LUISS

Degree Program in Economics and Business

Course of Money and Banking

Central Bank Digital Currencies (CBDCs): Transforming Monetary Policy and Reshaping Economic and Financial Stability

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Academic Year 2024/2025

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Introduction

The thesis looks at the evolution of money over the years, from primitive times to today's digital currencies. In particular, it focuses on cryptocurrencies and how they have reshaped the economic system. Indeed, they provide a cheaper and faster way to carry out transactions than the traditional banking channels, therefore competing with central-bank issued money. As a result, more and more countries are thinking about launching their own digital currency, the so-called CBDC. However, there are different design options available to central banks, which must carefully analyse the implications of CBDC introduction on the broader economy.

Chapter 1 focuses on the evolution of money and monetary instruments: it starts by defining money and its functions. Then, it focuses on the history of money, from bartering to today's blockchain-based currencies and, ultimately, introduces the concept of CBDC. Moreover, a general overview is given of the impact CBDC might have on the monetary policy framework and on the overall economic and financial stability.

Chapter 2 focuses in detail to effects a CBDC introduction would have on the different transmission channels of monetary policy. It starts by giving an introduction of the different channels in the traditional monetary policy transmission mechanism and consider a monetary policy restriction scenario to better show the effects on the various channels. In turn, each channel is discussed separately and the impact of CBDC on each of them is carefully analysed.

Chapter 3 shows an empirical study that aims at assessing the impact of CBDC on price stability. It only looks at countries that have introduced their official CBDC (no pilot version). Data is still limited since only Nigeria, Jamaica and the Bahamas are those that have launched their official version of CBDCs.

Chapter 1: Evolution of money and monetary instruments

1.1. Definition of money

The world in which we live in nowadays is driven by the concept of "money": a strange, invented notion, described as the great illusion.[1] Despite being used in our everyday life, defining money would be difficult due to the many phases of evolution it has been subject to over time. Money has plenty of definitions: it is abstract and has value only if people believe in it; it is the product of human imagination; it is power; it buys independence; it motivates us and releases human energy; it is a force that dictates the flow of people, goods and ideas around the globe; it is a social technology, like language, something that helps humans work more efficiently in large groups.[2] Economist Charles Goodhart defined money as a *"a social artefact which evolved to facilitate market trading between individual agents who were not so otherwise bound together by family, tribal or social ties that an immediate exchange of equivalent values in trade was unecessary*".[3]

Money is more than just cash and bank deposits. It is a human creation designed to solve specific problems related to accounting, payment and exchange. From ancient barter systems to the modern digital currencies, money has constantly evolved to meet society's changing needs. It is not merely a tool for exchange but a symbol of trust, value, and social organization, shaping how people interact and economies work. As civilizations have risen and fallen, so too has the nature of money, adapting to new challenges and opportunities across time.

[1] David McWilliams, *Money a story of humanity* (SIMON & SCHUSTER, 2024), p.3. During World War II, Hitler was planning on dropping fake sterling notes since it would increase the amount of money into circulation all over the British country, leading to a huge increase in inflation that would impair Britain's ability to fight Germany during the war. Despite this, Hitler was not able to execute his plan since the war situation had changed by 1943. However, Lenin, who may have had different views than Hitler's, had his same objective: shatter *"the great illusion of the value and power of money*".
[2] *Ibid.,* pp.4-6
[3] Charles Goodhart, *Money, Information and Uncertainty* (MACMILLAN EDUCATION LTD, 1989), p.22

1.2. *Money is what money does:* different functions of money

"Money is what money does"[4]: it plays a pivotal role in the economy through its various functions, which are at the basis of financial systems and economic interactions. The different functions of money help facilitate trade, provide an efficient measure of economic activity and foster economic stability.

Money as a unit of account simplifies transactions and increases quality of economic decisions. It is something that can be used to value goods and services, record debts and prices and it is the result of the need to keep track of the credit/debit relationships among members of the community. A unit of account has three fundamental characteristics: it is divisible, fungible and countable.[5] This function of money has laid the foundations for the subject of accounting, which allows us to conduct due diligence, analyse an investment decision and make forecasts and projections about the future. When we think of accounting, we think of today's Excel spreadsheets that collect all financial data of the subject under investigation. However, money as a unit of account was not born with Excel; indeed, evidence show that this function can be dated back to the Sumerians, that in 2100 B.C. were already thinking about finance, money and business models as we do nowadays, when an inscribed tablet, which can be compared to today's spreadsheets, was found in the Mesopotamian city of Drehem. It resembled a financial software, including projections and forecasts about an investment decision, along with assumptions used to make such forecasts.[6]

Money as a means of payment is a function that guarantees finality, since the payment is a unilateral transfer, from the payer to the payee that extinguishes any existing obligations between the two parties. It can be defined as a legal tender since the relevant authority has to decide on the type of payment to use, enforce its use through payment system and ensure that members of the community do not use any other means of payment (e.g. counterfeiting, forgery)[7]. Payment methods come in many varieties, ranging from conventional cash to the newest digital technologies. In the modern highly technological environment, they are essential for facilitating economic activities across different types of businesses, such as online shopping, physical retail establishments, and beyond.

Money as a medium of exchange is what anybody would accept in view of being able to spend it. It promotes trade by being widely acknowledged as valuable within the economy. As a result, sellers

[4] Francis A. Walker, *Money* (NEW YORK: HENRY HOLT AND CO, 1878), p.405
[5] Brunello Rosa with Casey Larsen, *Smart Money* (BLOOMSBURY PUBLISHING, 2024), p.60
[6] McWilliams, *Money a story of humanity,* pp.30-31
[7] Yang, Bill Z., *WHAT IS (NOT) MONEY? MEDIUM OF EXCHANGE ≠ MEANS OF PAYMENT (The American Economist 51, no. 2, 2007), pp 101-104*

are inclined to exchange goods for money, anticipating that they will use that money to purchase something else later on. Money as medium of exchange must possess certain features to facilitate its circulation in the market: standardisation (money should be uniform so that each unit has same form and value, ensuring its acceptance in the community), wide acceptance (it should be broadly accepted within the economy so that economic agents can use it to trade), divisibility (it should be easy to divide into smaller units to carry out transactions of different value), low carrying costs (storing money should be convenient and cheap) and durability (money should be able to sustain its value over time). In other words, if people stop considering money as valuable, then it will cease to be a good medium of exchange.

Money as a store of value gives an economic agent the ability to move purchasing power from the present to the future. In contrast to its roles as unit of account or means of payment, as a store of value money competes with both real and financial assets. At the same time, precious metals, like gold and silver, perform this same function. Furthermore, one of the advantages presented by money as a store of value is its liquidity, which refers to the quality of being readily usable in transactions without loss of value. Unlike many real and financial assets, money can be exchanged quickly and easily, with very low transaction costs and without significant impact on its value.

1.3. The history of money: from the barter system to fiat money

As outlined previously, money has been defined in several ways, reflecting its multilateral role in the society. Various definitions and functions highlight the complexity and versatility of money. Therefore, tracing its historical evolution from the barter systems to modern fiat currencies shows how these definitions and functions have shaped and adapted over time.

In prehistoric times, human beings used the barter system in order to exchange value between them. Indeed, since early human societies lived in small self-sustaining communities, people would produce what they needed and engage in barter by trading surplus goods, exchanging them directly.[8] However, the barter system had obvious limitations, such as: the unlikely event that both parties had the same want, and; divisibility, since not all goods are divisible. Despite these challenges, bartering worked for a long time and led to the establishment of more advanced trading systems.

Around 3000 B.C., humans realized that certain items had intrinsic value that could be used as a medium of exchange: for example, these commodities included goods that people already valued for

[8] McWilliams, *Money a story of humanity,* p.21

their utility or scarcity. Livestock, in many cultures, and cattle were the first forms of money. They were valuable because they provided food, clothing and labor. For example, Mesopotamians used grain as money, whose value was tied to its ability to feed people, which made it a natural choice for trade.[9] Furthermore, in some parts of the world, cowy shells were used as currency due to their rarity and ornamental appeal. Commodity money allowed for more efficient trade but still presented limitations.

Metal coins were the next innovation, appearing around 600 B.C. It was the Lydians who first minted coins,[10] from electrum, a naturally occurring alloy of gold and silver; these coins were standardised in size and weight, thus greatly facilitating trade. They offered significant improvements over the primitive forms of money discussed earlier, such as: a standard of value (a metric that a coin's worth was guaranteed by its weight and the metal contained in the coin), portability (coins were far easier to transport compared to, say, cattle or grain) and durability (in contrast to, for example, grain or livestock, coins did not perish or decompose).[11] The Greeks and Romans soon adopted the idea and coinage spread across the ancient world. They used coins extensively, often stamping their likeness on them to reinforce the political power behind the currency. This also marked the beginning of symbolic value in money, since money was not just a commodity anymore, but also a tool for communicating political authority.[12]

Paper money caused a revolutionary shift. While coins had served civilizations well for centuries, they presented significant downsides, such as their bulk when used in massive quantities. Around the 7th century, paper money was invented in China, under the Tang dynasty, even though it became more widespread during the Song dynasty, from 960 to 1279 A.D..[13] These early forms of paper money were essentially promissory notes issued by the government, representing a promise to pay a certain amount of precious metals, such as gold or silver. Such innovation was inspired by the problem of transporting substantial amounts of coins, especially for merchants travelling long routes, who, instead of carrying heavy metal coins, could carry paper certificates representing that value. Therefore, China's paper system represented a big step forward in the evolution of money and laid the foundation for the concept of fiat money, which will be later discussed.[14]

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[9] *Ibid.,* p.22
[10] Modern-day Turkey
[11] McWilliams, *Money a story of humanity,* p.40
[12] *Ibid.,* p.48
[13] Tikkanen A. (2020) *A Brief (and Fascinating) History of Money,* available at: https://www.britannica.com/story/a-brief-and-fascinating-history-of-money
[14] J.P. Morgan. (no date) *How paper money evolved,* available at: https://www.jpmorgan.com/payments/payments-unbound/volume-2/how-paper-money-evolved#:~:text=Paper%20money%20can%20be%20traced,been%20the%20battle%20against%20counterfeits.

Furthermore, it is also worth mentioning that Medieval and Renaissance times saw the emergence of early banking systems. During Middle Ages, in Europe, the need for more complex financial systems became clear. Merchants and bankers began issuing paper bills of exchange, which were early forms of checks. Moreover, the rise of Italian city-states, like Venice, Florence and Genoa, became fundamental for the development of early forms of banking. Merchants could deposit money and collect receipts they could redeem in different cities, making it easier to conduct international trade. For instance, the Medici family, in Florence, was one of the most famous banking families during this period: they developed methods to create letters of credit and loans that laid the foundation for modern banking systems. It was during this period that banking began to move from physical commodity exchanges to system based on trust and credit.[15]

As international trade and banking practices became more sophisticated, nations sought standardized systems to manage currency and facilitate global economic exchange, leading to the adoption of the Gold Standard, that marked a new era of currency during the 19th century. Under this system, countries agreed to fix the value of their currency to a specific amount of gold.[16] The system had several advantages, including: stability, since gold is a tangible and scarce resource, the value of currency was tied to a real asset, and; trust, as countries adhering to the Gold Standard had international credibility knowing their currency could be exchanged for gold. However, it presented significant disadvantages as well, such as: it restricted the volume of money that governments could print, as they were required to hold sufficient gold reserves to support their currency. This limitation became particularly challenging during wartime or economic downturns when governments needed to generate additional funds to support their activities.

