Michael Pirgmann

# Could CBDC be a threat to Monetary Policy?

## Abstract

Central Banks are generally exposed to the Effective Lower Bound (ELB) problem when conduction Monetary Policy (MP). It is not possible for a central bank (CB) to perform MP with negative interest rates over a significant period because market participants would convert their deposits into cash if costs for conversion, storage and insurance would be lower than costs for their remunerated deposits. With many CB contemplating Central Bank Digital Currencies (CBDC), this paper discusses the effects for MP under the restriction of the ELB. Under the assumption that the CB will implement a non-remunerated tier for CBDC to provide market participants with a cash like means of payment, it can be assumed that the ELB will increase from currently approximately -1% with only cash in existence, closer to zero when implementing CBDC. This is due to the lower costs of exchange, holdings and insurance when shifting deposits into a non-renumerated tier of CBDC instead of converting into cash in times of negative interest rates. Implementation of a tier of non-remunerated CBDC creates a significant "extra buffer" for market participants with a large destabilizing effect for MP which a CB needs to consider when performing MP at the ELB.

## Keywords

Monetary Policy, Effective Lower Bound, Cryptocurrencies, CBDC

## JEL classification

E41, E42, E43, E52, E58

## Introduction

At present, cash is used in the bulk of all payments on a global scale (Bilotta and Botti, 2021). Despite this, there is evidence that the shares of cash payments are declining, and have done so for the past twenty years, promoting the notion of a cash-free society (Engert and Fung, 2017).

In the wake of the Global Financial Crisis of 2008 and the following years and the rising distrust in the financial system, an individual with the pseudonym Satoshi Nakamoto released

a white paper introducing the concept of the first decentralised cryptocurrency (Nakamoto, 2008). Later that year, Nakamoto started the first version of the bitcoin network. Since then Bitcoin and other cryptocurrencies attracted increasing attention from investors and other market participants (Bouri *et al.*, 2017). Latest, since Meta (f. k. a. Facebook) planned to issue a stablecoin as its own proprietary currency (Bindseil, 2020; Sandner *et al.*, 2020) the interest by the public for cryptocurrencies in general is steadily increasing (Barotini and Holden, 2019). Today there are more than 10.000 different cryptocurrencies which most of them experiencing high volatility (Statista, 2022).

Compared to traditional assets and currencies, cryptocurrencies show some advantages for market participants. They have the potential to lower transaction costs because no middleman is needed. This also leads to a higher level of security since there is no single point of failure, and all transactions are transparent and immutable on an open distributed ledger based on the blockchain technology. Also, they are decentralised and therefore not controlled by a higher regulatory (Stefanoski *et al.*, 2020).

With the increasing interest by the public in cryptocurrencies which are not backed by any central authority, and large social networks like Facebook planning to issue stablecoins (Bindseil, 2020; Sandner *et al.*, 2020), central banks have begun contemplating about issuing Central Bank Digital Currencies as an additional means of payment since the mid-2010s (Barotini and Holden, 2019). It is notable, that cryptocurrencies and CBDC are a subset of digital currencies and might have a similar technological foundation. But CBDC are not necessarily based on the blockchain or distributed ledger technology like it is common for cryptocurrencies. A survey by Barotini and Holden, which was performed in 2018 among central banks (of which 63 central banks have replied, which together represent close to 80% of the world´s population and more than 90% of its economic output) has shown, that around 70% of the central banks are currently conducting conceptual and theoretical research about the implementation of CBDC. Among motivations like safe and efficient payments as well as financial inclusion, the main motivation for the central banks to consider CBDC is financial stability and monetary policy implementations (Barotini and Holden, 2019).

