate-bill/02665
Accenture.: 2017	The (R)evolution of Money Accenture. https://www.accenture.com/t20171116T025715Z__w__/us-en/_acnmedia/PDF-63/Accenture-Evolution-Money-Blockchain-Digital-Currencies.pdf
Agarwal, R., & Kimball, M.: 2015	Breaking Through the Zero Lower Bound. IMF Working Paper (WP/15/224).
Agur, I., Bergara, M., Bordo, M. D., Engert, W., Levin, A. T., Lis, S. F. de, Fung, B. S. C., Gnan, E., Niepelt, D., Judson, R., Masciandaro, D., Panetta, F., Pichler, P., Ponce, J., & Summer, M.: 2018	Do We Need Central Bank Digital Currency ? In E. Gnan & D. Masciandro (Eds.), Do We Need Central Bank Digital Currency? Economics, Technology and Institutions. SUERF – The European Money and Finance Forum.
Alfarano, R.: 2019	Central Bank Digital Currency In The Inside-Outside Money Competition Mechanism. The Universidade Católica Portuguesa.
Ali, R., Barrdear, J., Clews, R., & Southgate, J.: 2014a	Innovations in payment technologies and the emergence of digital currencies of the Bank's Financial Market Infrastructure Directorate, John Barrdear of the Bank's Monetary Assessment and Strategy Division, and Roger Clews and James Southgate of the Bank's. Quarterly Bulletin 2014 Q3, Q3(1), 262–275. https://www.bankofengland.co.uk/-/media/boe/files/quarterly-bulletin/2014/innovations-in-

	payment-technologies-and-the-emergence-of-digital-currencies.pdf?la=en&hash=AB46869B3EF355A0486F7B0BAF086F2EEE31554D
Ali, R., Barrdear, J., Clews, R., & Southgate, J.: 2014b	The economies of digital currencies. Quarterly Bulletin 2014 Q3, 43(1), 276–286.
Álveza, M., Lluberasa, R., & Ponce, J.: 2019	The cost of using cash and checks in Uruguay (No. 004–2019; Documento de Trabajo Del Banco Central Del Uruguay). https://www.bcu.gub.uy/Estadisticas-e-Indicadores/Documentos de Trabajo/4.2019.pdf
American Numismatic Society. :2020a	Gold Solidus of Anastasius I, Constantinople, AD 498 - AD 518. 1949.61.1. Byzantine Collections. http://numismatics.org/collection/1949.61.1?lang=tr
American Numismatic Society. :2020b	Silver Denarius, Rome, 104 B.C.. 1944.100.670. Roman Collections. http://numismatics.org/collection/1944.100.670?lang=tr
American Numismatic Society. :2020c	Silver Quadrigatus, Rome, 225 B.C. - 212 B.C. 1944.100.42. Roman Collections. http://numismatics.org/collection/1944.100.42?lang=tr
Andolfatto, D.:2015	Fedcoin: On the Desirability of a Government Cryptocurrency. MacroMania [Blog]. https://andolfatto.blogspot.com/2015/02/fedcoin-on-desirability-of-government.html
Andolfatto, D.:2019	Assessing the Impact of Central Bank Digital Currency on Private Banks. In Federal Reserve Bank of St. Louis, Working Papers (FRB St. Louis Working Paper). https://doi.org/http://dx.doi.org/10.20955/wp.2018.026

Andoni, M., Robu, V., Flynn, D., Abram, S., Geach, D., Jenkins, D., McCallum, P., & Peacock, A.:2019.	Blockchain technology in the energy sector: A systematic review of challenges and opportunities. Renewable and Sustainable Energy Reviews, 100, 143–174. https://doi.org/https://doi.org/10.1016/j.rser.2018.10.014
Andrist, R. K.:2015	The Gold Rush. New World City, Inc.
Angrick, S., & Nemoto, N.:2017	CENTRAL BANKING BELOW ZERO: THE IMPLEMENTATION OF NEGATIVE INTEREST RATES IN EUROPE AND JAPAN. In ADBI Working Paper (No. 740; ADBI Working Paper 740, Issue 740). https://www.adb.org/publications/central-bankingbelow-zero-negative-interest-rate-policies-europe-japan
Aristotle. :1999	Politics. (Çev. Benjamin, Jowet). Batoche Books, 192.
Arteta, Carlos; Kose, M. A., & Stocker, Marc; Taskin, T. :2016	Negative Interest Rate Policies : Sources and Implications. In Policy Research Working Paper: Vol. No. 7791 (Issue World Bank, Washington, DC.).
Ashton, T. S.:2006	An Economic History of England: the Eighteenth Century. https://doi.org/10.4324/9781315019314
Assenmacher, K., & Krogstrup, S.:2018	Monetary Policy with Negative Interest Rates: Decoupling Cash from Electronic Money. IMF Working Papers, 18(191), 1. https://doi.org/10.5089/9781484370025.001
Auer, R., Cornelli, G., & Frost, J. :2020	Covid-19, cash, and the future of payments. BIS Bulletin, 3. https://www.bis.org/publ/bisbull03.pdf
Aydar, M., Ayvaz, S., & Cetin, S. C. :2019	Towards a Blockchain based digital identity verification, record attestation, and record sharing system. http://arxiv.org/abs/1906.09791
Ball, L., Gagnon, J., Honohan, P., & Krogstrup, S.:2016	18th Geneva Report on the World Economy: What Else Can Central Banks Do? (Issue September).

Banco de la República Oriental del Uruguay.:2017 .	Billete Digital. https://www.bcu.gub.uy/Comunicaciones/Conferencias/20171103_BCU_Billete_Digital.pdf
Banco de Portugal.:2020	COVID 19. Merchants obliged to accept payment cards regardless of the transaction amount. Press Releases. https://www.bportugal.pt/en/comunicado/covid-19-merchants-obliged-accept-payment-cards-regardless-transaction-amount
Bank for International Settlements.:1996	Implications for central banks of the development of electronic money. In Working Paper (Issue October).
BANK INDONESIA.:2020	BI 7-Day Reverse Repo Rate Lowered 25 bps to 4,50 : Maintaining Stability, Mitigating The Risk of COVID-19. BI Graphic Governor's Meeting - March 2020. https://www.bi.go.id/en/ruang-media/siaran-pers/Pages/SP_222220.aspx
Bank of Canada.:2016	Introduction to Jasper. https://doi.org/10.1007/978-3-319-61783-1_15
Bank of Canada.:2018	Jasper Phase III Securities Settlement Using Distributed Ledger Technology. In Project Jasper (Issue October).
Bank of Canada.:2020a	Bank of Canada asks retailers to continue accepting cash. Announcements. https://www.bankofcanada.ca/2020/04/bank-canada-asks-retailers-continue-accepting-cash/?page_moved=1
Bank of Canada.:2020b	Contingency Planning for a Central Bank Digital Currency. Bank of Canada. https://www.bankofcanada.ca/2020/02/contingency-planning-central-bank-digital-currency/#1-Introduction
Bank of Canada, & Monetary Authority of Singapore. :2019	Jasper - Ubin Design Paper. https://www.mas.gov.sg/-/media/Jasper-Ubin-Design-

	Paper.pdf?la=en&hash=EF5857437C4857373A9287CD86F56D0E7C46E7FF
Bank of England. :2020a	Central Bank Digital Currency, Opportunities, challenges and design (Issue March).
Bank of England. :2020b	Early banknotes. Museum/Banknotes. https://www.bankofengland.co.uk/museum/online-collections/banknotes/early-banknotes
Bank of England. :2020c	What is quantitative easing? https://www.bankofengland.co.uk/monetary-policy/quantitative-easing
Bank of France. :2016	La Banque de France mène une expérimentation de «blockchain» interbancaire. PRESS RELEASE. https://www.banque-france.fr/sites/default/files/medias/documents/communique-de-presse_2016-12-15_la-banque-de-france-mene-une-experimentation-de-blockchain-interbancaire.pdf
Bank of Israel. :2018	Report of the team to examine the issue of central bank digital currencies. https://www.boi.org.il/en/NewsAndPublications/PressReleases/Documents/Digital currency.pdf
Bank of Japan. :2020	Reserves. Statistics. https://www.boj.or.jp/en/statistics/boj/other/reserve/index.htm/
Bank of Korea. :2020	Press Releases. Press Releases. www.bok.or.kr/viewer/skin/doc.html?fn=202002240520208972.pdf&rs=/webview/result/P0000559/202002
Barrdear, J., & Kumhof, M.:2016	The Macroeconomics of Central Bank Issued Digital Currencies. In Staff Working Paper (No. 605; Staff Working Paper, Issue 605). https://doi.org/10.2139/ssrn.2811208
Bascand, G.:2018.	In search of gold: Exploring central bank digital currency. The Point Conference, June.

	https://www.rbnz.govt.nz/research-and-publications/speeches/2018/speech2018-06-25
Bech, M., Faruqui, U., Ougaard, F., & Picillo, C.:2018	Payments are a-changin' but cash still rules. BIS Quarterly Review, March, 67–80.
Bech, M., & Garratt, R.:2017	Central Bank Cryptocurrencies. BIS Quarterly Review September 2017: International Banking and Financial Market Developments, September, 55–70. www.bis.org
Bech, M., & Malkhozov, A.:2016	How have central banks implemented negative policy rates? Basel Committee on Banking Supervision, March 31–44.
Belinky, M., Rennick, E., & Veitch, A. :2015	Santander InnoVentures – Fintech 2.0 Paper. Santander Innoventures, 20. http://santanderinnoventures.com/fintech2/
Benbunan-Fich, R., & Castellanos, A. :2018	Digitalization of land records: From paper to blockchain. International Conference on Information Systems 2018, ICIS 2018, November.
Benes, J., & Kumhof, M.:2012	The Chicago Plan Revisited (WP/12/202; IMF Working Paper). https://www.imf.org/external/pubs/ft/wp/2012/wp12202.pdf
Benhabib, J., Schmitt-Grohe, S., & Uribe, M. :2002	Avoiding Liquidity Traps. Journal of Political Economy, 110(3), 535–563.
Berentsen, A., & Schär, F.:2018	The case for central bank electronic money and the non-case for central bank cryptocurrencies. Federal Reserve Bank of St. Louis Review, 100(2), 97–106. https://doi.org/10.20955/R.2018.97-106
Bernanke, B. S.:2002	Deflation: Making Sure “It” Doesn’t Happen Here. Deflation: Making Sure “It” Doesn’t Happen Here.