The collapse of the Gold Standard and the rise of fiat currency over it was a watershed moment in monetary history. World War I began the process of weaning nations off the Gold Standard. As countries had to print huge amounts of money to fund their wars, many of them suspended this system and decided to print more paper money. By the time of the Great Depression, in 1930s, many countries moved away from the Gold Standard. The US, with the Executive Order 6102 signed by Franklin D. Roosevelt, prohibited private gold ownership and required citizens to exchange their gold for US dollar.[17]

In 1944, the Bretton Woods conference stands out as a pivotal point in the development of the economic order that followed World War II. Many representatives of dozens of countries participated

[15] McWilliams, *Money a story of humanity,* chap.8
[16] *Ibid*., p.273
[17] Roosevelt F.D. (1933), *Executive Order 6102,* available at: https://www.presidency.ucsb.edu/documents/executive-order-6102-forbidding-the-hoarding-gold-coin-gold-bullion-and-gold-certificates

to the conference, but only two of the many delegations were the ones that really mattered: that of the USA and United Kingdom, respectively represented by Harry Dexter White and John Mayard Keynes. Both of them acknowledged the catastrophic consequences of the past and developed different plans, aimed at preventing the occurrence of similar situations. Keynes was in favour of the establishment of "International Clearing Union", that would have functioned as a regulator for global trade balances. He wanted the union to adopt its own currency, the "bancor", pegged to national currencies at a fixed rate, aimed at stabilizing the global economy as a whole. On the other hand, White wanted the dollar to be the pivot of the new financial system, since this would have given the US a position of relevant importance in the context of international trade.[18] The Bretton Woods agreement of 1944 set up a new system, the one that White suggested, where the US dollar became the world's reserve currency, tied indirectly to gold. The agreement helped rebuild the global economy after World War II by creating a stable environment for international trade and laid the foundation for the modern global financial system: it established the International Monetary Fund, fostering economic stability and international cooperation. Eventually, in 1971, president Richard Nixon, with the so-called "Nixon shock", took the US off the Gold Standard completely, marking the full transition to fiat currency.[19] *" Where America led, the world followed",* [20] meaning that the US dollar and most other currencies around the globe were now based on trust in the government that issue them rather than the backing of a physical commodity, such as gold or silver.

After money was no longer tied to gold, it lost a direct tangible backing, but it gained flexibility, enabling governments to respond more dynamically to economic conditions and influence real variables more effectively. The government is the institution that controls the country and has the power to make fiat money work: it declares that a piece of paper is worth $10, $50 or $100. As long as the government is stable and strong, then people will trust the government and its currency. The word fiat[21] comes from Latin, which means "*let it be done*". Its value comes from trust of citizens towards the relevant authority, rather than something tangible, such as gold or silver. Fiat money is cost-effective: unlike the Gold Standard, where central banks needed gold reserves to print money, fiat money is cheaper as the central bank can print as much money as the economy needs. This gives the monetary authorities flexibility to manage the economy since, for example, during crises, the central bank can print more money to lower interest rates, offer more loans and stimulate the economy.

[18] Rosa and Larsen, *Smart money,* p.23
[19] *Ibid.*, p.27
[20] McWilliams, *Money a story of humanity,* p.321
[21] 1630s, "authoritative sanction," from Latin *fiat* "let it be done" (used in the opening of Medieval Latin proclamations and commands), third person singular present subjunctive of *fieri* "be done, become, come into existence" (from PIE root *bheue- "to be, exist, grow"), used as passive of *facere* "to make, do." Meaning "a decree, command, order" is from 1750. In English the word also sometimes is a reference to *fiat lux* "let there be light" in Genesis i.3. Source: etymonline.

At the same time, fiat money also presents some drawbacks, such as the risk of hyperinflation, whereby printing too much money could be very dangerous for the economy. If the government makes poor decisions or faces a crisis, people might lose confidence on them, and the currency, as a result, will depreciate. Therefore, fiat money gives governments and central banks more flexibility and power but it requires more careful management; otherwise, it could cause massive economic chaos, such as hyperinflation, as previously mentioned.[22]

Under this system, central banks issue base money: cash and bank reserves. Cash refers to metal coins and banknotes we carry in our wallets and use to settle peer-to-peer transactions. On the other hand, bank reserves are electronic instruments, whose access is granted only to commercial banks, that use the reserves to settle transactions in the interbank market. These two components are fundamental in the process of money supply and to the two theories that have been developed over the years regarding the supply of money in the economy.[23] When talking about fiat currency, there are typically two theories that are confronted. The so-called push theory,[24] which argues that central banks create money, print it and give it to commercial banks, and from there commercial banks leverage the amount, pushing money into the economy. In other words, the amount of money the economy requires is determined by the central bank, using complex and sophisticated economic models, the amount of money is then pushed from central bank to commercial banks, then to the economy. On the other hand, we have the pull theory,[25] according to which the central bank is being pulled by the economy and its demand for money, which is satisfied and served by commercial banks[26].

1.4. Private forms of money: from E-money to cryptocurrencies

As we have seen in the previous sections, money has undergone many phases of evolution, from the barter system to commodity money, then to metal coins, to Gold Standard and to Fiat money. Until fiat money, its development was largely driven and controlled by the State. However, this dynamic is shifting. The current phase of monetary evolution appears to be driven by the private sector, with the emergence of cryptocurrencies, stablecoins and digital payment platforms. As a result, it would be

[22] Chen J. (2024), *Fiat Money: What It Is, How It Works, Example, Pros & Cons*, available at: https://www.investopedia.com/terms/f/fiatmoney.asp

[23] European Central Bank (2024), *What is money?*, available at: https://www.ecb.europa.eu/ecb-and-you/explainers/tell-me-more/html/what_is_money.en.html

[24] Traditional view: causality runs from H (base money) to M (money supply). $M = \frac{(1+c)}{(c+r+e)} H = mH$

[25] Alternative view: as a result of financial innovation, the alternative view is gradually replacing the traditional one, stating that the causality runs from M to H. $H = \frac{(c+r+e)}{(1+c)} M = \frac{1}{m} M$

[26] McWilliams, *Money a story of humanity,* pp.330-331

fair to ask: Has the evolution of money come to an end? If not, will fiat money be eventually abandoned? What would replace it? The growing role of the private sector suggests that the future of money may no longer be only in the hands of governments.

In the late 20th century, technological discoveries revolutionized how we deal with money. Digital payments became widespread: credit cards, debit cards and electronic transfers allowed people to move money without the need of handling physical cash, making transactions faster and more efficient, especially as global trade increased. This shift followed significant changes in the economic system, notably the collapse of Bretton Woods agreement in 1971, which had previously anchored global currencies to US dollar and, indirectly, to gold. With the end of the Gold Standard, money became fully fiat, relying on trust in central banks rather than intrinsic value. Over time, concerns about inflation, centralized control and privacy grew, setting the stage for alternative systems. The rise of cryptocurrencies can be seen as a response to the fiat currency era. They represent the last evolution of monetary instruments and signal a potential turning point in the "new" history of money. More and more people are shifting to these instruments because of the many advantages offered over the traditional banking methods[27].

Private forms of money, issued by commercial banks and non-bank financial institutions in the form of the so-called Electronic money (or E-money)[28] have been growing in use, particularly favoured by development of new technologies, as previously mentioned, but also by the COVID-19 outbreak, that had a huge effect on the payment behaviour of consumers and contributed to the rapid decline in the use of cash. Indeed, due to the risk of contracting the virus, which could have been transmitted via handling physical cash, people started moving towards digital payments, and the trend continued even after the pandemic. Figure 1 shows this point: technology and the pandemic have reshaped the payment system. Certainly, in 2016, cash accounted for 79% of POS transactions, then the share started to decrease slowly up to 72%, but a huge decrease of 13% was seen in 2022, coinciding with the pandemic era. Even after, the use of cash kept declining, reaching the 52% in 2024, in favour of the digital payment instruments. Indeed, card payments saw an increase of 20% (from the 19% in 2016 to the 39% in 2024) in their respective share. In addition, also the payments via mobile apps,

[27] Jeffrey E. Garten (2021), *How the 'Nixon Shock' Remade the World Economy,* available at: https://insights.som.yale.edu/insights/how-the-nixon-shock-remade-the-world-economy

[28] Definition of electronic money in Article 2(2) of the E-money Directive (Directive 2009/110/EC, EMD2) reads as follows: "Electronic money' means electronically, including magnetically, stored monetary value as represented by a claim on the issuer which is issued on receipt of funds for the purpose of making payment transactions as defined in point 5 of Article 4 of Directive 2007/64/EC, and which is accepted by a natural or legal person other than the electronic money issuer". Source: European Banking Authority.

which were non-existent in 2016, now accounted, in 2024, for 6% of the total number of POS transactions carried out in the Euro Area.[29]

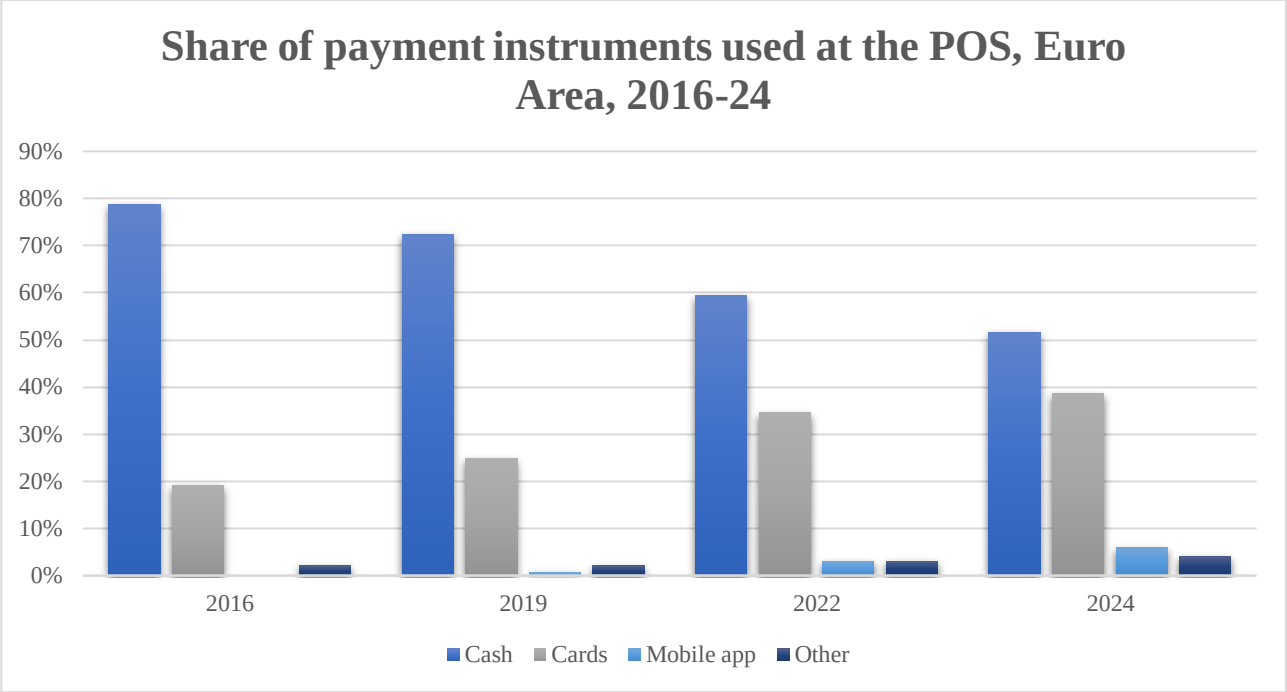

Figure 1: Share of payment instruments used at the POS, Euro Area, 2016-24. Source: European Central Bank