The Bank of England which spearheaded exploring CBDCs, took the first steps toward the development of its own CBDC as early as 2014, though, it is currently not planned to issue a CBDC (Kumhof and Noone, 2018; Klein, Groß and Sandner, 2020). The Bahamas was one of the first regions to declare the initiation of its own CBDC, the Sand Dollar which is a crypto token representative of the Bahamian Dollar (Alonso, Jorge-Vazquez and Forradellas, 2021). China orchestrated studies into their own CBDC in 2019 and concluded their tests in April

2020, after which the pilot was spread to nine Chinese cities. The Central Bank of Uruguay (CBU) finished a pilot project in 2018 as a segment of a wider government scheme to promote financial inclusion. The CBU distributed and circulated twenty million e-peso and is currently in the process of evaluating to issue the digital currency. Transactions were made instantaneously using a peer-to-peer verification system but in the absence of a blockchain (Alonso, Jorge-Vazquez and Forradellas, 2021). More recently, the European Central Bank (ECB) announced its intentions to amplify its efforts on the development of a Digital Euro (ECB, 2020; Passacantando, 2021).

It is discussed very controversial how a CBDC should look like. Different options for its architecture have been contemplated. Whether it shall bear an interest or not or whether it should be a full replacement for cash is a topic for ongoing discussions as well as the way of distribution and implementation. Either solution has a different impact on the financial market which needs to be carefully looked at.

For the MP, especially the existence of an ELB - due to cash being a remedy for market participants when exposed to low or negative nominal interest rates - needs to be considered when making decisions about the design of a CBDC. The ELB problem can be a serious threat to economies. To archive a desired price stability target, a CB can stimulate the economy by lowering the real interest rate and create more attractive conditions for investments. The real interest rate is equal to the nominal interest rate set by the CB (and other monetary policy measures), adjusted by the inflation rate. With the ELB in place, a CB has only limited options when the nominal interest rate is already at its lowest level and an economy needs further stimulus.

There is a lack in the literature of what the implications on MP at the ELB are, when implementing a non-remunerated CBDC tier.

The aim of the contribution is to answer the research question of how the effect on MP at the ELB can be evaluated when CBDC is introduced as a convenient and safe alternative to cash.

This paper is organized as follows: In the first chapter the CBDC is described with the relevant architectural features for contemplating the ELB problem. After that, the ELB problem in general will be outlined in the second chapter, before discussing the implications of a tiered non-remunerated CBDC on MP at the ELB. This paper will be summarized, and the research question will be answered in the concluding last chapter.

# 1 Central Bank Digital Currencies

CBDC is only a recent concept but there are global efforts being undertaken by central banks to investigate a potential implementation of CBDCs (Bordo and Levin, 2017; Auer, Cornelli and Frost, 2020). However, a monetary authority with an implemented CBDC had not previously existed, and a predominant reason for this is that the technology with the potential to make it a robust solution has not existed until recently (Barrdear and Kumhof, 2017). In most cases, CBDC is contemplated as an addition to cash and not thought of as a replacement of such. (Beniak, 2019). Despite this, some researchers examined the possibility of a full replacement of cash, leaving CBDC the only remaining currency in place (Bordo and Levin, 2017).

It is important to note, that CBDC is a risk free liability of the CB, which would be backed by assets (Panetta, 2021). Besides overnight deposits and bank notes, a CBDC could be seen as the third form of base money (Bindseil, 2020).

Whether a CBDC should be interest-bearing or non-interest-bearing is discussed controversial. With an interest-bearing CBDC, the CB could set the interest to a positive or negative rate, based on the economic situation. Either at their discretion, or under a rule-based approach (Pfister, 2020). An interest-bearing CBDC would give the central banks a tool to react flexible to economic circumstances and stimulate the economy with negative interest rates. But the stimulation would be limited as an interest-bearing CBDC would also impose the ELB problem as market participants would exchange their CBDC to banknotes like they would do with deposits in extended times of negative deposit interest rates.

A non-interest-bearing CBDC would be neutral to the economy and could be seen like cash nowadays. But if the interest rate trends towards zero or even into the negative area, it would impose an ELB effect, as market participants would change their deposits into banknotes and non-remunerated CBDC. An unrestricted and non-remunerated CBDC would set the ELB to zero, making it impossible for the CB to impose negative interest rates at all.

In case of the Digital Euro e.g., it has not been decided yet whether the DE shall be interest-bearing or non-interest bearing. The ECB is contemplating a remuneration for the DE due to monetary policy options (ECB, 2020). But, if the ECB would introduce a remunerated DE, a system with multiple tiers could be implemented. Bindseil and Panetta (2020) propose a two-tier system and suggest remunerating each tier differently. The so-called retail-tier would be zero-remunerated and would allow private households to use it as means of payment for their daily life just like cash. The authors propose that this tier shall never have a negative

interest rate and that the quantity needs to be limited, for example to EUR 3,000 per user. The second tier would begin above the first tier´s limit and could be unlimited but remunerated. The interest rate for the second tier could be negative when MP decisions make it necessary, and vice versa (Bindseil and Panetta, 2020).