Bernanke, B. S.:2016	What tools does the Fed have left? Part 1: Negative interest rates. The Brookings Institution Blog. https://www.brookings.edu/blog/ben-bernanke/2016/03/18/what-tools-does-the-fed-have-left-part-1-negative-interest-rates/
Bernanke, B. S., Reinhart, V. R., & Sack, B. P. :2004	Monetary Policy Alternatives at the Zero Bound: An Empirical Assessment. Brookings Papers on Economic Activity.
Bilgi, Ö. :1997	In Palmet I. In Klasik Çağ Öncesinde Anadolu'da Ticaret. (pp. 1–36).
Bilgiç, E.:1963	ESKİ MezopotamyKavimlerinde Kanun Anlayışı Ve anAnesi. Ankara Üniversitesi Dil ve Tarih-Coğrafya Fakültesi Dergisi, 21(3–4), 103–119. https://doi.org/10.1501/dtcfder_00000000497
Bindseil, U.:2019	Central Bank Digital Currency: Financial System Implications and Control. International Journal of Political Economy, 48(4), 303–335. https://doi.org/10.1080/08911916.2019.1693160
BIS. :2019	Proceeding with caution - a survey on central bank digital currency. Bank for International Settlements, 101(January), 1–15. https://econpapers.repec.org/RePEc:bis:bisbps:101
Bjerg, O.:2017	Designing New Money - The Policy Trilemma of Central Bank Digital Currency. SSRN Electronic Journal, 1503, 1–57. https://doi.org/10.2139/ssrn.2985381
Blanc, J.:2018	Tensions in the triangle: monetary plurality between institutional integration, competition and complementarity. Evolutionary and Institutional Economics Review, 15(2), 389–411. https://doi.org/10.1007/s40844-018-0101-1
Blanchard, O., Dell’Ariccia, G., & Mauro, P. :2010	Rethinking macroeconomic policy. Journal of Money, Credit and Banking, 42(SUPPL. 1), 199–215. https://doi.org/10.1111/j.1538-4616.2010.00334.x

Blanke, J., & Krogstrup, S.:2016	Negative interest rates: absolutely everything you need to know. World Economic Forum [Blog]. https://www.weforum.org/agenda/2016/11/negative-interest-rates-absolutely-everything-you-need-to-know/
Blinder, A. S.:2000	Monetary Policy at the Zero Lower Bound: Balancing the Risks: Summary Panel. Journal of Money, Credit and Banking, 32(4), 1093–1099.
Blomquist, N., Dam, N. A., & Spange, M. :2011	Monetary-Policy Strategies at the Zero Lower Bound on Interest Rates. 83–98.
Board of Governors of the Federal Reserve System: US. :2020	FRED Economic Data. https://www.federalreserve.gov/
Boesenach, E., Knaap, P. van der, & Vries, T. de. :2018	World Cash Report 2018. In G4S. https://www.g4scashreport.com/-/media/g4s/cash-report/files/2018-world-cash-report---english.ashx?la=en&hash=0F3BECD46B4820D7FA32112E99252AAB
Bordo, M. D., & Levin, A. T.:2017	Central Bank Digital Currency and the Future of Monetary Policy. In NBER Working Paper (No. 23711; NBER Working Paper). http://www.nber.org/papers/w23711
Borensztein, E., & Berg, A.:2000	The Pros and Cons of Full Dollarization. In IMF Working Paper (No. 50; IMF Working Paper). https://doi.org/10.2139/ssrn.267355
Borio, C.:2019	On money, debt, trust and central banking (No. 763; BIS Working Papers, Issue 763). https://www.bis.org/publ/work763.pdf
Boungou, W.:2020	Negative interest rates policy and banks' risk-taking: Empirical evidence. Economics Letters, 186, 108760. https://doi.org/10.1016/j.econlet.2019.108760

Broadbent, B.:2016	Ben Broadbent: central banks and digital currencies. Speech by Mr Ben Broadbent, Deputy Governor for Monetary Policy of the Bank of England, at the London School of Economics, London, 2 March 2016, March, 1–11.
Bryant, R. C., & Freedman, C.:2000.	Comment on Overcoming the Zero Bound on Interest Rate Policy. <i>Journal of Money, Credit and Banking</i> , 32(4), 1051–1057. https://www.jstor.org/stable/2601158
Buiter, W. H.:2005	Overcoming the zero bound on nominal interest rates: Gesell's currency carry tax vs. Eisler's parallel virtual currency. In <i>Hi-Stat Discussion Paper Series</i> (No. 96). https://doi.org/10.1007/s10368-005-0033-1
Buiter, W. H.:2007	Is numéraireology the future of monetary economics? Unbundling numéraire and medium of exchange through a virtual currency and a shadow exchange rate. <i>Open Economies Review</i> , 18(2), 127–156. https://doi.org/10.1007/s11079-007-9035-7
Buiter, W. H.:2009	Negative Nominal Interest Rates: Three ways to overcome the zero lower bound. In <i>NBER Working Paper</i> (No. 15118; NBER Working Paper). https://www.nber.org/papers/w15118.pdf
Buiter, W. H., & Panigirtzoglou, N.:1999	Liquidity Traps: How to Avoid Them and How to Escape Them (No. 7245; NBER WORKING PAPER SERIES). http://www.nber.org/papers/w7245
Buiter, W. H., & Panigirtzoglou, N.:2003	Overcoming the Zero Bound on Nominal Interest Rates with Negative Interest on Currency : Gesell ' s Solution. <i>The Economic Journal</i> , 113(490), 723–746. https://www.jstor.org/stable/3590280
Burenin, A. N.:2016	Negative Interest Rates: Central Banks Initiated an Experiment. <i>MGIMO Review of International Relations</i> , 4(49), 262–273.

Cadoux, T. J.:2020	Solon. Encyclopædia Britannica, Inc. https://www.britannica.com/biography/Solon
Campos, M. U.:2019	Going Negative at the Zero Lower Bound: The Effects of Negative Nominal Interest Rates (Working Paper2019-21; Working Paper2019-21). https://www.frbsf.org/economic-research/files/wp2019-21.pdf
CB Insights. :2018	What is Blockchain Technology.
CB Insights. :2019	Global Fintech Report, Q3. In CB Insights (Vol. 1, Issue 3).
Cecchetti, S., & Schoenholtz, K. :2017	Fintech, Central Banking and Digital Currency. Money and Banking. https://www.moneyandbanking.com/commentary/2017/6/1/1/fintech-central-banking-and-digital-currency
Central Bank of Kuwait. :2020	CBK Assures Smooth and Safe Banking Operations. Press Releases. https://www.cbk.gov.kw/en/cbk-news/announcements-and-press-releases/press-releases/2020/03/202003121418-press-release-cbk-assures-smooth-and-safe-banking-operations
Central Bank of The Bahamas. :2019	Project Sand Dolla : A Bahamas Payments System Modernisation Initiative. https://www.centralbankbahamas.com/publications/main-publications/project-sanddollar-a-bahamian-payments-system-modernization-initiative
Centre for European Policy Studies, & Ecorys. :2017	Study on an EU initiative for a restriction on payments in cash (Issue December). http://ec.europa.eu/smart-regulation/roadmaps/docs/plan_2016_028_cash_restrictions_en.pdf
Chaum, D.:1983	Blind Signatures for Untraceable Payments. (pp. 199–203). https://doi.org/10.1007/978-1-4757-0602-4_18
Chen, J.:2019	Securitization. Investopedia.Com. https://www.investopedia.com/terms/s/securitization.asp

Cheney, J. S.:2006	The Role of Electronic Payments in Disaster Recovery: Providing More Than Convenience. 25.
Chiu, J., Davoodalhosseini, S. M., Hua Jiang, J., & Zhu, Y.:2019.	Central Bank Digital Currency and Banking. In Staff Working Paper (Staff Working Paper).
Chiu, J., & Koepl, T. V.:2017.	The Economics of Cryptocurrencies Bitcoin and Beyond. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3048124
Chiu, J., & Koepl, T. V.:2019	Blockchain-Based Settlement for Asset Trading. In Review of Financial Studies (Vol. 32, Issue 5). https://doi.org/10.1093/rfs/hhy122
Citibank. :2019	Digital Money: A Journey Worth Taking. March 14. https://www.citibank.com/icg/sa/digital_symposium/digital_money_index/pdf/Citi_Digital_Money_Report_2019.pdf
Clapham, J. H.:1945.	The Bank of England: A History (Issue 2. c.). The University Press. https://books.google.com.tr/books?id=8j48AAAAIAAJ
Clough, S. B.:1952	Economic History of Europe.
Clouse, J., Henderson, D., Orphanides, A., Small, D. H., & Tinsley, P. A.:2003	Monetary policy when the nominal short-term interest rate is zero. Topics in Macroeconomics, 3(1). https://doi.org/10.2202/1534-5998.1088
Cœuré, B.:2016	Assessing the implications of negative interest rates. Yale Financial Crisis Forum, July 1–15. https://www.ecb.europa.eu/press/key/date/2016/html/sp160728.en.html
Coindesk. :2016.	10 Stock and Commodities Exchanges Investigating Blockchain Tech. Markets. https://www.coindesk.com/10-stock-exchanges-blockchain