In recent years, the cryptocurrency revolution has marked the beginning of a new era for money. The most famous example, Bitcoin, created in 2009 by Satoshi Nakamoto, was the first decentralized cryptocurrency. Cryptocurrencies are based on blockchain technology, which is a distributed and decentralized ledger that records peer-to-peer transactions across many computers ensuring transparency and security. As the word suggests, it is a chain of more blocks linked together, each of which stores information. For instance, if someone sends a cryptocurrency, the other party will immediately receive it, without the need of a central authority overseeing the transaction. Indeed, unlike fiat money, cryptocurrencies are not controlled by a central authority, but their value is determined by supply and demand on open markets.[30] This has led to significant interest in such currencies as both a store of value and a potential alternative to traditional banking systems, as well as to physical cash, which, unlike cryptocurrencies, cannot be transferred instantly across borders and does not offer the same level of digital and security features. Indeed, crypto transactions maintain anonymity since accounts do not require registration, allowing cryptocurrencies to be transferred

[29] European Central Bank (2024), *Study on the payment attitudes of consumers in the euro area (SPACE)*, chap. 2.2, available at: https://www.ecb.europa.eu/stats/ecb_surveys/space/html/ecb.space2024~19d46f0f17.en.html#toc7
[30] Rosa and Larsen, *Smart money,* pp.69-70

directly between computers. Users can also create multiple crypto addresses to separate or isolate their transactions. Another advantage of these transactions is that they are executed more efficiently and at a lower cost compared to conventional payment methods. For instance, while an international bank transfer occurs via the Society for Worldwide Interbank Financial Telecommunication (SWIFT),[31] requiring several days to be successfully completed due to the many regulatory issues to comply with, blockchain technology ensures that the amount is immediately transferred from one party to the other. How? Thanks to mathematics and algorithms. In turn, this raises further questions on how cryptocurrencies are used, since such an immediate transfer is non-traceable and might be employed as payment method for money-laundering and other illegal economic activities. However, supporters of the blockchain technology argue that it would be possible to capture a transaction that does not comply with Anti-Money Laundering and Combating the Financing of Terrorism (AML/CFT) rules by, simply, integrating compliance measures in the protocols.[32] These measures can include automated monitoring systems that flag suspicious patterns and identity verification mechanisms built directly into the blockchain infrastructure.

Furthermore, there are many debates on whether these newly developed digital instruments, have to be considered as money, since one of the key characteristics of money is the stability of its value over time. This was a point made by the former President of the European Central Bank Mario Draghi that criticized the prime cryptocurrency, Bitcoin, by saying in an interview: *"A euro today is a euro tomorrow, its value is stable. The value of Bitcoin oscillates wildly"* [33]. He also added that he would not consider Bitcoin as a currency because while the Euro is backed by the European Central Bank, *"Nobody backs Bitcoin"*[34]. Indeed, cryptocurrencies in general are characterised by high volatility in prices, and are seen as investment opportunity by risk-seeking investors. Considering Bitcoin as example, Figure 2 shows its price over a 1-year period. The average price is $75,052.84, while the standard deviation for the period under investigation is 15,732.3, remarking the high volatility of such instruments. The high volatility is the result of different factors combined, for example, the relatively small market size compared to traditional assets, meaning that large buy or sell orders can have a significant impact on the price.

[31] Network that allows communication among banks, ensuring that the right amount is transferred to the right person and that the transaction complies with the Anti-Money Laundering and Counter-terrorism Financing rules.
[32] Rosa and Larsen, *Smart money,* pp.74-75
[33] European Central Bank (2018) *#AskDraghi: "A euro today is a euro tomorrow" – can the same be said for #bitcoin?* available at: https://www.youtube.com/watch?v=lRc7eLQ34Ts
[34] *Ibid.*

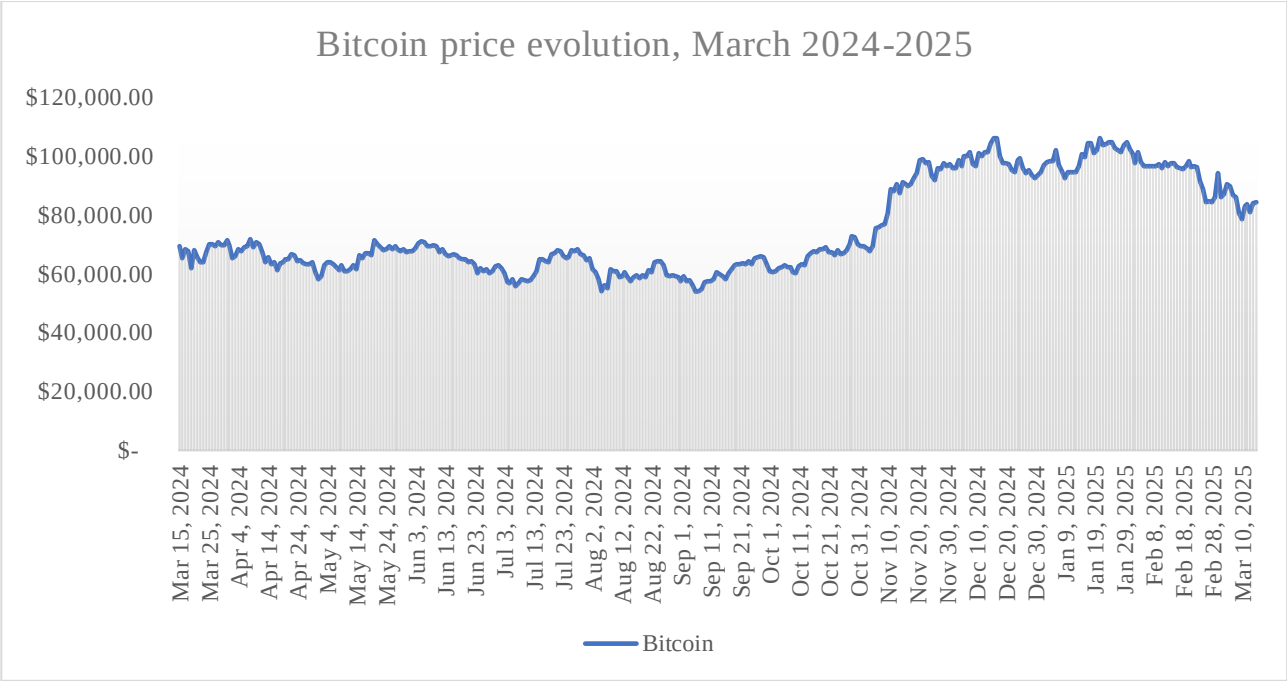

Figure 2: Bitcoin price in USD from March 15, 2024 to March 15, 2025. Source: Statista

Despite its high volatility, there are countries, like El Salvador, that decided to adopt Bitcoin as a legal tender. Its case is a very unique one. In June 2021, Nayib Bukele, El Salvador's president, published the legislation making Bitcoin legal tender, alongside the already adopted US dollar, starting from September 2021. El Salvador was the first country to take this big step forward, for several reasons, such as: increasing efficiency in international remittances, since most citizens depend on money transfers from the rest of the world; decreasing percentage of underbanked people, since most of the population did not have a bank account, and; reducing reliance upon the US dollar. However, the project did not go as planned. In principle, the decision was not appreciated by the International Monetary Fund and the World Bank, that warned El Salvador of the potential macroeconomic, financial and legal issues associated with the adoption of Bitcoin as a legal tender.[35] Many merchants struggled to adopt Bitcoin, and also widespread scepticism about its volatility led the Salvadorans to prefer the US dollar. The government launched the Chivo wallet to facilitate transactions, but again, also this instrument proved to be a failure due to the hacking and technical issues faced. Most citizens sticked to the dollar and only few businesses accepted Bitcoin. Recently, the International Monetary Fund had reached an agreement for a $1.4 billion loan with the government of President Nayib Bukele,

[35] PWC (2021), *El Salvador's law: a meaningful test for Bitcoin*, available at: https://www.pwc.com/gx/en/financial-services/pdf/el-salvadors-law-a-meaningful-test-for-bitcoin.pdf

but the agreement was conditioned upon the removal of Bitcoin as a legal tender. Thus, the president was left with no choice, but to abandon Bitcoin.[36]

However, there are cryptocurrencies, the *stable coins*, which offer the right compromise between blockchain technology and fiat money. They are digital coins that maintain a relatively stable price over time and are usually pegged to a pool of assets, such as currencies or precious metals. Therefore, they combine the advantages offered by blockchain technology, such as higher efficiency and faster transaction processing, and the advantage offered by fiat money, such as the stability in value over time.[37]

Thus, cryptocurrencies are booming. Many companies have been getting into them, allowing customers to make payments via the blockchain-based technology.[38] Whether all this turns cryptocurrencies into viable monetary instruments rather than a speculative investments is yet to be seen, but there is an increasing number of governments around the world that are not going to wait around. Figure 3 shows the growing interest towards crypto-assets of Euro Area citizens. From 2022 to 2024, the percentage share of those owning crypto-assets doubled for 15 out of the 21 countries under examination, with 5 of them tripling the relevant share. For instance, Italy was the country that saw the largest growth, from 2% to 9%, an increase of 350%. Thus, as it can be deduced, cryptos are gaining power, more and more people decide to purchase them and this is not something that central banks want to put up with.