With such a system the ECB could set different interest rates to different user groups such as private households, large institutions, commercial banks, or foreigners and adjust the attractiveness of the DE. So, it would give the ECB an instrument to influence money flows and consequently support the commercial banking sector (Bindseil, 2020).

Also, with a multi-tiered CBDC, certain user groups could be excluded, e. g. individuals or companies from certain jurisdictions or countries (ECB, 2020). But, if at all feasible from a technical and political perspective, such regulation of excluding certain user groups would cause major friction and a competitive disadvantage for market participants and the DE per se (Ferrari and Mehl, 2021).

To summarize this point, a multi-tiered system with at least one remunerated and one non-remunerated tier as an equivalent to cash nowadays can be expected to have a high acceptance among the public. Such a system can also have advantages for the CB regarding efficiently performing monetary policy. Hence, the following considerations are under the assumption, that a non-remunerated tier is part of an implemented CBDC.

## 2 The Effective Lower Bound

The existence of non-renumerated cash constraints central banks to impose their policy interest rates significantly below zero. Assumed, that the negative policy rate would be transmitted via the banking system to market participants, they would convert their deposits into the paper form of the currency to avoid higher costs. This restraint is referred to as the “zero lower bound” (ZLB) or “effective lower bound” (ELB), to reflect that converting and holding the currency comes at a cost. Hence, the ELB actually lies at a point below zero, where the costs of negative interest rates are equal to the costs of exchange, storage and insurance of cash or CBDC.

How far below zero the ELB could be, is an ongoing discussion among economists. The empirical findings of Witmer and Yang consider that the ELB can be negative due to the costs of insuring, storing and transporting of physical banknotes and coins (Witmer and Yang, 2016). Other economists conclude that the effective lower bound is at around -1% (Witmer and Yang, 2016; De Fiore and Tristani, 2018; Ciżkowicz, Rzońca and Torój, 2019). The Czech National Bank calculated the threshold for the short term nominal interest rate

in a corridor of -2% to -0,4%, with the mean at approximately -1% (Kolcunová and Havránek, 2018).

Also, it is to note that there are other factors besides the nominal interest rate that influence the ELB such as the time frame over which the negative interest rates are imposed. The interest rate must be limited by the ELB for a longer time span while they could be lowered for one quarter without a great effect on the ELB (Swanson, 2018).

But how negative could the interest rate be if the ELB was removed? Theoretically, there is no limit. When the Global Financial Crisis hit the US, e. g. the simulations by the Fed staff indicated in June of 2009, that the policy rate should ideally be set to -8% (FOMC, 2015; Nelson, 2021).

## 3 Monetary Policy at the ELB

To understand the impact of the ELB on MP by the CB, MP effects need to be considered when being already at the ELB with the nominal interest rate at a point where the CB is no longer able to decrease the policy rate any further without causing the market participants to start converting their deposits into cash.

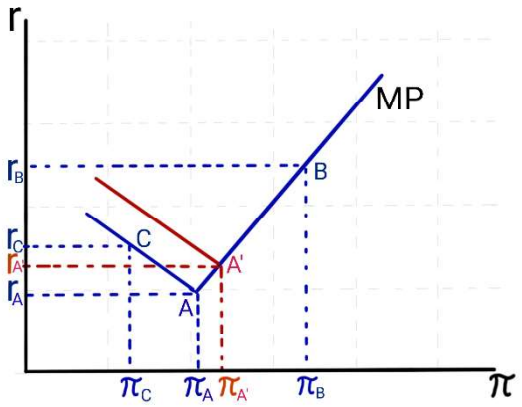
A simplified description of the MP shows how the CB reacts to economic conditions. The measures of MP can either be a set mechanism in a rule-based regime (e.g., the Taylor-rule), or the CB can just set the nominal interest rate at an elected rate when it is in a discretionary system (Pfister, 2020). The form of the MP curve is depending on the Fisher equation. According to the Fisher equation ($r = i - \pi$), the real interest rate $r$ is equal to the nominal interest rate $i$ minus the (expected) inflation rate $\pi$. Again, the MP is not only depending on the policy rate but is describing policy measures at a whole with the nominal interest rate being the primary conventional policy tool for most economies to reach the desired inflation rate.