Committee on Payments and Market Infrastructures: CPMI, Norges Bank, IBM Blockchain, & OMFIF.:2018	Central bank digital currencies. In Bank for International Settlements (BIS, Suiça) (NORGES BANK PAPERS, Vol. 174, Issue March). https://www.bis.org/cpmi/publ/d174.pdf
CPMI. :2019	Wholesale digital tokens (Issue December). https://www.bis.org/cpmi/publ/d190.htm
CPMI: Committee on Payments and Market Infrastructures.:2015	Digital currencies (Issue September).
Cseresnyés, P.:2020.	Coronavirus: Hungary's Central Bank Quarantines and Cleans Banknotes. Hungary Today.
Dai, W.:1998	B-money. http://www.weidai.com/bmoney.txt
Danezis, G., & Meiklejohn, S. :2016	Centrally Banked Cryptocurrencies (Issue February).
Danmarks Nationalbank. :2015	Negative Interest Rates and Their Impact on Credit Institutions' Earnings. In Financial Stability 1st Half 2015. Danmarks Nationalbank.
Danmarks Nationalbank. :2017	Central bank digital currency in Denmark?
Danthine, J. P.:2017.	The Interest Rate Unbound? Comparative Economic Studies, 59(2), 129–148. https://doi.org/10.1057/s41294-017-0019-3
Davies, S. J.:2003.	Japan's Deflation and the Feasibility of Negative Interest Rates. Kobe Economic & Business Review, 47, 93–115. https://econpapers.repec.org/RePEc:kob:review:feb2003::v:47:p:93-115

Davies, S. J.:2005.	National Money of Account, with a Second National Money or Local Monies as Means of Payment: A Way of Finessing the Zero Interest Rate Bound. Kobe Economic & Business Review, 49, 69–91. https://ideas.repec.org/a/kob/review/feb2005v49p69-91.html
Davoodalhosseini, S. M.:2018	Central Bank Digital Currency and Monetary Policy. In Staff Working Paper (No. 36; Staff Working Paper). https://doi.org/10.2139/ssrn.3011401
De Almeida, P., Fazendeiro, P., & Inácio, P. R. M.:2018 .	Societal risks of the end of physical cash. Futures, 104(June), 47–60. https://doi.org/10.1016/J.FUTURES.2018.07.004
Demiralp, S., Eisenschmidt, J., & Vlassopoulos, T.:2017 .	Negative interest rates, excess liquidity and bank business models: Banks’ reaction to unconventional monetary policy in the euro area S. Demiralp (Koc University), J. Eisenschmidt (ECB) and T. Vlassopoulos (ECB) 1. February. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2941377
Demiralp, S., Eisenschmidt, J., & Vlassopoulos, T.:2019 .	Negative interest rates, excess liquidity and retail deposits: banks’ reaction to unconventional monetary policy in the euro area. In ECB Working Paper Series (No. 2283; Working Paper Series, Vol. 2283). https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp2283~2ccc074964.en.pdf
Deutsche Bundesbank. :2020	Contactless payment becomes the norm. Press Releases. https://www.bundesbank.de/en/press/press-releases/contactless-payment-becomes-the-norm-822412
Dewey, D. R.:2015.	Financial History of the United States. Arkose Press.

Diez de Los Rios, A., & Zhu, Y. :2020	CBDC and Monetary Sovereignty. Staff Analytical Notes. https://www.bankofcanada.ca/2020/02/staff-analytical-note-2020-5/
Dovbnya, A.:2019.	The Origin of “Satoshi Nakamoto” Pseudonym Revealed by Craig Wright: Document. U.Today. https://u.today/the-origin-of-satoshi-nakamoto-pseudonym-revealed-by-craig-wright-document
Draghi, M.:2016	Introductory statement to the press conference. Press Conferences.
Dyson, B., & Hodgson, G.:2016	DIGITAL CASH: Why Central Banks Should Start Issuing Electronic Money. Positive Money, 1–36. https://positivemoney.org/wp-content/uploads/2016/01/Digital_Cash_WebPrintReady_20160113.pdf
Eagleton, C., & Williams, J.:2007.	Money: A History (2nd Revise). British Museum Press.
ECB. :2019	Exploring anonymity in central bank digital currencies. In Focus, December(4), 1–11. https://www.ecb.europa.eu/paym/intro/publications/pdf/ecb.mipinfocus191217.en.pdf
Economist Intelligence Unit. :2017	Denmark’s experience with negative interest rates. http://www.eiu.com/public/subscriber_only.aspx?x=1716177555
Eder, G.:2019	Digital Transformation: Blockchain and Land Titles. 2019 OECD Global Anti-Corruption & Integrity Forum, 12. http://www.oecd.org/corruption/integrity-forum/academic-papers/Georg_Eder-Blockchain-Ghana_verified.pdf
Eggertsson, G. B., & Woodford, M.:2003a	Optimal Monetary Policy in a Liquidity Trap. NBER WORKING PAPER SERIES.

Eggertsson, G. B., & Woodford, M.:2003b	The Zero Bound on Interest Rates and Optimal Monetary Policy. Brookings Papers on Economic Activity, 233(1), 139–233. https://doi.org/10.1353/eca.2003.0010
Ehrenberg, R.:1928	Capital and Finance in the Age of the Renaissance (Translated). BUTLER Sf TANNER LTD. https://archive.org/stream/capitalandfinanc037633mbp/capitalandfinanc037633mbp_djvu.txt
Eisler, R.:1924	Das Geld.
Eisler, R.:1932	Stable Money: The Remedy for the Economic World Crisis: a programme of financial reconstruction for the international conference 1933. Search Publishing Co. Ltd.
Elasrag, H.:2019	Blockchains for Islamic finance: Obstacles & Challenges. Munich Personal RePEc Archive, 03, 1–39.
Elwell, C. K.:2011	Brief History of the Gold Standard in the United States. Congressional Research Service, R41887, 18.
Engert, W., & Fung, B. S. C.:2017	Central Bank Digital Currency: Motivations and Implications. Staff Discussion Paper, January, 1–30. www.bank-banque-canada.ca
Erol, H.:2019	Old Assyrian Metal Trade, Its Volume and Interactions. Türk Tarih Kurumu Belleten, 83(298), 779–806.
European Central Bank. :2005	Consumers' Inflation Perceptions. Still at Odds with Official Statistics? Monthly Buletin, December, 30–32. https://www.ecb.europa.eu/pub/pdf/other/mb200504_focus03.en.pdf
European Central Bank. :2020a	Asset purchase programmes. https://www.ecb.europa.eu/mopo/implement/omt/html/index.en.html
European Central Bank. :2020b	Excess Reserves. Statistical Data Warehouse. http://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=117.BSI.M.U2.N.R.LRE.X.1.A1.3000.Z01.E

European Central Bank. :2020c	Tiered CBDC and the financial system. ECB Working Paper, 2351, 42.
European Systemic Risk Board. :2016	Macroprudential policy issues arising from low interest rates and structural changes in the EU financial system. Report by Joint Task Force ECB and ESRB, November, 1–61.
Federal Reserve Bank of New York.:2020	Large-Scale Asset Purchases. https://www.newyorkfed.org/markets/programs-archive/large-scale-asset-purchases
Federal Reserve Bank of St. Louis.:2020	Excess Reserves of Depository Institutions. Monetary Data > Reserves. https://fred.stlouisfed.org/series/EXCSRESNS
Financial Stability Board.:2020	Addressing the regulatory, supervisory, and oversight challenges raised by “global stablecoin” arrangements (Issue April). https://www.fsb.org/wp-content/uploads/P140420-1.pdf
Finley, M. I.:1953	Land, Debt, and the Man of Property in Classical Athens. Political Science Quarterly, 68(2), 249–268. https://doi.org/10.2307/2144970
Fisher, I.:1896	Appreciation and Interest. American Economic Association, XI(4), 331–442. https://doi.org/10.2307/2140136
Fisher, I.:1933	Stamp Scrip. In Classic. Adelphi Company. http://ir.nmu.org.ua/handle/123456789/14826
Fonseca, G.:2019	An analysis of the legal impact of central bank digital currency on the European payments landscape. Journal of Payments Strategy and Systems, 13(4), 288–299.
Frank, T., & Johnson, A. C.:1933	. An economic survey of ancient Rome, (T. Frank (ed.)). The Johns Hopkins Press.
Friedman, M.:1969	The Optimum Quantity of Money.
Fukao, M.:2005.	The effects of “Gesell” (currency) taxes in promoting Japan’s economic recovery. International Economics and

	Economic Policy, 2(2–3), 173–188. https://doi.org/10.1007/s10368-005-0032-2
Gang, Y. :2020	Interview with PBC Governor Yi Gang by Financial News and China Finance on Key Issues During “Two Sessions.” Speeches. http://www.pbc.gov.cn/en/3688110/3688175/4031198/index.html
Gesell, S.:1916.	Die natürliche Wirtschaftsordnung durch Freiland und Freigeld. Selbstverlag, Les Hauts Geneveys 1916 9. Auflage Herausgegeben von Karl Walker: Rudolf Zitzmann Verlag, Lauf 1949.
Gill, N. S.:2017.	Social War 91-88 B.C. ThoughtCo. https://www.thoughtco.com/social-war-91-88-bc-120568
Glahn, R. von, & von Glahn, R. :2016	An Economic History of China: From Antiquity to the Nineteenth Century. Cambridge University Press. https://books.google.com.tr/books?id=Z02SCwAAQBAJ
Goetze, A.:1951	The Laws of Eshnunna. The Annual of the American Schools of Oriental Research, 31, 197. https://doi.org/10.2307/3768534
Goldberg, L. S., & Karimov, I.:1997	Black-Markets for Currency, Hoarding Activity and Currency Reform. Journal of International Economics, 43/1(2), 42. https://www.nber.org/papers/w4153.pdf
Goodfriend, M.:2000	Overcoming the Zero Bound on Interest Rate Policy. Journal of Money, Credit and Banking, 32(4), 1007–1035.
Goodhart, C., Bartsch, E., & Ashworth, J. :2016 .	Central banks and credit creation: the transmission channel via the banks matters. Sveriges Riksbank Economic Review: Rethinking the Central Bank’s Mandate, 55–68. http://www.riksbank.se/Documents/Rapporter/POV/2016/2016_3/rap_pov_161129_eng.pdf

Gouveia, O. C., Dos Santos, E., de Lis, S. F., Neut, A., & Sebastián, J. :2017 .	Central Bank Digital Currencies: Assessing Implementation Possibilities and Impacts (Issue March). https://www.bbvaresearch.com/wp-content/uploads/2017/09/WP_CBDC_mod.pdf
Gross, M., & Siebenbrunner, C. :2019 .	Money Creation in Fiat and Digital Currency Systems. In IMF Working Papers (WP/19/285; IMF Working Paper, Vol. 19, Issue 285). https://doi.org/10.5089/9781513521565.001
Grüner, A., Mühle, A., & Meinel, C. :2018	On the Relevance of Blockchain in Identity Management. 1–7. http://arxiv.org/abs/1807.08136
Grym, A., Heikkinen, P., Kauko, K., & Takala, K. :2018	BoF Economics Review.
Güleç, T. C.:2018.	Blockchain Tabanlı Kripto Para Birimlerinin Mevcut Durumuna Dair Finansal Analizler ve Geleceği.
Haber, S., Stornetta, W. S., & Scott Stornetta, W. :1991 .	How to time-stamp a digital document. Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 537 LNCS(2), 99–111. https://doi.org/10.1007/BF00196791
Hall, I.:2020	Governments quarantine banknotes as coronavirus puts ‘dirty’ money in spotlight. Global Government Forum. https://www.globalgovernmentforum.com/governments-quarantine-banknotes-as-coronavirus-puts-dirty-money-in-spotlight/
Hammurabi. :1780 B.C.E.	The Code of Hammurabi.