[36] France24 (2025), *El Salvador merchants no longer obliged to accept bitcoin*, available at: https://www.france24.com/en/live-news/20250130-el-salvador-merchants-no-longer-obliged-to-accept-bitcoin
[37] Rosa and Larsen, *Smart money,* pp.77-78
[38] Crypto.com (no date), *Who Accepts Bitcoin Payments in 2025?*, available at https://crypto.com/bitcoin/who-accepts-bitcoin-payments-in-2024

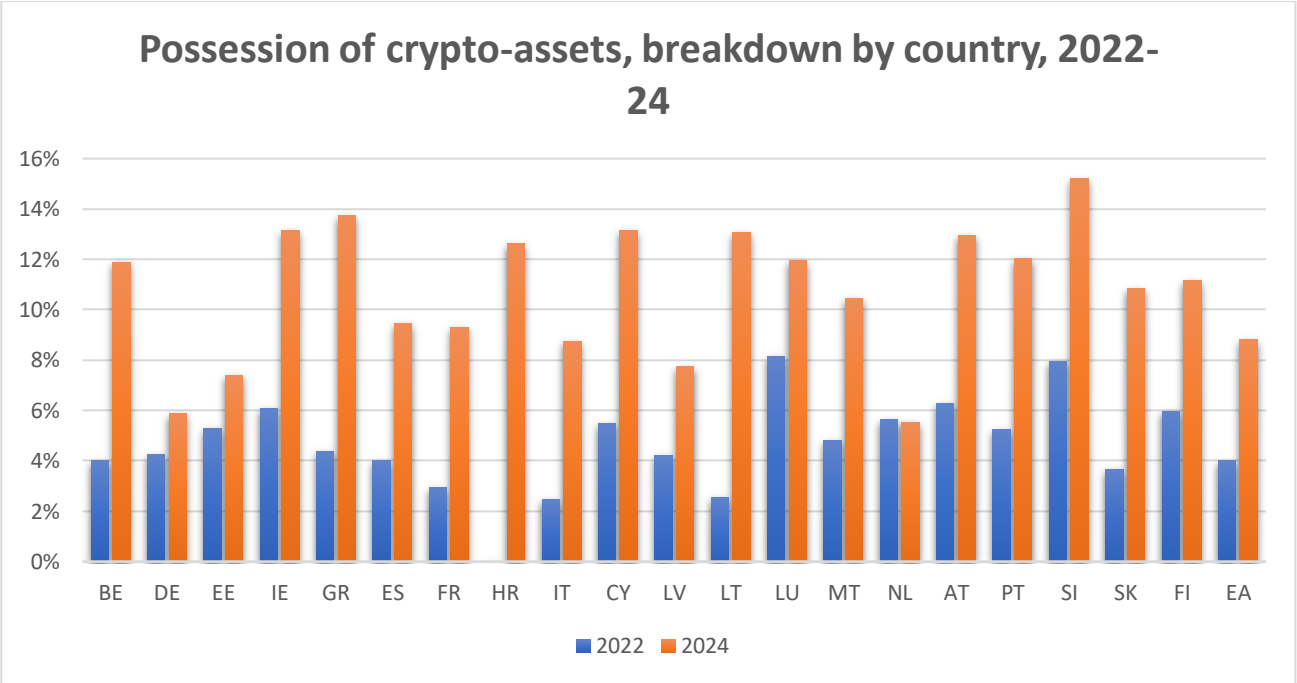

Figure 3: Possession of crypto-assets, breakdown by country, 2022-24. Source: European Central Bank [39]

In addition, Figure 4 shows why citizens are moving towards the world of cryptos. In all EU countries, most purchase such assets for investment purposes, 51% in Lithuania was the lowest and 90% in Netherlands the highest. The reasons for investing in cryptocurrencies are many: long-term growth potential, store of value (i.e., Bitcoin is considered by many as the "digital gold") and its limited supply acting as an hedging instrument against inflation.

[39] Data not collected for Croatia in 2022, since it joined the European Union in 2023

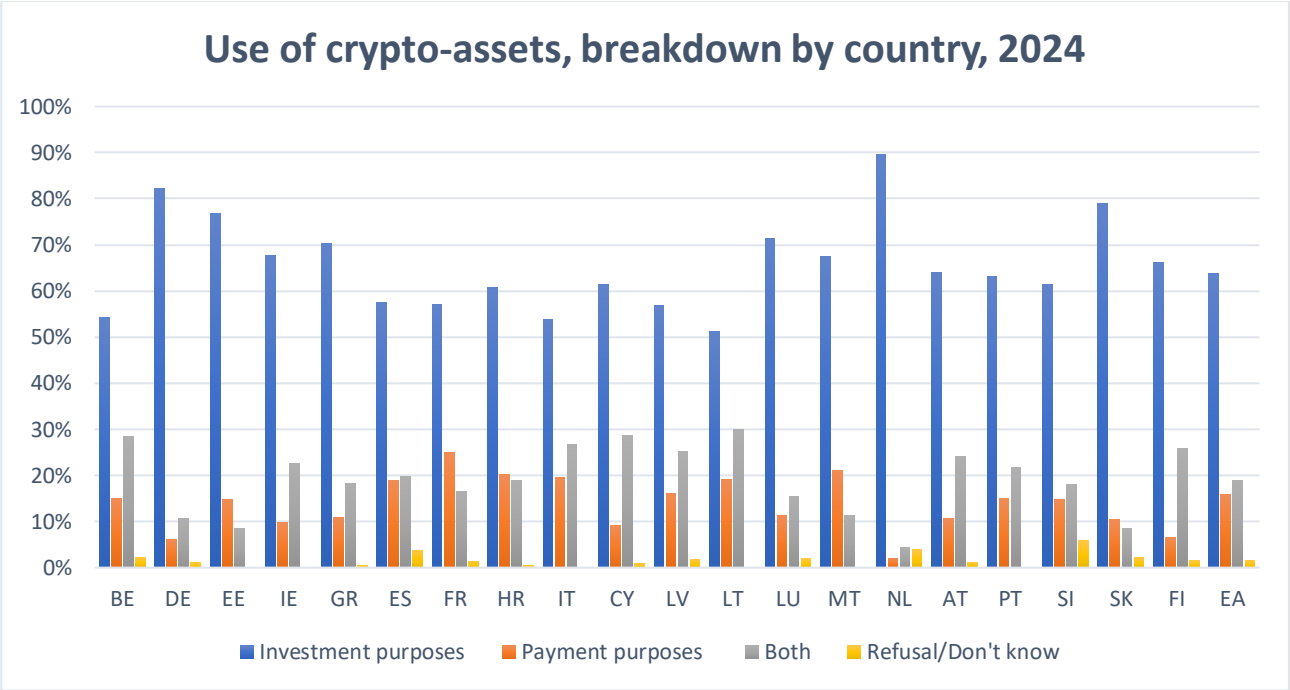

Figure 4: Use of crypto-assets, breakdown by country, 2024. Source: European Central Bank

The previously analyzed case of El Salvador shows the approach of central banks and public authorities regarding cryptocurrencies. The most critical factor is that cryptocurrencies are private and money is public. In 1999, the 1976 Nobel Prize in Economic Sciences winner, Milton Friedman argued: *"I think that the internet is going to be one of the major forces for reducing the role of government".*[40] Furthermore, for example, Hayek was in favour of a reduced government power. In his "*The Denationalisation of Money",* he argued that government monopoly over money led to excessive inflation and proposed a system that would allow private institutions to issue their own currencies, which would compete in the market. This, according to him, would have resulted in higher purchasing power stability and lower risk of inflation and market manipulation[41].

[40] Ray K. (2024), *Milton Friedman's Vision And Bitcoin: A Free Market Economist's Take*, available at: https://www.forbes.com/sites/digital-assets/2024/02/18/milton-friedmans-vision-and-bitcoin-a-free-market-economists-take/

[41] Maria Alejandra Madi (2017), *On Hayek, Digital Currencies and Private Money,* available at: https://www.worldeconomicsassociation.org/newsletterarticles/hayek-digital-currencies/

1.5. Central Bank Digital Currency: a public cryptocurrency?

Cryptocurrencies may be a threat to the economic stability central banks aim to achieve via the monetary policy. Cryptocurrencies are decentralized, fiat money is controlled by central banks; cryptocurrencies are limited in supply, fiat money can be printed in the amounts central banks want. They are the two counterparties of a "battle" which is about to start, with central banks studying the adoption of their own digital currency.

Some countries have adopted, some others are studying, the introduction of a digital currency backed by their respective central bank, also known as Central Bank Digital Currency (CBDC).[42] A CBDC would be the third form of central-bank issued money, in addition to cash and bank reserves. Introducing such digital currency would enable digital transactions to occur more efficiently and at quicker times. Moreover, there are different designs which are being studied. In a CBDC economy, the payment would be a transfer of the central bank liability, which would then be recorded on a general ledger, which is going to be centralised, decentralised or a combination of the two. Both approaches present pros and cons: a centralised ledger would enable central banks to carry out transactions more comfortably, while maintaining the monetary system under control, but, at the same time, a centralized ledger would give central banks access to a wide range of data regarding citizens' habits, which can in turn be a threat to privacy, and favour government surveillance; a decentralized ledger, on the other hand, could facilitate peer-to-peer and offline transactions,[43] but, would give central bank less control over the economy, potentially weaking the monetary policy tools it uses in order to meet its mandate.[44]

A CBDC must have the following key features: convertible, meaning that it could be exchanged at par with other monetary instruments; convenient, should be easy to use in order to favour its adoption and accessibility; accepted and available, should be usable in any transaction and incorporate a feature allowing offline transactions; low-cost, as end-users should face low or no cost, as well as minimum investment in the technology required to operate such system.[45] CBDCs bring up long-standing arguments over the function of central bank funds, who should have direct access to them, and the potential effects they may have on the broader economy. Traditionally, central banks have only allowed banks and some other financial institutions to access digital, account-based central bank money. However, cash, the other form of central bank money, is available to everyone. Thus, there is

[42] 87 countries (that make up 90% of world GDP) are considering the introduction a CBDC, while 9 countries have already introduced them in their respective economies.
[43] Bank for International Settlements (2020), *Central bank digital currencies: foundational principles and core features,* p.12 available at https://www.bis.org/publ/othp33.pdf
[44] Rosa and Larsen, *Smart money*, p.81
[45] Bank for International Settlements, *Central bank digital currencies: foundational principles and core features*, p.11

a high standard for making changes to this system since it has served the public and the financial sector well over time.