As shown in figure 1, to archive the goal of the CB to stimulate or slow down the economy, the CB will define a target inflation rate which is shown in figure 1 as $\pi^B$. Thus, the CB will perform measures to adjust the real interest rate by setting the policy rate and e. g. by changing the minimum reserves or engage in open market operations. These measures are intended to either stimulate or slow down the economy by setting the real interest rate at a level, so that the target inflation can be archived, thus giving the MP curve it´s upward sloping form. For example, if inflation is decreasing from our target level $\pi^B$ towards $\pi^A$, the CB is going to want to decrease the real interest rate to stimulate the economy and move the target price level back to $\pi^B$. Thus, the CB is going to decrease $i$ by a certain factor, which will result

in moving down the MP curve from point *B* to *A*. So, the CB will attempt to lower the real interest rate to $r^A$, which is supposed to stimulate the economy in the next period and move back up the MP curve to the target inflation.

Vice versa, if the CB is afraid, that the economy is getting too strong and that the inflation will increase above $\pi^B$, the CB would increase *i* to lift the real interest rate and slow down the economy.

**Figure no. 1: Monetary Policy at the Effective Lower Bound with and without Central Bank Digital Currency**




Source: Author´s own

It is important to note, that the shape of the MP curve changes when we are in point *A* at the ELB, so *i* is already at its lowest level possible. If inflation inclines towards $\pi^C$, then the CB can no longer reduce *i* to decrease the real interest rate. Hence, according to the Fisher Equation the real interest rate is actually moving up again to point *C*, thus, resulting in the descending inflation rate being fully reflected in rising real interest rates instead of the desired decreasing real interest rate. The higher real interest rates will lead to lower investments, which will slow down the economy even further. Thus, this could lead to a deflationary downward spiral which can only be approached with drastic uncommon MP measures.

## 4 Monetary Policy at the ELB with CBDC

When CBDC is intended to be implemented as an alternative to cash, the CB would need to provide market participants with a non-renumerated (limited or unlimited) tier of CBDC. The CBDC would be the third liability on the CB balance sheet, besides reserves and cash. Also, the CBDC would need to be perfectly elastically available at a zero interest rate and agents must be able to decide between CBDC, cash and reserves (Meaning et al., 2021).

The reason for the lower bound being below zero is, that market participants have opportunity costs for exchanging and storing cash. The higher these costs for cash are, the lower the interest rates could be set by the CB, without triggering a wide conversion from deposits to cash (Witmer and Yang, 2016). The costs for exchanging and holding CBDC can be expected to be closed to zero, allowing a frictionless and cheap conversion from deposits into CBDC. Also, as the CBDC will be held in some sort of cryptographically secured wallet, the holding and insurance cost can be expected to be neglectable. Another advantage for CBDC-users is, that it will be safe central bank money, and, opposed to deposits at commercial banks, without any bankruptcy risk of the issuer. So, in times of financial stress, it can be anticipated that market participants will distrust the banking sector and would seek a more secure way of holding their values. They would seek for CBDC as a second form of central bank money which – besides cash – would be widely accessible, but without the costs involved of holding physical coins and banknotes (Meaning *et al.*, 2021). Obviously, these in and outflows from deposits into CBDC and back, could destabilise the banking sector which would need to be compensated by the CB. This could even create a bank-run on CBDC much sooner than what could be experienced in the past with bank-runs on physical cash. But opposed to a bank-run on a commercial bank where the amount of cash is limited, the CB must allow the stock of CBDC to increase. This either means a decline of reserves or an expansion of the monetary base (Meaning *et al.*, 2021).