Hawlitsek, F., Notheisen, B., & Teubner, T. :2018 .	The limits of trust-free systems: A literature review on blockchain technology and trust in the sharing economy. Electronic Commerce Research and Applications, 29, 50–63. https://doi.org/https://doi.org/10.1016/j.elerap.2018.03.005
Hawtrey, R.:1995	A Century of Bank Rate. Taylor & Francis Group. https://books.google.com.tr/books?id=z0TULL8YFBkC
Hayes, A.:2016.	Decentralized Banking: Monetary Technocracy in the Digital Age. In Banking Beyond Banks and Money (pp. 239–278). https://doi.org/https://doi.org/10.1007/978-3-319-42448-4_7
Hearing, A.:2020	Cardless in the coronavirus crisis. Financial Times. https://www.ft.com/content/f06c27d1-409b-4636-b314-59d7940cfc52
Henry, J.:1976.	Calling in the Big Bills. Washington Monthly, May, 27–33.
Homer, S., & Sylla, R.:2005	A History of Interest Rates (Fourth edi). John Wiley & Sons, Inc.
Hong Kong Monetary Authority. :2016.	Whitepaper On Distributed Ledger Technology. Astri, 98. https://doi.org/10.1155/2013/957862
Huang, X., Kuijpers, D., Li, L., Sha, S., & Xia, C. :2020 .	How Chinese consumers are changing shopping habits in response to COVID-19. McKinsey Insights. https://www.mckinsey.com/featured-insights/asia-pacific/how-chinese-consumers-are-changing-shopping-habits-in-response-to-covid-19?cid=other-eml-alt-mip-mck&hlkid=d3bee3652a4344bdb8ee6673b326b581&hctky=11387689&hdpid=c10cf4af-b41f-4111-9e2f-07a9b3b4eefd#
Huber, J.:2019.	Digital Currency: Design Principles to Support a Shift from Bankmoney to Central Bank Digital Currency. Real-World Economics Review, 88, 76–90.

Hukkinen, T., Mattila, J., Ilomäki, J., & Seppälä, T. :2017	A Blockchain Application in Energy.
Hwang, J., Choi, M., Lee, T., Jeon, S., Kim, S., Park, S., & Park, S.:2017	Energy Prosumer Business Model Using Blockchain System to Ensure Transparency and Safety. Energy Procedia, 141, 194–198. https://doi.org/https://doi.org/10.1016/j.egypro.2017.11.037
IBM Blockchain, & OMFIF. :2018	Central Bank Digital Currencies.
Ildız, E.:2013.	Eski Çağ’da Bankacılık ve Bankerlik. Türkiye Bankalar Birliği.
IMF. :2017.	International Monetary Fund. August. http://www.imf.org/external/pp/ppindex.aspx
IMF. :2020	Policy Responses to COVID-19. Policy Tracker. https://www.imf.org/en/Topics/imf-and-covid19/Policy-Responses-to-COVID-19
Jobst, A., & Lin, H.:2016.	Negative Interest Rate Policy (NIRP): Implications for Monetary Transmission and Bank Profitability in the Euro Area. IMF Working Paper, 49. https://www.imf.org/external/pubs/ft/wp/2016/wp16172.pdf
Jørgensen, A., & Risbjerg, L. :2012	Negative Interest Rates. Monetary Review, 3rd Quarter, Part 1, 59–72. https://doi.org/10.4135/9781483381503.n835
Judson, R.:2012	Crisis and Calm : Demand for U.S. Currency at Home and Abroad from the Fall of the Berlin Wall to 2011. In International Finance Discussion Papers (Issue November). https://www.federalreserve.gov/pubs/ifdp/2012/1058/ifdp1058.pdf

Juškaitė, A., Šiaudinis, S., & Reichenbachas, T.:2019	CBDC – in a whirlpool of discussion (Occasional Paper Series, Issue 29).
Justinian I.:1932	THE CODE OF JUSTINIAN, Translated by Samuel P. Scott. https://droitromain.univ-grenoble-alpes.fr/Anglica/codjust_Scott.htm
Kabir Hassan, M., Choudhury, K., & Waheeduzzaman, M.:1995.	On black market exchange rate and demand for money in developing countries: The case of Nigeria. Atlantic Economic Journal, 23(1), 35–44. https://doi.org/10.1007/BF02298988
Kampf, G., Todt, D., Pfaender, S., & Steinmann, E. :2020 .	Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. Journal of Hospital Infection, 104(3), 246–251. https://doi.org/10.1016/j.jhin.2020.01.022
Karahan, Ç., & TÜFEKÇİ, A.:2019.	Blokzincir Teknolojisinin Dijital Kimlik Yönetiminde Kullanımı: Bir Sistemik Haritalama Çalışması. Journal of Polytechnic, 0900(2), 483–496. https://doi.org/10.2339/politeknik.654503
Keister, T., & Sanches, D.:2019	Should Central Banks Issue Digital Currency? (WP 19-26; Vol. 26, Issue 19). https://doi.org/10.21799/frbp.wp.2019.26
Keynes, J. M.:1936.	The General Theory of Employment, Interest and Money. Palgrave Macmillan UK.
Khiaonarong, T., & Humphrey, D.:2019	Cash use across countries and the demand for central bank digital currency. Journal of Payments Strategy and Systems, 13(1), 32–46. https://doi.org/10.5089/9781484399606.001
Kiff, J.:2020	Countries Where Retail CBDC Is Being Explored. Kiffmeister.Blogspot.Com. https://kiffmeister.blogspot.com/2019/12/countries-where-retail-cbdc-is-being.html?m=1

Kiff, J., Alwazir, J., Davidovic, S., Farias, A., Khan, A., Khiaonarong, T., Malaika, M., Monroe, H., Sugimoto, N., Tourpe, H., & Zhou, P. :2020 .	A Survey of Research on Retail Central Bank Digital Currency (WP/20/104; IMF Working Papers).
Kimball, M. S.:2015	Negative Interest Rate Policy as Conventional Monetary Policy. National Institute Economic Review, 234(1), 5–14. https://doi.org/10.1177/002795011523400102
Kimura, T., Kobayashi, H., Muranaga, J., & Ugai, H. :2002 .	The effect of the increase in the monetary base on Japan ’ s economy at zero interest rates: an empirical analysis. Institute for Monetary and Economic Studies Discussion Paper, 19, 286–312.
Klarin, A.:2019	The decade-long cryptocurrencies and the blockchain rollercoaster: Mapping the intellectual structure and charting future directions. Research in International Business and Finance, 51(January 2019), 101067. https://doi.org/10.1016/j.ribaf.2019.101067
Klengel, H.:2006	Basra Körfezinden Akdeniz’e: Eski Yakın Doğu’da Ticaret. In Ü. Yalçın, C. Pulak, & R. Slotta (Eds.), Uluburun Gemisi 3000 Yıl Önce Dünya Ticareti (p. 370).
Konashevych, O.:2020.	Cross-Blockchain Databases for Governments: The Technology for Public Registries and Smart Laws. SSRN Electronic Journal, 1–28. https://doi.org/10.2139/ssrn.3537258
Koning, J. P.:2014	Fedcoin. Jpkoning.Blogspot.Ca. http://jpkoning.blogspot.com/2014/10/fedcoin.html

Kortelainen, M.:2017	BoF Economics Review. In BoF Economics Review (Vol. 2).
KÖSE, Y., ATİK, M., & YILMAZ, B. :2015 .	Türkiye için Negatif Faiz Oraninin Uygulanabilirliği ve Analitik Olarak İncelenmesi. Finansal Araştırmalar ve Çalışmalar Dergisi, 7(13), 321. https://doi.org/10.14784/jfrs.11457
Kosse, A., Chen, H., Felt, M. H., Dongmo, V., Nield, K., & Welte, A. :2017 .	The Costs of Point - of - Sale Payments in Canada (2017-4; Staff Discussion Pape). https://www.bankofcanada.ca/wp-content/uploads/2017/03/sdp2017-4.pdf
Kotane, I.:2018.	Concept of Virtual Currencies in Modern Economies. Latgale National Economy Research, 1(10), 63. https://doi.org/10.17770/lner2018vol1.10.3605
Krugman, P. R.:1998.	It's baaack: Japan's slump and the return of the liquidity trap. Brookings Papers on Economic Activity, 2, 137–205. https://doi.org/10.2307/2534694
Kumhof, M., & Noone, C.:2018.	Central Bank Digital Currencies - Design Principles and Balance Sheet Implications. SSRN Electronic Journal, 725. https://doi.org/10.2139/ssrn.3180713
Lagarde, C.:2018	Winds of Change: The Case for New Digital Currency; by Christine Lagarde, IMF Managing Director. 1–7.
Lane, F. C.:1937	Venetian Bankers, 1496-1533: A Study in the Early Stages of Deposit Banking. Journal of Political Economy, 45(2), 187–206. http://www.jstor.org/stable/1824517
Lannquist, A.: World E. F.:2020	Central Bank Digital Currency Policy-Maker Toolkit (Issue January, pp. 1–47). http://www3.weforum.org/docs/WEF_CBDC_Policymaker_Toolkit.pdf
Laroche, E.:1959	DICTIONNAIRE DE LA LANGUE LOUVITE (French) (JEAN MAISO). Librairie Adrien-Maisonneuve.