Central banks are exploring two systems for its implementation: token-based and account-based. These systems not only differ in their technological foundations but also in their implications for privacy and access. In a token-based system, users need to become familiar with the public-private key pair[46] utilized by CBDCs to gain access and assert their claims of ownership. This model is similar to how cryptocurrencies operate, where ownership is validated by possessing the digital token and authorizing transactions using private key. While this approach typically ensures a significant degree of anonymity, central banks retain the authority to enforce identity verification requirements for network access, particularly during wallet registration or for transactions exceeding the regulatory thresholds. Token-based CBDCs are considered to be more inclusive as they can work without a bank account, potentially providing access to underbanked countries. Moreover, since the system operates like a bearer-instrument, the responsibility for validating the authenticity of the token is typically on the payee, who must ensure that the token is valid. Offline functionality would be more feasible in this model, despite some technical challenges. Conversely, claims and access related to account-based CBDCs are linked directly to a bank account that is tied to the identity of the account holder. This approach relies on established digital identity infrastructures and is similar to the existing financial account systems. Each payment would be processed by crediting the recipient's CBDC account and debiting the sender's, with transactions being verified via identity verification processes[47]. The account-based CBDC simplifies the process for complying with regulatory framework like Know Your Client (KYC) and Anti-Money Laundering (AML), since the identities of users are known. However, it raises concerns about data privacy and surveillance, as authorities have greater access to users' transactions. In addition, since access requires a verified identity, universal access may be difficult to achieve, especially in those countries with limited banking infrastructures. Furthermore, a key difference in these two systems is found in the form of verification: the token-based system heavily rely on the payee's capacity to ensure that the payment instrument is valid; the account-based system depends on the payee's ability to verify the identity of the account holder. In practice, many central banks are considering hybrid models that combine elements of both systems.[48] For example,

[46] It is a cryptographic mechanism consisting of two mathematically linked keys: a public and a private one. The public key can be openly shared and is used for encryption or signature verification; while the private key is kept secret and used for encryption or signing

[47] Deloitte (2021), *Central bank digital currencies: The next disruptor*, p.6 available at https://www.deloitte.com/gh/en/Industries/financial-services/perspectives/cbdc-central-bank-digital-currency.html

[48] Committee on Payments and Market Infrastructures, Bank for International Settlements (2018), *Central bank digital currencies*, p.4 available at https://www.bis.org/cpmi/publ/d174.htm

the ECB proposed allowing anonymity for low-value payments, while requiring identification of identity for transactions of higher value.[49]

Additionally, it is also worth noting that another main distinction has to be drawn between wholesale and retail CBDCs. These two categories serve different purposes and different user groups. A wholesale variant reminds of the current system under which bank reserves are traded. The access to these instruments is limited to a predefined group of financial institutions. The key innovation in this approach regards the digitization and programmability of central bank-issued money, which could significantly improve interbank settlements, improve liquidity management and would streamline cross-border transactions. For example, wholesale CBDCs could enable instantaneous cross-border payments via Distributed Ledger Technology (DLT), without delays and costs associated with banking networks, leading to greater efficiency in financial markets. On the other hand, a retail CBDC is designed to be widely accessible to the general public, functioning as digital component of physical cash. It is intended for everyday transactions and could be pivotal, especially in countries where cash usage is declining. In such countries, retail CBDCs could help maintain financial sovereignty over payments system and could also enhance financial inclusion, especially if they were to operate without a bank account. Moreover, depending on the design choices, they could allow for greater monetary policy transmission. As a result, there are several types of CBDCs one can imagine, with differing implications for payment systems, the transmission of monetary policy, and the overall structure and stability of the financial system.[50]

Although it may seem that such digital currencies are advantageous for the overall economy, there are also some issues to be addressed. CBDCs come with challenges, such as ensuring compliance with Anti-money Laundering and Countering the Financing of Terrorism (AML/CFT) rules, addressing legal and operational issues, and managing privacy concerns if anonymity is allowed. In addition, as previously mentioned, wholesale CBDCs, especially when paired with distributed ledger technology, could make settling securities and derivatives transactions faster and more efficient. However, current designs mostly resemble existing systems and do not show any clear benefits over them. Future experiments might offer better solutions, but, at the moment, central banks need more testing and experience to safely adopt these technologies.[51]

Moreover, another key aspect which has been subject of many debates, and that will also be the subject of Chapter 2, is the implications CBDCs might have on the transmission of monetary policy,

[49] ECB (2020), *Report on a digital euro*, available at: https://www.ecb.europa.eu/pub/pdf/other/Report_on_a_digital_euro~4d7268b458.en.pdf
[50] Committee on Payments and Market Infrastructures, *Central bank digital currencies,* pp.7-8
[51] *Ibid.*, p.9

as well as how they could help central banks manage the overall economic and financial stability. The selection of design and features of CBDCs are of fundamental importance for the different implications they would have on how central banks conduct monetary policy. For example, they might help pass changes in central bank rates more directly to the broader economy or address limits on lowering interest rates. Nevertheless, a retail CBDC could compete with bank deposits, potentially disrupting how banks raise money and price their services.[52] Therefore, a CBDC raises broader concerns since it could destabilize bank funding if, during times of stress, people quickly move their money to the central bank, causing a "digital bank run",[53] potentially pushing central banks into a more important role in financial systems. Additionally, for countries with currencies widely used in global trade, these challenges could become even more serious since introducing a CBDC in one country might negatively impact others, especially during periods of economic uncertainty.[54]

Thus, before launching a CBDC, central banks need to carefully study its potential effects on interest rates, financial markets, and global stability. They must collaborate internationally and stay informed about digital innovations to prepare for future developments.[55]

Despite continuous experiments regarding the CBDCs all over the world, some countries have already introduced their own digital currency and the first of all was China. The Working Group on E-CNY Research and Development of the People's Bank of China defined cryptocurrencies as instruments that "*pose potential risks to financial security and social stability*"[56] and thus developed a digital version of their traditional fiat currency, the digital Yuan (e-CNY). It is a retail CBDC, issued with the intention of replicating cash;[57] also known as Digital Currency Electronic Payment (DCEP), this currency is designed to offer users a safe, stable and convenient way to do business. It operates under a two-tier system, with the People's Bank of China (PBOC) issuing the digital currency to commercial banks, which in turn distribute it to individuals and businesses. This structure allows the central bank to control the money supply, so that it can, in turn, stabilize the economy via the monetary policy. The e-CNY's design allows it to work with existing payment systems and infrastructures (e.g., Alipay, WeChat Pay) to ensure simplicity and acceptance. Unlike cash in the physical realm, the e-CNY is traced and monitored, giving the PBOC live updates of money velocity, inflation, and overall

[52] *Ibid.*, pp.14-15
[53] Rosa and Larsen, *Smart money*, p.87
[54] Committee on Payments and Market Infrastructures, *Central bank digital currencies*, pp.14-15
[55] *Ibid.,* p.14
[56] Working Group on E-CNY Research and Development of the People's Bank of China (2021), *Progress of Research & Development of E-CNY in China,* p.2 available at http://www.pbc.gov.cn/en/3688110/3688172/4157443/4293696/2021071614584691871.pdf
[57] Since it is issued in parallel with physical currency and is treated the same way, it does not have interest-bearing characteristic.

economic activity. That data can, in turn, be used to adjust interest rates, tame inflation, and stimulate the economy. The digital currency also allows cross-border transactions, resulting in a potential impact on traditional foreign exchange system. Currently, cross-border payments often require multiple intermediaries to check the transaction and it may take some days to reach the successful completion of the process; on the other hand, the e-CNY could enable faster and more efficient cross-border payments, potentially bypassing the traditional system altogether. If the e-CNY becomes widely adopted for cross-border payments, it could potentially reduce the demand for dollars and weaken its position as the world's reserve currency.

Furthermore, it is crucial to analyse the motivations that pushed China to take this big step forward. They go beyond the simple explanation of China wanting to adapt to the digitalization of the payment instruments; indeed, the reason seems to come from the fact that the US dollar is widely used in international transactions and holdings of foreign reserves. Figure 5 shows the most used currencies, for January 2025, for international transactions (in terms of value). The chart marks the strength of the US dollar, being used in about 60% of the transactions' value, with the Euro and Japanese Yen following, respectively at 12.97% and 5.42%. While, the Chinese Yuan accounts only for 2.73% of the total value, being the 6th most used currency for international transactions.

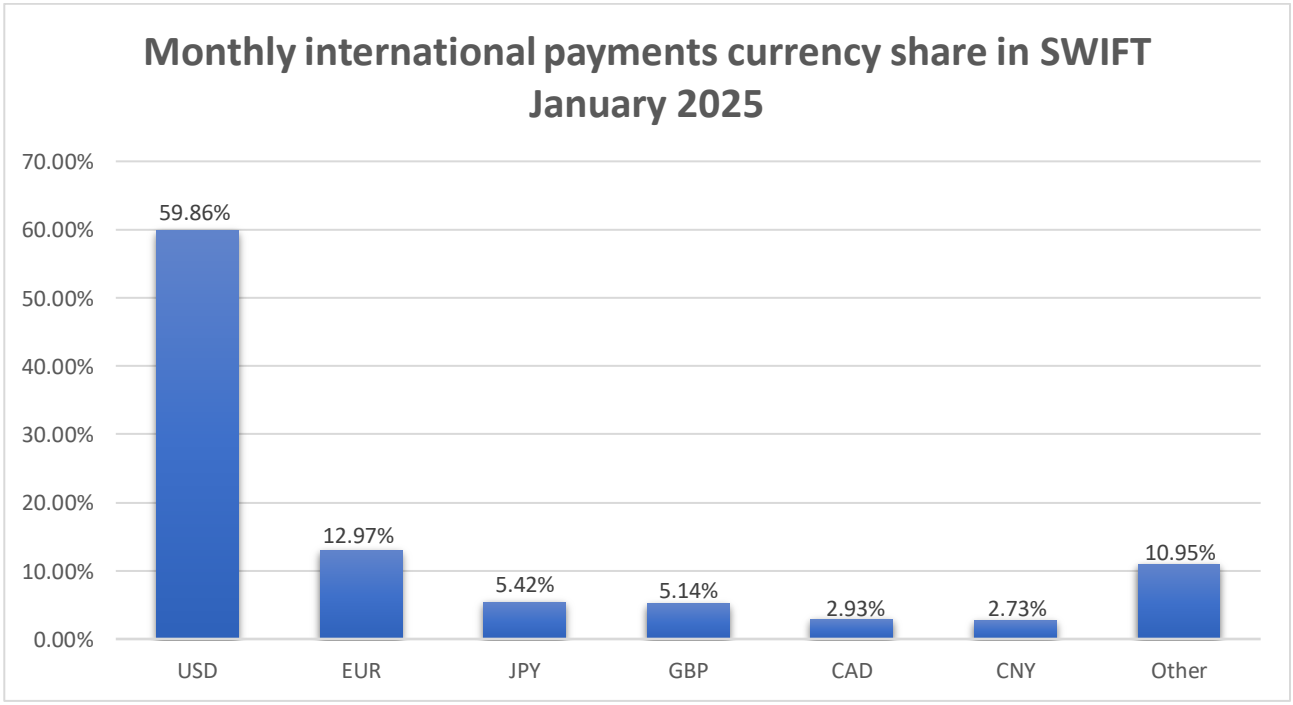

Figure 5: Most used currencies in the world for international payments in SWIFT January 2025, based on share in total transaction value. Source: Statista

Figure 6, on the other hand, shows the share of the world GDP, in terms of purchasing power parity, as of 2025. The chart shows the dominance of China, being the country with the highest share of total GDP, about 19%, with the US and the European Union (EU) coming after, with 14.84% and 14.19%, respectively.[58] Thus, despite China's contribution to GDP being the highest worldwide, about 4.5% higher than the US (in terms of purchasing power parity), the Yuan accounts only for less than 3% of global payments, while the US dollar is widely used, as previously said. Thus, Chinese government had to accept that the Yuan was very unlikely to take up the US dollar on the global stage. As a result, as Professor B. Rosa argues, "*China would have to play an entirely new game, with new sets of rules*"[59] and this is where the digital Yuan comes in.