So, it can be seen in figure 1 that the real interest rate is increasing again in point *A* when inflation falls, due to the ELB. The ELB is expected to move from being effectively below zero when cash is in place, towards an interest rate of zero when opportunity costs of exchanging and holding value in form of CBDC declines to zero. Hence, the turning point on the MP curve - where the real interest rate would rise again when the inflation rate declines further - would lie higher on the MP-curve in point *A'*.

This results in a situation where the CB would need to implement unconventional MP measures - besides decreasing the policy rate - much sooner than nowadays, where the only remedy from negative interest rates is cash. What can be misinterpreted as a small shift, would actually be a potential volume equal to the aggregated non-remunerated tiered amount of CBDC for all market participants. Even a low amount for a remunerated tier, e. g. like EUR 3,000 as it is suggested by Bindseil for the Digital Euro (Bindseil, 2020), would result in a significant extra buffer for the market participants to escape from negative interest rates. In economies like the US or Europe with more than 300 million individuals and a large

commercial and public sector, these small amounts would add up to billions of US-Dollars and Euros and would have the ability to destabilise monetary policy.

## Conclusion

The ELB, in general, is a non-remunerated cash problem and would not exist if non-interest-bearing bank notes would not exist (Agarwal and Kimball, 2015). Some researchers propose the removal of cash parallel to implementing a remunerated CBDC to solve the problem (Bordo and Levin, 2017). These measures would make MP much more efficient and high negative interest rates possible to effectively break through todays ELB (Lilley *et al.*, 2019). However, it is unlikely that cash will be removed or fully replaced with a CBDC which would allow renumeration anytime soon. Instead, an implementation of CBDC in parallel to the existence of cash is likely. (Engert and Fung, 2017).

This paper shows that implementing a CBDC with a non-remunerated tier could influence the efficiency of performing MP for CB negatively. The conversion and holding of deposits of CBDC would come at a much lower cost for market participants than the exchange to banknotes and coins. Hence, as costs for exchange, holding and insuring values in CBDC compared to banknotes decrease, the ELB, which is experienced to be at roughly -1% nowadays, is expected to rise closer to zero. Implementing a non-remunerated tier for CBDC would create an extra buffer for market participants to escape negative interest rates. Even small amounts, e. g. like EUR 3,000 suggested by Bindseil (Bindseil, 2020) for the Digital Euro, would add up to large sums over an economy as a whole and could easily reach billions of USD or EUR. These in- and outflows of deposits in the banking sector could destabilise the banking sector (Meaning *et al.*, 2021) as well as making MP less efficient.

This paper is intended as an early step in the research of the effect on Monetary Policy at the ELB when non-remunerated CBDC was to be implemented to a certain extent.

Questions remain unanswered and should be a topic for further research. Since the ELB is an aggregate function and assumed to be the same for all market participants, it could make sense to take a more differentiated approach to the opportunity costs for exchanging and holding money for different user groups. E. g., understanding the ELB from private household versus larger corporation could help setting the remuneration for different tiers differently to increase the efficiency of MP and diminish disintermediation of the banking sector.

Significant theoretical and empirical research is suggested on this topic in the near future to avoid unforeseen problems on monetary policy when considering a non-renumerated tiered CBDC.

## Abbreviations

| | | |
|---|---|---|
| CB | - | Central Bank |
| CBDC | - | Central Bank Digital Currency |
| ECB | - | European Central Bank |
| ELB | - | Effective Lower Bound |
| FED | - | Federal Reserve Bank |
| DLT | - | Distributed Ledger Technology |
| MP | - | Monetary Policy |
| ZLB | - | Zero Lower Bound |

## References


[1] AGARWAL, Ruchir and KIMBALL, Miles. Breaking Through the Zero Lower Bound. *IMF Working Papers* [online]. Vol. 15, no. 224, 2015. ISSN 1018-5941. Available at: doi:10.5089/9781513567327.001

[2] ALONSO, Sergio Luis Náñez, JORGE-VAZQUEZ, Javier and FORRADELLAS, Ricardo Francisco Reierl. Central banks digital currency: Detection of optimal countries for the implementation of a CBDC and the implication for payment industry open innovation. *Journal of Open Innovation: Technology, Market, and Complexity* [online]. Vol. 7, no. 1, 2021. pp. 1–23. ISSN 21998531. Available at: doi:10.3390/joitmc7010072

[3] AUER, Raphael, CORNELLI, Giulio and FROST, Jon. Rise of the Central Bank Digital Currencies: Drivers, Approaches and Technologies. *CESifo Working Paper*. No. 8655, 2020.