Lars E.O. Svensson. :2010	INFLATION TARGETING. NBER Working Paper No. 16654. http://www.nber.org/papers/w16654
Larsen, M. T.:1974	The Old Assyrian Colonies in Anatolia. Journal of the American Oriental Society, 94(4), 468–475. https://doi.org/10.2307/600590
Lee, J.:2018	Distributed Ledger Technologies (Blockchain) in Capital Markets: Risk and Governance. SSRN Electronic Journal, 1–25. https://doi.org/10.2139/ssrn.3180553
Li, K.:2019	The Blockchain Scalability Problem & the Race for Visa-Like Transaction Speed. Towardsdatascience.Com. https://towardsdatascience.com/the-blockchain-scalability-problem-the-race-for-visa-like-transaction-speed-5cce48f9d44
Li, Y., Yang, W., He, P., Chen, C., & Wang, X. :2019 .	Design and management of a distributed hybrid energy system through smart contract and blockchain. Applied Energy, 248, 390–405. https://doi.org/https://doi.org/10.1016/j.apenergy.2019.04.132
Link. :2020.	Statistics and trends. LINK Cash Withdrawal Values. https://www.link.co.uk/about/statistics-and-trends/
Lomsadze, G.:2020	Georgians literally laundering their cash during coronavirus. Eurasianet. https://eurasianet.org/georgians-literally-laundering-their-cash-during-coronavirus
Lundström, V. K.:2016	Impact from the blockchain technology on the Nordic capital market capital market [Uppsala Universitet]. In Uppsala Universitet. http://uu.diva-portal.org/smash/get/diva2:937451/FULLTEXT01.pdf
Macaulay, T. B.:1848.	The History of England, from the Accession of James II — Volume 4. Porter & Coates. http://www.gutenberg.org/files/2613/2613-h/2613-h.htm

Maliye Bakanlığı :Gelir İdaresi Başkanlığı . :2015	VERGİ USUL KANUNU GENEL TEBLİĞİ. Resmî Gazete. https://www.resmigazete.gov.tr/eskiler/2015/12/20151224-6.htm
Mancini-Griffoli, T., Soledad Martinez Peria, M., Agur, I., Ari, A., Kiff, J., Popescu, A., Rochon, C., Grinberg, F., Khan, A., Poh, K., Tobias Adrian, B., Muhleisen, M., Obstfeld, M., Adrian, T., Alwazir, J., Bayoumi, T., Berkmen, P., Brandao Marques, L., Cheng, J., ... International Monetary Fund. :2018 .	Casting Light on Central Bank Digital Currency With contributions from Fabio Comelli Authorized for distribution. IMF Staff Discussion Note, 08. https://www.imf.org/en/Publications/Staff-Discussion-Notes/Issues/2018/11/13/Casting-Light-on-Central-Bank-Digital-Currencies-46233
Mankiw, G. N.:2009.	It May Be Time for the Fed to Go Negative. The New York Times.
Mastrobuoni, G.:2004	The Effects of the Euro-Conversion on Prices and Price Perceptions. In CEPS Working Paper No. https://gceps.princeton.edu/wp-content/uploads/2017/01/101mastrobuoni.pdf

Mattila, J.:2016	The Blockchain Phenomenon The Disruptive Potential of Distributed Consensus Architectures. ETLA Working Papers, 38, 26.
Mayer, T., & Huber, R.:2014	Vollgeld: Das Geldsystem der Zukunft. Unser Weg aus der Finanzkrise. Tectum Wissenschaftsverlag.
McCallum, B. T.:2000	THEORETICAL ANALYSIS REGARDING A ZERO LOWER BOUND ON NOMINAL INTEREST RATES. In NBER WORKING PAPER SERIES (No. 7677). http://www.nber.org/papers/w7677%0ANATIONAL
McLeay, M., Radia, A., & Thomas, R.:2014a	Money Creation in the Modern Economy. Bank of England Quarterly Bulletin 2014 Q1, 1, 14–27. https://ssrn.com/abstract=2416234
McLeay, M., Radia, A., & Thomas, R.:2014b.	Money in the Modern Economy: An Introduction. Bank of England Quarterly Bulletin 2014 Q1, 10. https://ssrn.com/abstract=2416229
Meaning, J., Dyson, B., Barker, J., & Clayton, E.:2018	Broadening Narrow Money: Monetary Policy with a Central Bank Digital Currency. SSRN Electronic Journal, 724. https://doi.org/10.2139/ssrn.3180720
Meggyesi, P.:2010	Reflections on negative interest rates in Switzerland. February.
Mengelkamp, E., Notheisen, B., Beer, C., Dauer, D., & Weinhardt, C. :2018 .	A blockchain-based smart grid: towards sustainable local energy markets. Computer Science - Research and Development, 33(1), 207–214. https://doi.org/10.1007/s00450-017-0360-9
Merkle, R. C.:1988.	A digital signature based on a conventional encryption function. In Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics): Vol. 293 LNCS (pp. 369–378). https://doi.org/10.1007/3-540-48184-2_32

Merriam-Webster. :2018	Bank run. In Merriam-Webster.Com Dictionary. Retrieved May 2, 2020, from https://www.merriam-webster.com/dictionary/bank run
Mersch, Y. :2015	Keynote speech Euro Finance Week. https://www.ecb.europa.eu/press/key/date/2015/html/sp151118.en.html
Mersch, Y. :2017	Digital Base Money: an assessment from the ECB's perspective - Speech. Farewell Ceremony for Pentti Hakkarainen. https://www.ecb.europa.eu/press/key/date/2017/html/sp170116.en.html
Mersch, Y. :2020	An ECB digital currency – a flight of fancy? Consensus 2020 Virtual Conference. https://www.ecb.europa.eu/press/key/date/2020/html/ecb.s p200511~01209cb324.en.html
Michel, C.:2008	The Old Assyrian Trade in the light of Recent Kültepe Archives. Journal of the Canadian Society for Mesopotamian Studies, 3(the Canadian Society for Mesopotamian Studies), 71–82. http://halshs.archives-ouvertes.fr/docs/00/64/28/27/PDF/Michel_2009_CSMS.pdf
Molyneux, P., Reghezza, A., Thornton, J., & Xie, R.:2020	Did Negative Interest Rates Improve Bank Lending? Journal of Financial Services Research, 57(1), 51–68. https://doi.org/10.1007/s10693-019-00322-8
Motley, J. L.:1856	The rise of the Dutch Republic: A history (VOLUME I). Harper & Brothers. https://hdl.handle.net/2027/hvd.hwkmad
Nabilou, H.:2019	Testing the waters of the Rubicon: the European Central Bank and central bank digital currencies. Journal of Banking

	Regulation, 0123456789. https://doi.org/10.1057/s41261-019-00112-1
Nagarajan, K. V.:2011	The Code of Hammurabi: An Economic Interpretation. International Journal of Business and Social Science, 2(8), 109–117.
Nakamoto, S.:2008	Bitcoin: A Peer-to-Peer Electronic Cash System Satoshi Nakamoto Institute. In 2008-10-31. https://bitcoin.org/bitcoin.pdf
Natarajan, H., Krause, S. K., & Gradstein, H. L.:2017	Distributed Ledger Technology (DLT) and Blockchain. FinTech Note, 1, 1–60.
National Bank Of Georgia. :2020	The National Bank Encourages the Population to Observe the Recommended Hygiene Norms When Using Cash. Press Releases. https://www.nbg.gov.ge/index.php?m=340&newsid=3877&lng=geo
National Bank of Ukraine. :2019	Analytical Report on the E-hryvnia Pilot Project. https://bank.gov.ua/admin_uploads/article/Analytical Report on E-hryvnia.pdf?v=4
Nederlandse Vereniging van Banken. :2020	PIN needed less often when making contactless payments. Corona Press Release. https://www.nvb.nl/english/corona-pin-needed-less-often-when-making-contactless-payments/
New Economics Foundation, & Copenhagen Business School. :2017	Making Money From Making Money: Seigniorage in The Modern Economy. https://neweconomics.org/2017/01/making-money-making-money
Ney, J., & Xuan-Yi Zhang, N.:2019	Central Bank Digital Currencies and the Long-Term Advancement of Financial Stability. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3456753

Nissen, H. J.:2004	Ana Hatlarıyla Mezopotamya: Yakınođu Arkeolojisi'nin İlk Dönemleri (İ.Ö. 9000-2000) (Çev. Z. Zü). Arkeoloji ve Sanat Yayınları.
Nomos AG. :2020a	ATTICA. Athens. Circa 500/490-485/0 BC. https://nomosag.com/default.aspx?page=ucAuctionDetails&auctionid=20&id=144&p=2&s=&ca=0&type=auction
Nomos AG. :2020b	KINGS OF LYDIA. Time of Ardys to Alyattes, circa 630s-564/53 BC. https://nomosag.com/default.aspx?page=ucAuctionDetails&auctionid=20&id=232&p=3&s=&ca=0&type=auction
Noonan, J. T. J.:1957	The scholastic analysis of usury. Harvard University Press.
Norges Bank. :2018	Central bank digital currencies (NORGES BANK PAPERS).
Norland, E.:2020	Sweden's Experiment with Negative Rates. https://www.cmegroup.com/education/featured-reports/swedens-experiment-with-negative-rates.html
O'Donovan, P., & O'Sullivan, D. T. J.:2019	A systematic analysis of real-world energy blockchain initiatives. Future Internet, 11(8). https://doi.org/10.3390/fi11080174
Oates, J.:1986	Babylon. Thames & Hudson.
Oates, J.:2004.	Babil. Çev. Fatma Çizmeli, Arkadaş Yayınları.
OECD. :2019.	The Policy Environment for Blockchain Innovation and Adoption: 2019 OECD Global Blockchain Policy Forum Summary Report. In OECD Blockchain Policy Series. www.oecd.org/finance/2019-OECD-Global-Blockchain-Policy-Forum-Summary-Report.pdf
Oesterreichische Nationalbank. :2020	Kein erhöhtes Infektionsrisiko durch Bargeld. Press Releases.
Ossowski, S.:1963	Class Structure in the Social Consciousness. Routledge.
Özgüç, T.:2005	Kültepe - Kaniş / Neşa (Birinci Ba). Yapı Kredi Yayınları.