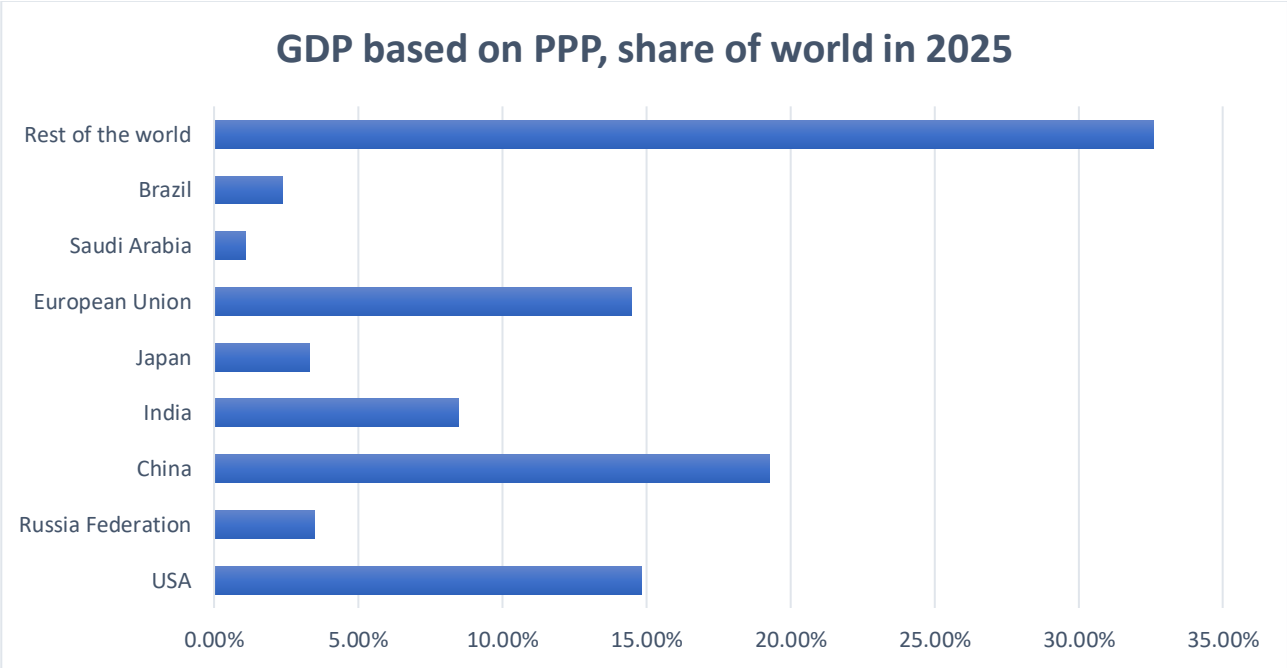

Figure 6: GDP based on PPP, share of the world in 2025. Source: International Monetary Fund

By removing the reliance on financial intermediaries and centralized issuers, cryptocurrencies contributed to the separation between money and state. As touched upon previously, this decentralization challenged the traditional monetary order and led governments to realize that they might use new technologies to move their national currencies into the digital space. China was the first major country to appreciate the vast implications of this shift and recognizing the potential of a

[58] International Monetary fund (2025), *GDP based on PPP, share of world*, available at https://www.imf.org/external/datamapper/PPPSH@WEO/OEMDC/ADVEC/WEOWORLD
[59] Rosa and Larsen, *Smart money*, p.93

CBDC not only for efficiency but also for strategic and geopolitical advantages, started working on its CBDC in 2014. If currency were to exist solely in a digital format instead of as physical cash, it would need to transfer directly over the internet between the parties involved in a transaction: this would eliminate the necessity for various financial institutions, between the two parties, that are often subject to the influence of the US government.[60] By moving to a CBDC, China saw an opportunity to circumvent the institutional obstacles and protocols that currently uphold the dollar's position as the leading global reserve currency, thereby establishing entirely new systems. Transactions could occur directly between the parties without the need for approval from the SWIFT messaging system, the consent of international commercial banks, or compliance with international sanctions imposed by traditional banking infrastructures. Thus, the Chinese CBDC could facilitate cross-border transactions without reliance on US-controlled infrastructures, undermining the dollar's hegemony as the dominant global reserve currency. In fact, if China were to lead the future of digital currency, it could potentially be the one imposing sanctions. Recognizing this early on, China understood that the competition to shape the future of money was a critical geopolitical struggle, not only a matter of financial innovation and that winning this competition would allow it to take the lead in global influence from the United States. With this strategy, China is wagering that the global economy will eventually transition to digital currency, necessitating new payment infrastructures. Therefore, the launch and scaling of CBDC could serve as the foundation for an alternative financial system, modifying not only how value is exchanged but also who controls the infrastructure of global trade.[61]

1.6. Monetary Policy and Economic Stability in the Age of CBDCs

It is clear that the emergence of a CBDC reflects what can be considered as a new phase in the evolution of money and monetary instruments. Previous section has analyzed the reasons for introducing a CBDC and the different design options central banks have at hand. They are still considering the introduction of their own digital currency, weighing both pros and cons. As a result, it is crucial to consider the potential effects CBDCs might have on the monetary policy, and, consequently, on the economic stability.

[60] *Ibid.,* p.94
[61] *Ibid.*, pp.94-95

A unit of account to price goods and services; a method of storing value, and; an efficient medium of exchange that would facilitate trade among economic agents. These are the three characteristics a government-issued currency must possess, and consequently, features we must find in a CBDC[62].

Monetary policy implementation is the operational arm of central banking. It translates the target rate and the policy goals of central banks into real-market effects. Adding CBDCs to the system could bring the potential for higher efficiency and may require adjustments to the way these operations are conducted[63]. We consider an inflation-targeting regime, since most economies operate under such system, where central banks conduct monetary operations in order to achieve their final target. These operations comprise objective, or final target (price stability), intermediate targets (helps central bank to adjust monetary policy stance from any deviation arising from the target), operational targets (economic variables that central banks control on a daily basis in view of achieving their objective) and monetary policy instruments (tools central banks use in order to achieve their operational targets, e.g. OMOs, SFs, Reserve Requirements). In an inflation-targeting regime, central banks set short-term policy rate as operational target and use monetary policy instruments to manage the liquidity situation, ensuring that market rates remain not far from the policy rate[64].

Furthermore, access, remuneration and holding limits are the most important factors to consider when studying a CBDC. Depending on the design features selected, CBDCs might have different implications for central bank-issued money, as well as on bank deposits. Thus, it is important to carefully analyse the implications of the design options on the financial system as a whole. For example, suppose the adoption of a retail, non-remunerated CBDC, which would replicate cash: less transactions would be carried out using banknotes and coins, especially in those economies where the use of cash is declining. Such design would not imply any change in the size of balance sheets of central bank, households and banking sector, which, among the three, is the only one not being directly affected by CBDC introduction. Indeed, supposing a one-to-one substitution ratio of cash into CBDC, households' cash would decrease by, for example, 5 and CBDC would increase by 5, leaving the total value of assets unaffected. On the other hand, central bank-issued money are a liability for central banks, thus cash would decrease by 5 and CBDC would increase by the same

[62] Michael D Bordo and Andrew T Levin (2017), *CENTRAL BANK DIGITAL CURRENCY AND THE FUTURE OF MONETARY POLICY,* available at: https://www.nber.org/system/files/working_papers/w23711/w23711.pdf
[63] Enea Caccia, Jens Tapking and Thomas Vlassopoulos (2023), *Central bank digital currency and monetary policy implementation*, available at: https://www.ecb.europa.eu/pub/pdf/scpops/ecb.op345~4b4eeee055.en.pdf
[64]Tansaya Kunaratskul, Andre Reslow and Manmohan Singh (2024), *Implications of Central Bank Digital Currencies for Monetary Operations*, available at: https://www.imf.org/en/Publications/fintech-notes/Issues/2024/10/04/Implications-of-Central-Bank-Digital-Currency-for-Monetary-Operations-555883

amount.[65] Figure 7, 8 and 9 show effects of a non-remunerated, retail CBDC on the three balance sheets aforementioned.

Households and Firms Balance Sheet	
Assets	Liabilities
Cash: 30 (-5) = 25	Loans
Deposits	Accounts payable
CBDC: 5 (+5) =10	Taxes payable
Other	Other

Figure 7: Non-bank sector balance sheet (non-remunerated CBDC)

Central Bank Balance Sheet	
Assets	Liabilities
Foreign assets (net)	Cash: 30 (-5) = 25
Government balances (net)	Reserves
Central Bank Operations (net)	CBDC: 5 (+5) = 10
Other	Other

Figure 8: Central bank balance sheet (non-remunerated CBDC)

Banks Balance Sheet	
Assets	Liabilities
Reserves	Deposits
Loans to third parties	Borrowing from third parties
Other	Other

Figure 9: Banks' balance sheet (non-remunerated CBDC)

[65] *Ibid.*

Thus, in this case, a CBDC does not have any significant impact on short-term interest rates, since the balance sheet of commercial banks is not directly affected. However, the digital feature and the high speed via which CBDC transactions would be carried out might cause CBDC demand to be more volatile than cash, making liquidity forecasting more difficult. Consequently, they should be included as an additional autonomous factor used in forecasting liquidity. Indeed, a given increase in money velocity might imply higher inflation[66]. As a result, countries operating under an inflation-targeting regime would need to undertake some additional monetary operations, such as fine-tuning operations or reserve management interventions, to achieve the desired inflation rates[67].

1.7. Financial Stability, Risks and Broader Economic Implications in a CBDC World

However, the picture changes significantly when considering alternative CBDC designs, particularly those that are remunerated. Unlike non-renumerated CBDCs, interest-bearing ones introduce the potential for deposit substitution, bank disintermediation, and a reconfiguration of the financial sector's structure. These implications stretch beyond monetary policy implementation, raising critical questions about financial stability, systemic risk, and the broader economic architecture.

A central function of the banking system is their role as financial intermediaries. The process is fundamental to increase investments, create credit and favour overall economic growth. However, a remunerated CBDC may lead to replacement of bank deposits, especially when holding CBDCs offers a return higher than bank deposits. Assuming CBDCs are accessible to those having a bank account, the banking sector would need to exchange reserves or collateral for CBDCs. To put that into perspective, it is crucial to analyse effects on balance sheets, as previously done with the non-remunerated case.