[4] BAROTINI, Christian and HOLDEN, Henry. Proceeding with caution - a survey on central bank digital currency. *BIS Papers* [online]. No. 101, 2019. pp. 1–15. ISSN 1682-7651. Available at: www.bis.org

[5] BARRDEAR, John and KUMHOF, Michael. The Macroeconomics of Central Bank Issued Digital Currencies. *SSRN Electronic Journal* [online]. No. 605, 2017. ISSN 1556-5068. Available at: doi:10.2139/ssrn.2811208

[6] BENIAK, Patrycja. Central bank digital currency and monetary policy: a literature review. *MPRA Paper* [online]. No. 96663, 2019. Available at: https://ideas.repec.org/p/pra/mprapa/96663.html

[7] BILOTTA, Nicola and BOTTI, Fabrizio. *The (Near) Future of Central Bank Digital Currencies*. Bern: Peter Lang, 2021. ISBN 9783034342759.

[8] BINDSEIL, Ulrich. *Tiered CBDC and the financial system*. Frankfurt am Main: European Central Bank, 2020. ISBN 9789289939942. Dostupné z: doi:10.2866/134524

[9] BINDSEIL, Ulrich and PANETTA, Fabio. Central bank digital currency remuneration in a world with low or negative nominal interest rates. *VOXEU CEPR Policy Portal* [online]. 2020. [cit. 2022-04-02]. Available at: https://voxeu.org/article/cbdc-remuneration-world-low-or-negative-nominal-interest-rates

[10] BORDO, Michael D. and LEVIN, Andrew T. Central Bank Digital Currency and the Future of Monetary Policy. *National Bureau of Economic Research.* [online]. 2017. Available at: http://www.nber.org/papers/w23711

[11] BOURI, Elie, GUPTA, Rangan, TIWARI, Aviral Kumar and ROUBAUD, David. Does Bitcoin hedge global uncertainty? Evidence from wavelet-based quantile-in-quantile regressions. *Finance Research Letters.* Vol. 23, 2017. Pp. 87–95. ISSN 15446123. Available at: doi:10.1016/j.frl.2017.02.009

[12] CIŻKOWICZ, Piotr, RZOŃCA, Andrzej and TORÓJ, Andrzej. In Search of an Appropriate Lower Bound. The Zero Lower Bound vs. the Positive Lower Bound under Discretion and Commitment. *German Economic Review*. Vol. 20, no. 4, 2019. Pp. e1028–e1053. ISSN 14680475. Available at: doi:10.1111/geer.12203

[13] DE FIORE, Fiorella and TRISTANI, Oreste. 2018. (Un)conventional policy and the effective lower bound. *Working Paper Series.* No. 2183, 2018. Available at: doi:10.2866/219561

[14] ECB. *Report on a digital euro.* [online]. 2020. Dostupné z: https://www.ecb.europa.eu/

[15] ENGERT, Walter and FUNG, Ben. Central Bank Digital Currency: Motivations and Implications. *Staff Discussion Paper*. No. 2017-16, 2017. pp. 1–30. ISSN 1914-0568. Available at: https://www.bankofcanada.ca/2017/11/staff-discussion-paper-2017-16/

[16] FERRARI, Massimo and MEHL, Arnaud. *(B) Central bank digital currency and global currencies* [online] 2021. [cit. 2021-06-07]. Available at: https://www.ecb.europa.eu/pub/ire/html/ecb.ire202106~a058f84c61.en.html#toc2

[17] FOMC. Monetary Policy Alternatives. *FOMC Bluebook* [online]. 2009. Available at: https://www.federalreserve.gov/monetarypolicy/files/FOMC20090624bluebook20090618.pdf

[18] KLEIN, Manuel, GROSS, Jonas and SANDNER, Philipp. The Digital Euro and the Role of DLT for Central Bank Digital Currencies. *Frankfurt School Blockchain Center Working Paper* [online]. May 2020. [cit. 2021-02-12]. Available at: https://www.researchgate.net/publication/341354711_The_Digital_Euro_and_the_Role_of_DLT_for_Central_Bank_Digital_Currencies