Panait, A., Olimid, R. F., Stefanescu, A., & Technology, C. :2020 .	Identity Management On Blockchain – Privacy And Security Aspects. Proceedings Of The Romanian Academy, 21(1), 45–52.
Panetta, F.:2020	Beyond monetary policy – protecting the continuity and safety of payments during the coronavirus crisis. THE ECB BLOG. https://www.ecb.europa.eu/press/blog/date/2020/html/ecb.blog200428~328d7ca065.en.html
Pawczuk, L., Massey, R., & Holdowsky, J. :2019	Deloitte’ s 2019 Global Blockchain Survey - Blockchain gets down to business. Deloitte Insights, 2–48. https://www2.deloitte.com/content/dam/insights/us/articles/2019-global-blockchain-survey/DI_2019-global-blockchain-survey.pdf
Payments Canada, Bank of Canada, & R3. :2017.	Jasper: A Canadian Experiment with Distributed Ledger Technology for Domestic Interbank Payments Settlement. 1–66. https://www.payments.ca/sites/default/files/29-Sep-17/jasper_report_eng.pdf
People’s Bank of China. :2020	Explanations on Issues Related to Cash Use During Epidemic Control. Fight Against COVID-19. http://www.pbc.gov.cn/en/3688006/3995557/3993309/index.html
Pfister, C.:2017	Monetary Policy and Digital Currencies: Much Ado About Nothing? SSRN Electronic Journal, September. https://doi.org/10.2139/ssrn.3038906
Piccolo, A.:2017	Distributed ledger technology in the capital market Shared versus private information in a permissioned blockchain. http://www.diva-portal.org/smash/get/diva2:1120587/FULLTEXT01.pdf

Pieroni, A., Scarpato, N., Di Nunzio, L., Fallucchi, F., & Raso, M. :2018	Smarter City: Smart energy grid based on Blockchain technology. International Journal on Advanced Science, Engineering and Information Technology, 8(1), 298–306. https://doi.org/10.18517/ijaseit.8.1.4954
Popovska-Kamnar, N.:2014	The use of electronic money and its impact on monetary policy. Journal of Contemporary Economic and Business Issues, 1(2), 79–92. https://www.econstor.eu/bitstream/10419/147460/1/86795244X.pdf
Qian, Y. :2019	Central Bank Digital Currency: optimization of the currency system and its issuance design. China Economic Journal, 12(1), 1–15. https://doi.org/10.1080/17538963.2018.1560526
Rachel, L., & Smith, T. D.:2015.	Staff Working Paper No. 571 Secular drivers of the global real interest rate Staff Working Paper No. 571. 571.
Raskin, M., & Yermack, D.:2016.	Digital currencies, decentralized ledgers and the future of central banking. Research Handbook on Central Banking, 474–486. https://doi.org/10.4337/9781784719227.00028
Reeves, K., Frost, L., & Fahey, C.:2010	INTEGRATING THE HISTORIOGRAPHY OF THE NINETEENTH-CENTURY GOLD RUSHES. Australian Economic History Review, 50(2), 111–128. https://doi.org/https://doi.org/10.1111/j.1467-8446.2010.00296.x
Reserve Bank of India. :2020	Availability of Digital Payment Options. Press Releases.
Reuters. :2020.	Argentina black market peso weakens to 136 per U.S. dollar - traders. Reuters.Com. https://www.reuters.com/article/argentina-peso/argentina-black-market-peso-weakens-to-136-per-u-s-dollar-traders-idUSL1N2CW19E
Ripple. :2020.	RippleNet. https://ripple.com/ripplenet

Rodney, E., Tor, J., & Waldenström, D.:2018	Introduction. In E. R, J. T, & W. D (Eds.), Sveriges Riksbank and the History of Central Banking (pp. 1–25). Cambridge University Press. https://doi.org/10.1017/9781108140430.001
Rogoff, K.:1998	Blessing or Curse? Foreign and Underground Demand for Euro Notes. <i>Economic Policy</i> , April, 261–303.
Rogoff, K.:2014	The Costs and Benefits of Phasing Out Cash. In NBER WORKING PAPER SERIES (Vol. 9). https://doi.org/10.1017/CBO9781107415324.004
Rogoff, K.:2017a	Dealing with monetary paralysis at the zero bound. <i>Journal of Economic Perspectives</i> , 31(3), 47–66. https://doi.org/10.1257/jep.31.3.47
Rogoff, K.:2017b	The Curse of Cash: How Large-Denomination Bills Aid Crime and Tax Evasion and Constrain Monetary Policy (Paperback). Princeton University Press.
Roover, R. de.:1948a	Money, Banking and Credit in Mediaeval Bruges. The Mediaeval Academy of America.
Roover, R. de.:1948b	THE MEDICI BANK: Its Organization, Management, Operations, and Decline. New York University Press.
Rosengren, E. S.:2019	Monetary Policymaking in Today ’ s Environment : Finding “ Policy Space ” in a Low-Rate World. Federal Reserve Bank of Boston Speeches. https://www.bostonfed.org/news-and-events/speeches/2019/monetary-policymaking-in-todays-environment.aspx#collapse2
Rostagno, M., Bindseil, U., Kamps, A., Lemke, W., Sugo, T., & Vlassopoulos, F.:2016.	Breaking through the zero line: the ECB’s negative interest rate policy. Presentation at Brookings Institution, June.

Rostovtzeff, M.:1930.	A history of the ancient world translated from the Russian by J. D. Duff. (Duff, J. D). The Clarendon Press.
Rutkowski, M., Mora, A. G., Bull, G. L., Guermazi, B., & Grown, C. :2020 .	Responding to crisis with digital payments for social protection: Short-term measures with long-term benefits. Blogs Worldbank. https://blogs.worldbank.org/voices/responding-crisis-digital-payments-social-protection-short-term-measures-long-term-benefits
Sapovadia, V.:2015	Chapter 13 - Legal Issues in Cryptocurrency. In Handbook of Digital Currency Bitcoin, Innovation, Financial Instruments, and Big Data (pp. 253–266).
Schepens, G.:2018	Bank lending under negative policy rates. Research Bulletin, 43(43), 1–5.
Shabsingh, G., Khiaonarong, T., & Leinonen, H. :2020	Distributed Ledger Technology Experiments in Payments and Settlements (FINTECH NOTE).
Shafir, E., Diamond, P., & Tversky, A. :1997 .	Money Illusion. Quarterly Journal of Economics, CXII(2), 341–374.
Skingsley, C.:2016.	Should the Riksbank issue e-krona? FinTech Stockholm 2016, Berns, November, 1–10.
Smart Dubai. :2020	BLOCKCHAIN. Wwww.Smartdubai.Ae. https://www.smartdubai.ae/initiatives/blockchain
SNB. :2017	Survey on payment methods 2017. August 2017, 2018. https://www.snb.ch/en/mmr/reference/paytrans_survey_report_2017/source/paytrans_survey_report_2017.en.pdf
South African Reserve Bank. :2020	South African Reserve Bank warns the public that it is NOT withdrawing banknotes and coin because of COVID-19. Media Statement. https://www.resbank.co.za/Lists/News and Publications/Attachments/9779/The SARB warns the

	public that it is NOT withdrawing banknotes and coin because of COVID-19.pdf
South African Reserve Bank: SARB.:2018	Project Khokha.
Sraders, A.:2020	What Is Fintech? Uses and Examples in 2020. TheStreet.Com. https://www.thestreet.com/technology/what-is-fintech-14885154
Stiglitz, J. E.:2016	What's Wrong With Negative Rates? Project Syndicate. https://www.project-syndicate.org/commentary/negative-rates-flawed-economic-model-by-joseph-e--stiglitz-2016-04
Stroukal, D., & Kadeřábková, B.:2016	Negative Interest Rates and Housing Bubbles. Stavební Obzor - Civil Engineering Journal, 25(4), 1–8. https://doi.org/10.14311/cej.2016.04.0020
Summers, L.:1996	Commentar : Why Are Central Banks Pursuing Long-Run Price Stability ? 35–44.
Summers, L. H.:2014	U.S. economic prospects: Secular stagnation, hysteresis, and the zero lower bound. Business Economics, 49(2), 65–73. https://doi.org/10.1057/be.2014.13
Surujnath, R.:2017	Off The Chain! A Guide to Blockchain Derivatives Markets and the Implications on Systemic Risk. Fordham Journal of Corporate & Financial Law, 22(2), 257.
SVERIGES RIKSBANK. :2019	The Riksbank proposes a review of the concept of legal tender. PRESS RELEASE. https://www.riksbank.se/globalassets/media/nyheter--pressmeddelanden/pressmeddelanden/2019/the-riksbank-proposes-a-review-of-the-concept-of-legal-tender.pdf

Swiss National Bank.:2016	Monetary policy assessment- March 2016. 1–3.
Syed, H.:2019	Power To The People: How Blockchain Based Digital Identity Can Empower Disadvantaged Individuals [The University of Texas]. https://doi.org/http://dx.doi.org/10.26153/tsw/2617
Systems, W. G. on E. P.:1994	Prepaid cards, May 1994. REPORT TO TKE COUNCIL OF THE EUROPEAN MONETARY INSTITUTE, May.
Szabo, N.:1996	Smart Contracts: Building Blocks for Digital Markets. https://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart_contracts_2.html
Szabo, N.:1998	Bit Gold. https://nakamotoinstitute.org/bit-gold/
Szostek, D.:2019	Chapter III. Blockchains in finance. In Blockchain and the Law (1st ed., pp. 54–96). Nomos Verlagsgesellschaft mbH & Co. KG. https://doi.org/10.5771/9783845298290-54
Tan, S., Wang, X., & Jiang, C.:2019	Privacy-preserving energy scheduling for ESCOs based on energy blockchain network. Energies, 12(8). https://doi.org/10.3390/en12081530
Tetlow, R. J., & Williams, J. C. :1998	Implementing price stability bands, boundaries and inflation targeting. Federal Reserve Bank of San Francisco, Proceedings.
The Eastern Caribbean Central Bank: ECCB.:2019	DXCDCaribe pilot. https://www.eccb-centralbank.org/p/about-the-project
The Internal Revenue Service.:2020.	Cash payment report helps government combat money laundering. https://www.irs.gov/newsroom/cash-payment-report-helps-government-combat-money-laundering