Total assets and liabilities value for both households and central bank would not change, meaning that the size of the balance sheet is not altered due to the decrease in deposits being compensated by an equal increase in CBDC holdings. On the other hand, the banking sector balance sheet, as shown in Figure 12, experience a decrease in deposits (liability) and a decrease in reserves (assets). Therefore, both assets and liabilities would decrease by the amount of bank deposits being converted in CBDC holdings: in this case, 10.

[66] Inutu Lukonga (2023), *Monetary Policy Implications of Central Bank Digital Currencies*, available at: https://www.imf.org/en/Publications/WP/Issues/2023/03/17/Monetary-Policy-Implications-Central-Bank-Digital-Currencies-Perspectives-on-Jurisdictions-531074
[67] *Ibid.*

Households and Firms Balance Sheet	
Assets	Liabilities
Cash	Loans
Deposits: 60 (-10) = 50	Accounts payable
CBDC: 10 (+10) = 20	Taxes payable
Other	Other

Figure 10: Non-bank sector balance sheet (interest-bearing CBDC)

Central Bank Balance Sheet	
Assets	Liabilities
Foreign assets (net)	Cash
Government balances (net)	Reserves: 50 (-10) = 40
Central Bank Operations (net)	CBDC: 10 (+10) = 20
Other	Other

Figure 11: central bank balance sheet (interest-bearing CBDC)

Banks Balance Sheet	
Assets	Liabilities
Reserves: 50 (-10) = 40	Deposits: 60 (-10) = 50
Loans to third parties	Borrowings from third parties
Other	Other

Figure 12: banks' balance sheet (interest-bearing CBDC)

As opposed to the case of a non-remunerated CBDC, an interest-bearing one would affect short-term interest rates, due to the shrinking in the banking sector balance sheet. Since CBDC would be preferred to bank deposits, leading to a leftward shift of both supply and demand for reserves, the amount of reserves would decrease. The movement of short-term interest rate is ambiguous since it depends on the magnitude of the two shifts: if demand falls more than supply, interest rate decreases below the target level; vice versa if demand falls less than supply[68]. As shown in Figure 13, a decrease

[68] Kunaratskul, Reslow and Singh, *Implications of Central Bank Digital Currencies for Monetary Operations.*

in both supply and demand for reserves depends on the magnitude of such shifts. Point A indicates the initial equilibrium, with quantity of reserves being 50 and a corresponding interest rate of 1%. As more people move away from bank deposits in favour of CBDC holdings, the shifts would be more severe. As previously mentioned, in case of demand falling less than supply, the interest rate increases above the target rate, as seen in point B: interest rate increases up to approximately 1.1% and reserves drop to 40 units. On the other hand, in case the shift in demand for reserves is more severe than the shift in supply, the interest rate falls below target, as shown in point C, where reserves have decreased to 40 and interest rate has dropped to approximately 0.75%.

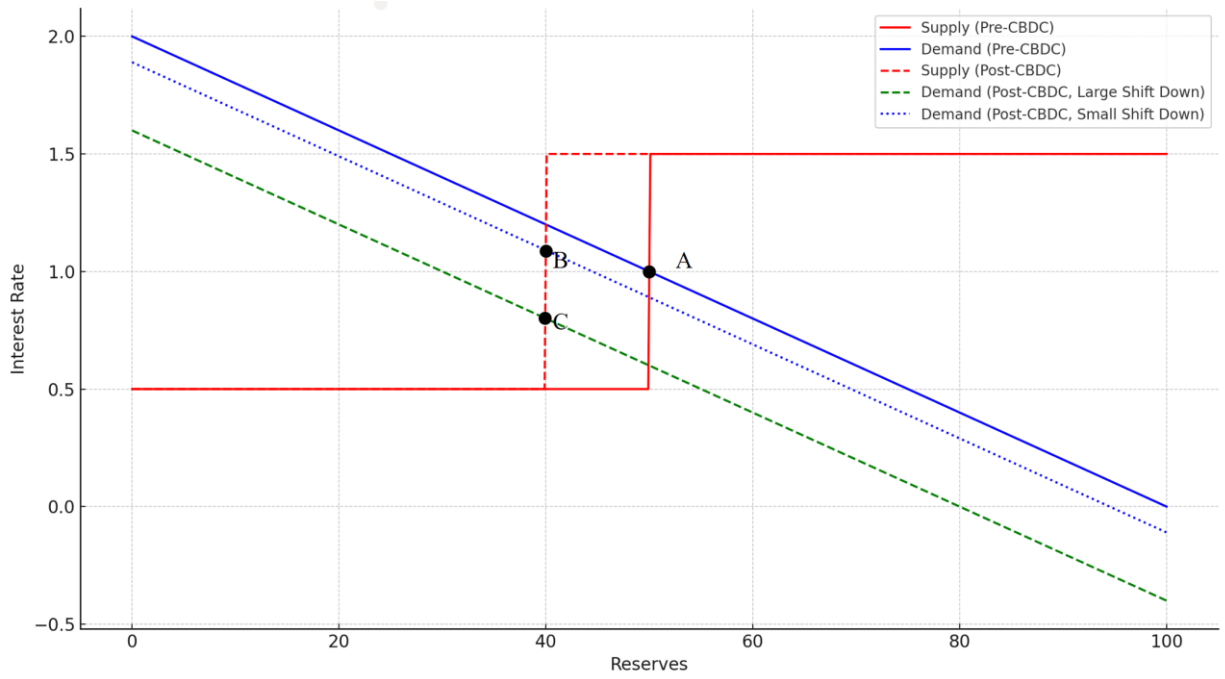

Figure 13: CBDC Impact on reserves and short-term interest rate

In this scenario, central banks could inject additional reserves into the system to counter upward pressure on interest rates, and, vice versa, absorb liquidity from the market to counter downward pressure on interest rates. Such system, especially during periods of economic stress or uncertainty might cause massive bank runs, potentially disrupting financial stability. Indeed, in case of economic downturns, people would quickly move their money from bank deposits to CBDC since they offer risk-free and accessible alternatives to bank deposits[69]. In other words, widespread adoption of CBDC may give rise to a crowding out effect, where safer central bank liabilities displace the deposit-based funding model of commercial banks. As deposits fall, banks would face limitations in their ability to extend credit to the real economy. How easily the conversion between CBDCs and bank deposits

[69] *Ibid*

takes place may shrink the time horizon in which central banks can respond to loss of confidence in the banking system. Traditional tools may not be enough if no limits are imposed on the ability to convert bank deposits into CBDCs[70]. This is why, it is crucial to consider the third element previously mentioned in design choices of CBDCs: holding limits. For example, the ECB, studying the introduction of a digital Euro, is considering to apply holding limits to CBDCs for households, which should be between € 3,000 and € 4,000. As a result, applying holding limits to CBDCs would favour financial stability since it would prevent bank deposits falling to 0 during periods of economic stress[71].

Another potential solution to limit the risk of bank runs would be to implement tiered interest rates, as suggested by the current Director General of Market Infrastructures and Payments at ECB Ulrich Bindseil. A limited amount of CBDCs holdings could earn competitive interest, with the remaining amount earning 0 or negative interest. The suggested solution would discourage the use of CBDCs as a store of value[72], but could also reduce the potential for CBDCs to be used as an additional monetary policy instrument.

[70] ECB, *Report on a Digital Euro*
[71] Caccia, Tapking and Vlassopoulos, *Central bank digital currency and monetary policy implementation*
[72] Ulrich Bindseil (2020), *Tiered CBDC and the financial system*, available at: https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp2351~c8c18bbd60.en.pdf

Chapter 2: The Transmission Mechanism of Monetary Policy via CBDCs

2.1. Traditional Monetary Policy Transmission Mechanism

Monetary policy transmission describes the process by which central banks decisions affect economic variables, such as inflation and output growth. The transmission mechanism is, in turn, composed of different channels. This subchapter considers a tightening monetary policy and its influence on the transmission chain. Then, the potential CBDCs' implications on the model would be analyzed.

A monetary policy restriction begins with central bank increasing official interest rates. The magnitude of the policy decision may be enhanced by either reducing the amount of bank refinancing or increasing the reserve requirement coefficient, with the aim of reducing the inflationary pressure. The first round effects are seen in the interbank market: the central bank increases the official interest rates, resulting in an upward shift of the supply and demand curve for reserves. Consider a hypothetical scenario (Figure 14): prior to the monetary policy restriction, floor and ceiling rate were 1% and 3%, respectively, with the interbank rate corresponding to the rate at point A, approximately 2.5%. On the other hand, a monetary policy restriction causes official interest rates to increase, so that the supply curve shifts upwards and the floor and ceiling rates move to 1.5% and 3.5%, respectively. The new equilibrium point B shows an increase in the interbank rate, as compared to initial equilibrium A.

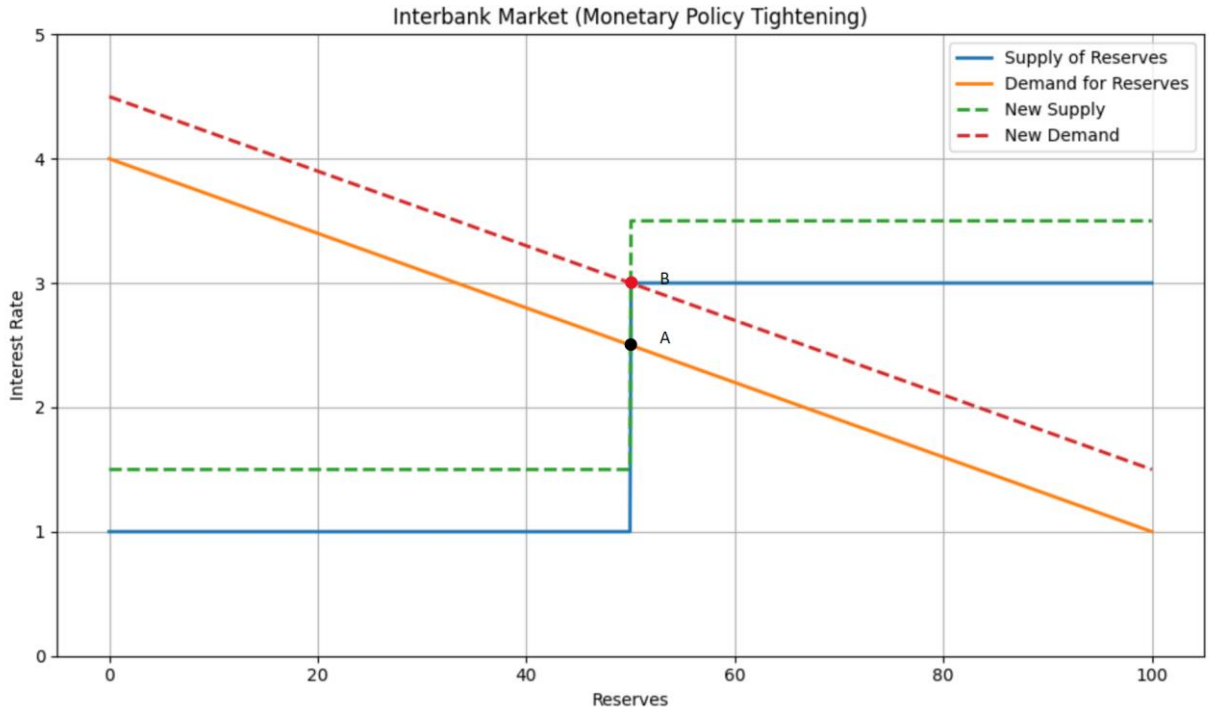

Figure 14: Effects of Monetary Policy Restriction in Interbank Market

Thus, as central banks increase official interest rates, money market rates would move in the same direction, since banks pass the higher rates to each other (interbank market) and more investors would be drawn into the market.