[19] KOLCUNOVÁ, Dominika and HAVRÁNEK, Tomáš. Estimating the Effective Lower Bound on the Czech National Bank's Policy Rate. *Review*. Vol. 85, no. 6, 2018. Available at: doi:10.20955/r.85.67

[20] KUMHOF, Michael and NOONE, Clare. Central Bank Digital Currencies - Design Principles and Balance Sheet Implications. *Bank of England Working Paper*. No. 725, 2018. ISSN 1556-5068. Available at: doi:10.2139/ssrn.3180713

[21] LILLEY, Andrew and ROGOFF, Kenneth. *The Case for Implementing Effective Negative Interest Rate Policy*, [online]. 2019. Available at: https://ssrn.com/abstract=3427388

[22] MEANING, Jack, DYSON, Ben, BARKER, James and CLAYTON, Emily. Broadening narrow money: Monetary policy with a central bank digital currency. Vol. 17 no. 2, 2021. pp. 1–42. ISSN 18157556. Available at: doi:10.2139/ssrn.3180720

[23] NAKAMOTO, Satoshi. 2008. Bitcoin Whitepaper. *Artificial Life*. Vol. 23, no. 4, 2008. pp. 552–557. ISSN 15309185 Available at: doi:10.1162/ARTL_a_00247

[24] NELSON, Bill. *The Benefits and Costs of a Central Bank Digital Currency for Monetary Policy - Bank Policy Institute* [online]. 2021. [cit. 2022-03-30]. Available at: https://bpi.com/the-benefits-and-costs-of-a-central-bank-digital-currency-for-monetary-policy

[25] PANETTA, Fabio. Evolution or revolution? The impact of a digital euro on the financial system. *Brugel* [online]. 2021. 1–14. Available at: https://www.ecb.europa.eu/press/key/date/2021/html/ecb.sp210210~a1665d3188.en.html

[26] PASSACANTANDO, Franco. Could a digital currency strengthen the euro? *Policy Brief*. No. 9/2021, 2021. Available at: https://sep.luiss.it/wp-content/uploads/2022/09/PB9.21-Could-a-digital-currency-strengthen-the-euro.pdf

[27] PFISTER, Christian. Retail CBDC Remuneration: The Sign Matters. *SUERF Policy Note*. No. 205, 2020. Available at: www.suerf.org/policynotes

[28] SANDNER, Philipp, GROSS, Jonas, GRALE, Lena and SCHULDEN, Philipp. The Digital Programmable Euro, Libra and CBDC: Implications for European Banks. EBA Policy Research Workshop: New technologies in the banking sector – impacts, risks, and opportunities, 2020. Available at: doi:10.2139/ssrn.3663142

[29] STATISTA. Number of crypto coins 2013-2022. *Statista*. [online] 2022 [cit. 2022-03-15]. Available at: https://www.statista.com/statistics/863917/number-crypto-coins-tokens/

[30] STEFANOSKI, Darko, SAHIN, Orkan, BANUSCH, Benjamin, FUCHS, Stephanie, ANDERMATT, Silvan and QUERTRAMP, Alexandra. Tokenization of Assets. *Ey* [online]. Vol. 1, 2020. Available at: https://assets.ey.com/content/dam/ey-sites/ey-com/en_ch/topics/blockchain/ey-tokenization-of-assets-broschure-final.pdf

[31] SWANSON, Eric T. The federal reserve is not very constrained by the lower bound on nominal interest rates. *Brookings Papers on Economic Activity*. 2018. pp. 555–572. ISSN 15334465. Available at: doi:10.1353/eca.2018.0015

[32] WITMER, Jonathan and YANG, Jing, 2016. Estimating Canada's Effective Lower Bound. *Bank of Canada Review*. Vol. 2016, 2016. pp. 3–14. Available at: https://www.bankofcanada.ca/wp-content/uploads/2016/05/boc-review-spring16-witmer.pdf

## Contact

Michael Pirgmann
University of Finance and Administration
Ballindamm 15
20095 Hamburg / Germany
37328@mail.vsfs.cz