The Malta Independent. :2019	Registry of Companies to be the first agency in the world run by a Blockchain-based system. Articles. https://www.independent.com.mt/articles/2019-05-08/local-news/Registry-of-Companies-to-be-first-agency-in-the-world-run-by-a-Blockchain-based-system-6736207848
The Monetary Authority of Singapore: MAS.:2017	The Future is Here - Project Ubin: SGD on Distributed Ledger. In Project Ubin. https://doi.org/10.1088/1757-899X/209/1/012028
The Reserve Bank of New Zealand.:2020	Cash and other payments systems ready for COVID-19. News. https://www.rbnz.govt.nz/news/2020/03/cash-and-other-payments-systems-ready-for-covid-19
The Riksbank.:2017a	The Riksbank's e-krona project 1 (Issue September). http://www.riksbank.se/Documents/Rapporter/E-krona/2017/rapport_ekrona_170920_eng.pdf
The Riksbank. :2017b	The Riksbank's e-krona project Action plan for 2018. December 2017.
The Riksbank. :2018	The Riksbank's E-Krona Project: Report 2 (Issue October).
The Riksbank. :2020a	The Riksbank's e-krona pilot. https://www.riksbank.se/globalassets/media/rapporter/e-krona/2019/the-riksbanks-e-krona-pilot.pdf
The Riksbank. :2020b	The Riksbank to test technical solution for the e-krona. Press Releases. https://www.riksbank.se/en-gb/press-and-published/notices-and-press-releases/notices/2020/the-riksbank-to-test-technical-solution-for-the-e-krona/
The World Bank. :2017	1.1 Billion 'Invisible' People without ID are Priority for new High Level Advisory Council on Identification for Development. Press Releases. https://www.worldbank.org/en/news/press-release/2017/10/12/11-billion-invisible-people-without-id-

	are-priority-for-new-high-level-advisory-council-on-identification-for-development
Thornton, D. L.:1999.	Monetary Trends Nominal Interest Rate : Less Than Zero ? January.
Tian, F.:2018	An Information System for Food Safety Monitoring in Supply Chains Based on Haccp, Blockchain and Internet of Things (Issue March) [WU Vienna University of Economics and Business]. http://epub.wu.ac.at/6090/1/Dissertation_of_Feng_Tian.pdf#page=66
Tobin, J.:1985	The Case for Preserving Regulatory Distinctions. Bank of Japan Monetary and Economic Studies, 3(2), 19–29.
Tokic, D.:2017	Negative interest rates: Causes and consequences. Journal of Asset Management, 18(4), 243–254. https://doi.org/10.1057/s41260-016-0035-2
Tschorsch, F., & Scheuermann, B.:2016	Bitcoin and beyond: A technical survey on decentralized digital currencies. IEEE Communications Surveys and Tutorials, 18(3), 2084–2123. https://doi.org/10.1109/COMST.2016.2535718
Turk, R. A.:2016	Negative Interest Rate : How Big a Challenge for Large Danish and Swedish Banks ? IMF Working Paper, WP / 16 / 198, 30.
Ullersma, C. A.:2002	THE ZERO LOWER BOUND ON NOMINAL INTEREST RATES AND MONETARY POLICY EFFECTIVENESS : A SURVEY. De Economist, 3, 273–297. https://doi.org/https://doi.org/10.1023/A:1016113811607
Üzer, B.:2017	Sanal Para Birimleri.

van Bokkem, D., Hageman, R., Koning, G., Nguyen, L., & Zarin, N. :2019	Self-Sovereign Identity Solutions: The Necessity of Blockchain Technology. 1–8. http://arxiv.org/abs/1904.12816
Viñals, J., Gray, S., & Eckhold, K.:2016	The Broader View: The Positive Effects of Negative Nominal Interest Rates. IMF Blog. https://blogs.imf.org/2016/04/10/the-broader-view-the-positive-effects-of-negative-nominal-interest-rates/
Voshmgir, S.:2019	Token Economy: How Blockchains and Smart Contracts Revolutionize the Economy. BlockchainHub Berlin; Auflage.
Waldenström, D.:2014	Swedish Stock and Bond Returns, 1856–2012. In Historical Monetary and Financial Statistics for Sweden, Volume II: House Prices, Stock Returns, National Accounts, and the Riksbank Balance Sheet, 1620–2012 (eds. Rodney Edvinsson, Tor Jacobson and Daniel Waldenström) Sveriges Riksbank and Ekerlids. (pp. 223–292). www.ifn.se
Wang, X., Yu, G., Zha, X., Ni, W., Liu, R. P., Guo, Y. J., Zheng, K., & Niu, X. :2019	Capacity of blockchain based Internet-of-Things: Testbed and analysis. Internet of Things, 8, 100109. https://doi.org/10.1016/j.iot.2019.100109
Werner, R. A.:2003	Princes of the Yen. Routledge.
Werner, R. A.:2014a	Can banks individually create money out of nothing? — The theories and the empirical evidence. International Review of Financial Analysis, 36, 1–19. https://doi.org/10.1016/j.irfa.2014.07.015
Werner, R. A.:2014b	How do banks create money, and why can other firms not do the same? An explanation for the coexistence of lending and deposit-taking. International Review of Financial

	Analysis, 36, 71–77. https://doi.org/10.1016/j.irfa.2014.10.013
Wetterberg, G.:2009	Money and Power From Stockholms Banco 1656 to Sveriges Riksbank Today. Sveriges riksbank.
Williams, J.:2017	Preparing for the Next Storm: Reassessing Frameworks & Strategies in a Low R-Star World. In FRBSF Economic Letter.
Williamson, S.:2019	Central Bank Digital Currency: Welfare and Policy Implications. In Society for Economic Dynamics 2019 Meeting Papers. https://ideas.repec.org/p/red/sed019/386.html
Winton.:2018	Shining a Light on Currency Black Markets. Insights-Winton Web Page. https://www.winton.com/longer-view/currency-black-market-exchange-rates
Woodford, M.:2003	Interest and Prices: Foundations of a Theory of Monetary Policy. Princeton University Press.
Wright, C. W.:1941	Economic History of the United States. McGraw-Hill Book Company.
Xing, X., Wang, M., Wang, Y., & Stanley, H. E.:2020	Credit creation under multiple banking regulations: The impact of balance sheet diversity on money supply. Economic Modelling, 91, 720–735. https://doi.org/https://doi.org/10.1016/j.econmod.2019.09.030
Yanagawa, N., & Yamaoka, H.:2019	Digital Innovation, Data Revolution and Central Bank Digital Currency. http://www.boj.or.jp/en/research/wps_rev/wps_2019/data/wp19e02.pdf
Yıldız, F.:1989	Bankacılığa Atılan İlk Adım. Sanat Dünyamız, 38, 61–64.

Ziebarth, E.:1924	Hellenistische Banken. ZEITSCHRIFT FÜR NUMISMATIK. http://numismatics.org/zfn/38060000322933/23259.pdf
Zwitter, A. J., Gstrein, O. J., & Yap, E. :2020	Digital Identity and the Blockchain: Universal Identity Management and the Concept of the “Self-Sovereign” Individual. Frontiers in Blockchain, 3(May), 1–14. https://doi.org/10.3389/fbloc.2020.00026





Appendix 1: DLT Experiments and Research in Payments and Settlements

Large-value Payment Systems	Securities Settlement Systems
Project Jasper (Phase 1) (Canada)	Project Blockbuster (Germany)
Project Jasper (Phase 2) (Canada)	Project by Depository Trust and Clearing Corporation (United States)
Project Khokha (South Africa)	Project ASX replacement of CHES (Australia)
Project Stella (Phase 1) (Euro Area/Japan)	Project Jasper (Phase 3) (Canada)
Project Ubin (Phase 1) (Singapore)	Project Stella (Phase 2) (Euro Area/Japan)
Project Ubin (Phase 2) (Singapore)	Project Ubin (Phase 3) (Singapore)
Project Inthanon (Phase 1) (Thailand)	Project Inthanon (Phase 2) (Thailand)
Project Salt (Brazil)	
Cross-Border Payment Arrangements	
CLSNet foreign exchange netting service (United States)	
SWIFT DLT research (Belgium)	
Utility Settlement Coin (Switzerland)	
JPM Coin (United States)	
Project Jasper (Phase 4)—Project Ubin (Phase 4) (Canada, Singapore)	
Cross-border interbank settlements (Canada, United Kingdom, Singapore)	
Project Stella (Phase 3) (Euro Area/Japan)	
Project Inthanon (Phase 3) — LionRock (Thailand, Hong Kong)	

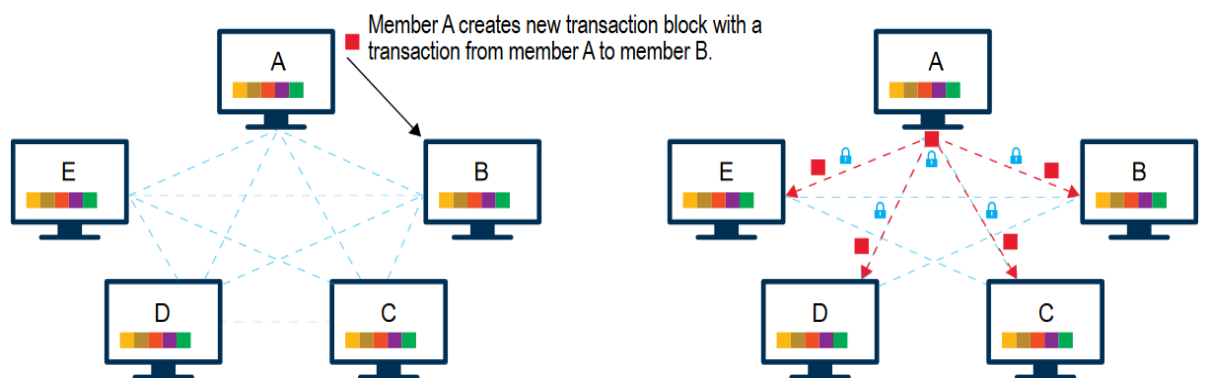
Source: Respective Central Banks; Shabsingh et al., (2020)

Appendix 2: Distributed Ledger Technology (DLT)

Distributed Ledger Technology stands for a new and rapidly evolving approach to sharing and saving data in the network that includes multiple data stores (ledgers) that are collectively held and controlled by a network of distributed servers, each of which has precisely the same data records and is called a node. Natarajan et al. (2017) specify the followings regarding DLT:

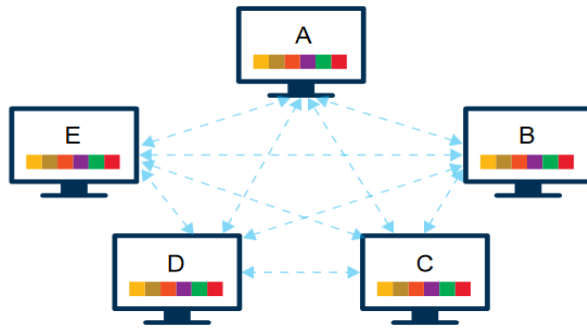
'Blockchain-based DLT systems take the form of an append-only chain of data 'blocks.' New additions to the database are initiated by one of the members (nodes), who creates a new "block" of data containing several transaction records.

Information about this new data block is then shared across the entire network, containing encrypted data, so transaction details are not made public.'



Source:(Natarajan et al., 2017)

One block's validity determines collectively by all participants of the network via pre-specified rules with a consensus mechanism. When the validation realizes, all nodes agree on the new block, and the new block becomes their ledgers' last block. With this consensus mechanism, the ledger updates its self to a new version of its self and distributes these replicated ledgers across the entire network to make sure that every node has the same ledger (Natarajan et al., 2017).

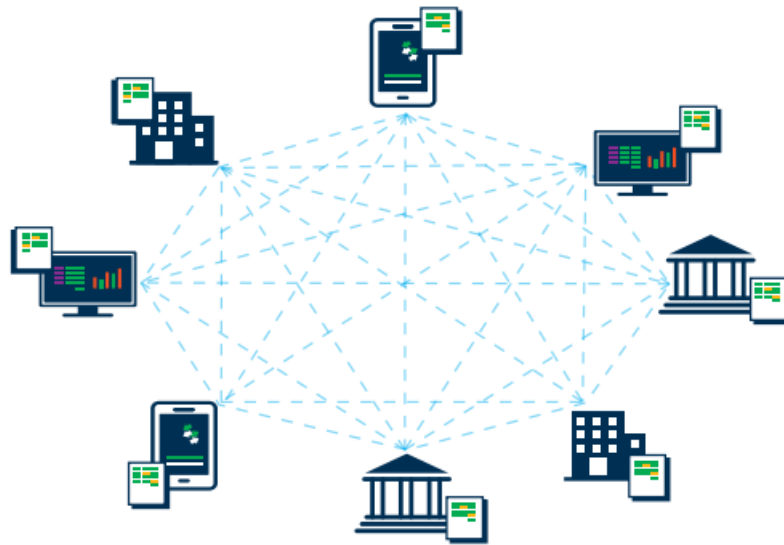


Source: (Natarajan et al., 2017)

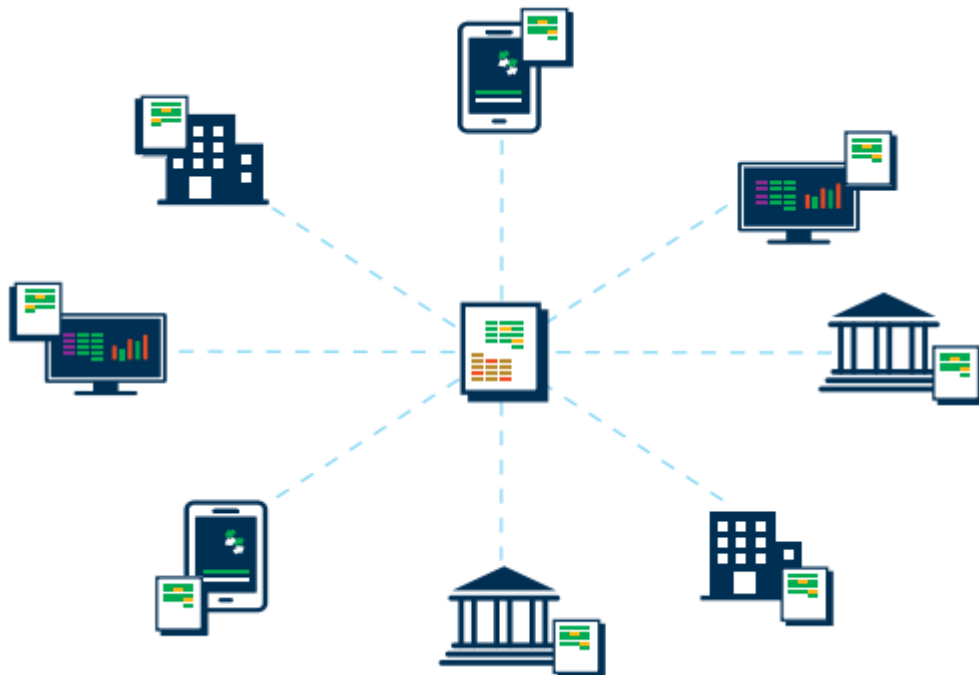
Blockchain allows participants of the network to log into an information record, and changed and updated information in the network can control by nodes. Each node gets identical information; thus, every node makes an update on their own records. Therefore there is no need for a central authority to validate the information and maintain transactions.

In a blockchain, there are two essential ingredients; tokens and smart contracts. Voshmgir (2019, p. 137) makes the definition of tokens as follows: '*Cryptographic tokens represent programmable assets or access rights, managed by a smart contract and an underlying distributed ledger. They are accessible only by the person who has the private key for that address and can only be signed using this private key. Tokens might affect the financial world in the same way as email affected the postal system.*' As the author stated out, they are programmable assets and runs by smart contracts. Smart contracts are like robots waiting for their duty to implement for what they have programmed. Szabo (1996) firstly articulated the smart contract term as: '*A set of premises, specified in digital form.*' After some time, smart contracts gain their attraction again through DLT/Blockchain since blockchain provides various specifications such as immutability and distributed ledgers.

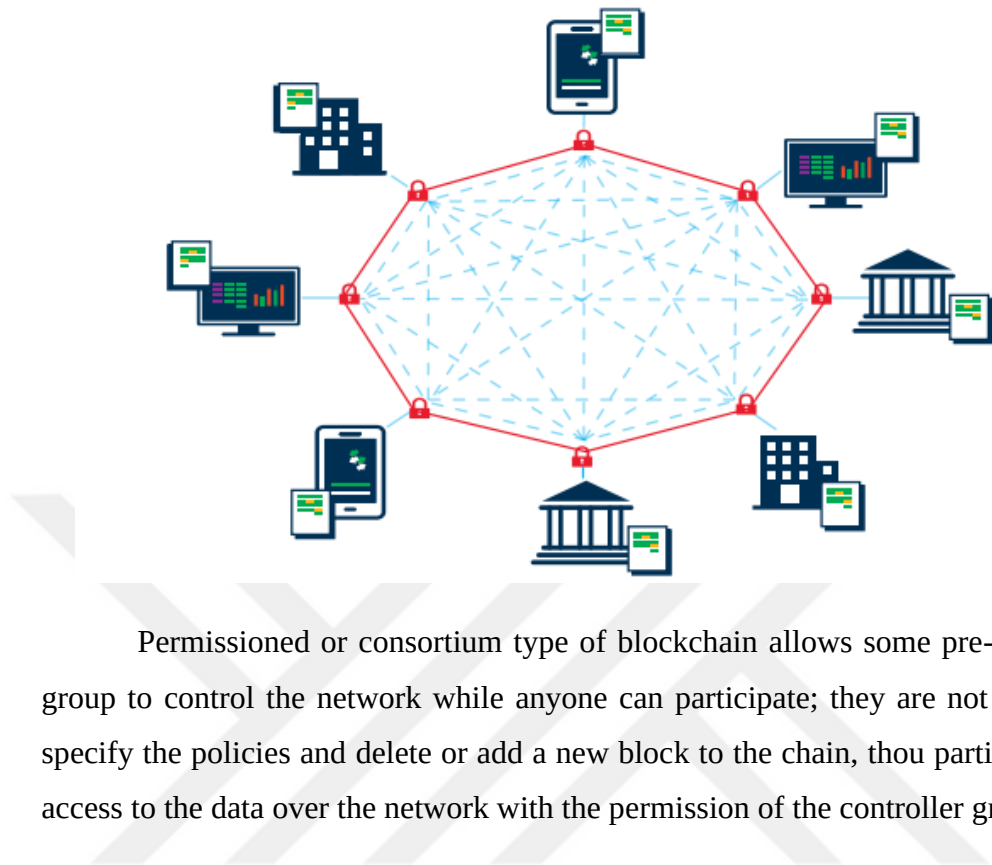
There are three types of blockchain, namely, private blockchain, permissioned, and permissionless.



Distributed ledgers provide a public ledger, which is called permissionless blockchain, that anyone can be a part of this network. In this type, nodes can access all the data on the network and can be a part of these new blocks. Anonymity is a crucial part of this type of blockchain throughout the proof of work concept; each node approves the validity of the new information on the network.



In the private type of blockchain, one entity has complete control of the ledger, and only the controller can write new data to the ledger.



Permissioned or consortium type of blockchain allows some pre-determined group to control the network while anyone can participate; they are not allowed to specify the policies and delete or add a new block to the chain, though participants can access to the data over the network with the permission of the controller group.

Appendix 3: Parameters

Descriptions	Parameter
Real Growth Rate	χ
Inflation Rate	π^p
Inflation Feedback	π^p
Real Policy Interest Rate	β_u
Policy Rate Inflation Feedback	m_π
Elasticity Ξ	ϕ_b
Spread between the policy rate and the CBDC rate	sp
Money Supply Shock	S_t^{ms}
CBDC/GDP	m_t^{rat}
The Target Quantity	$\overline{m^{rat}}$
Government debt-to-GDP ratio	b_t^{rat}