Monetary policy works primarily through the interest rate channel, whereby a monetary policy restriction would result in higher rates, that would negatively impact investments and ultimately decrease the level of output.

The effects would be as follows:

$$i_{OFF} \uparrow \Rightarrow i_{MM} \uparrow \Rightarrow i_{loans} \uparrow \Rightarrow r \uparrow \Rightarrow I \downarrow \Rightarrow Y \downarrow$$

The increase in money market rates would lead banks to increase the interest rate on loans offered to their clients. Thus, as nominal interest rate goes up, real interest rate would move in the same direction, since adjustments in inflation are not immediate. In turn, the increase in real interest rate would cause investment spending, GDP and aggregate demand to fall.

The next effects are seen in the exchange rate transmission channel, which would operate as follows:

$$i_{OFF} \uparrow \Rightarrow i_{MM} \uparrow \Rightarrow Demand_{Domestic} \uparrow \Rightarrow Supply_{Foreign} \uparrow \Rightarrow E \uparrow \Rightarrow NX \downarrow \Rightarrow Y \downarrow$$

As money market rates go up, deposits and financial assets denominated in domestic currency become more attractive for foreign investors, leading to an increase in supply of foreign currency and demand for domestic currency. As shown in Figure 15, this would cause an upward shift of both curves leading to a new equilibrium point, with domestic currency appreciation relative to the foreign. As this happens, exchange rate goes up, negatively impacting net exports, aggregate demand and GDP.

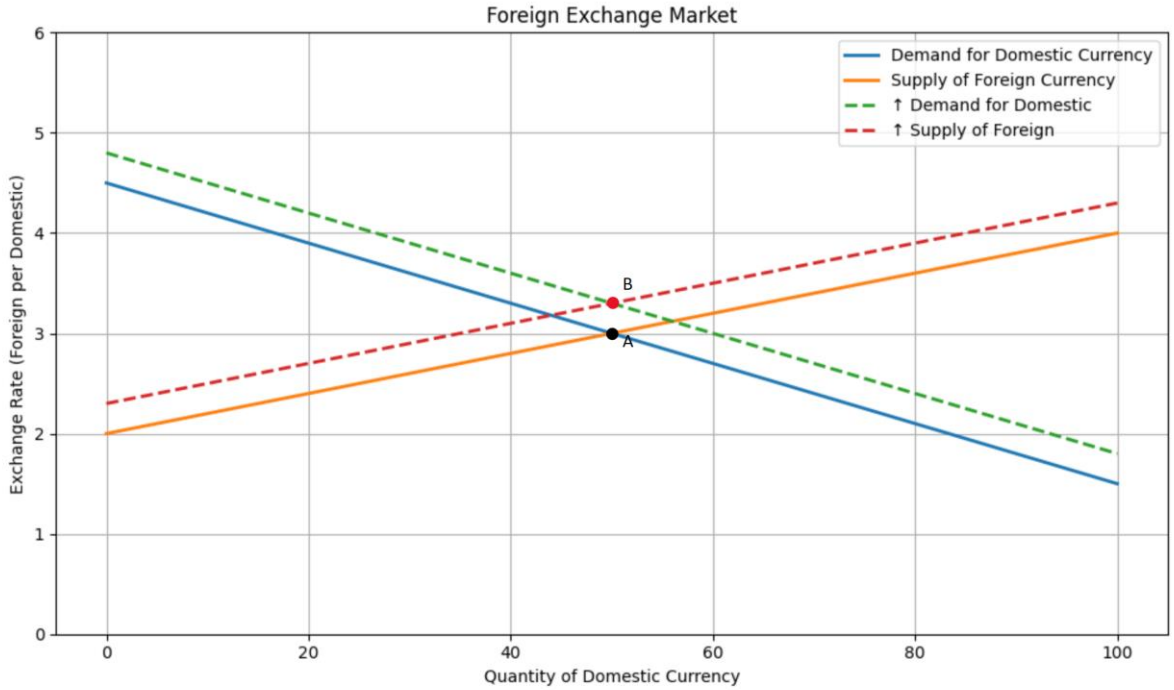

Figure 15: Effects of Monetary Policy Restriction on Forex Market

Furthermore, the monetary policy also affects the economy through asset prices. The asset price channel refers to both real and financial assets. In particular, we consider the Tobin's q framework, which revolves around the equation:

$$q = \frac{Market\ Value\ of\ Firm}{Replacement\ cost\ of\ capital} = \frac{P_{e_t} \times Number\ of\ shares}{Replacement\ cost\ of\ capital}$$

Where $P_{e_t} = \frac{P_{e_{t+1}}}{1+i} + \frac{Div_{exp_{t+1}}}{1+i}$

$Div_{exp_{t+1}}$ represents the expected profits for equity holders. As interest rates rise, the discount factor increases and the term P_{e_t} decreases. As price of equity goes down, the value of Tobin's q drops: the same holds for investment spending, and, therefore, for aggregate demand and GDP.

$$i_{OFF} \uparrow \Rightarrow\ i_{MM} \uparrow \Rightarrow (1+i) \uparrow \Rightarrow\ P_{e_t} \downarrow \Rightarrow q\ \downarrow \Rightarrow I \downarrow \Rightarrow Y \downarrow$$

This holds true also for real estate: As P_{e_t} goes down, households' wealth decreases (wealth effect). Therefore, consumption would fall and so would *Y:*

$$i_{OFF} \uparrow \Rightarrow\ i_{MM} \uparrow \Rightarrow (1+i) \uparrow \Rightarrow\ P_{e_t} \downarrow \Rightarrow wealth\ \downarrow \Rightarrow C \downarrow \Rightarrow Y \downarrow$$

These changes have a negative impact on financial statements of the non-banking sector. In particular, revenues decline due to weaker economic activity, while costs rise, lowering profits, or increasing losses (Figure 16). At the same time, as assets value and equity fall, the size of the balance sheet shrinks (Figure 17).

Income Statement	
Revenues ↓	Costs ↑
	Total: Profits ↓ / Losses ↑

Figure 16: non-banking sector income statement

Balance Sheet	
Assets ↓	Liabilities
	Equity ↓

Figure 17: non-banking sector balance sheet

Moving to the credit channel, as asset and equity decline following a monetary restriction banks would respond by tightening lending conditions: they reduce the loan supply and increase interest rate on loans to compensate for the higher credit risk. The result would be the following:

$$i_{OFF} \uparrow \Rightarrow i_{MM} \uparrow \Rightarrow Reserves \downarrow \Rightarrow Bank\ deposits \downarrow \Rightarrow Bank\ Loans \downarrow \Rightarrow I \downarrow \Rightarrow Y \downarrow$$

Assuming there is no perfect substitutability between bank loans and other source of funding, an increase in the official rates would cause the interest rate on bank loans to increase (similarly to what seen before with interest rate transmission channel). The initial increase in the official interest rates, causes the amount of money in the economy and, consequently, reserves and bank deposits to fall. The results are shown in the loan market, where on the one hand, a decrease in deposits causes loan supply to increase and on the other hand, loan demand to be ambiguous due to the increase in interest rate and the decrease in reserves (Figure 18). In turn, the amount of bank loans would fall and the interest rate on loans will increase, raising the cost of capital and ultimately decreasing investment spending, aggregate demand and GDP.

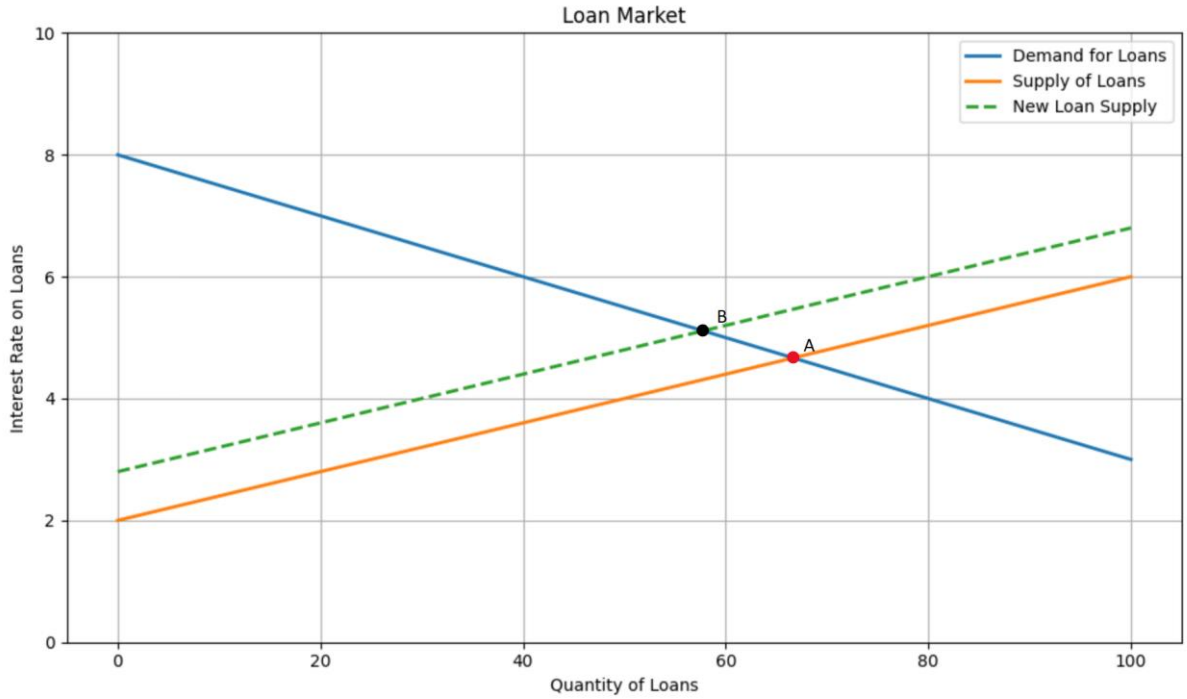

Figure 18: Effects of Tightening Monetary Policy on Loan Market

So, where would CBDCs fall in the transmission chain just analyzed?

It is a fair question to ask. With their introduction, the transmission mechanism may change considerably, especially via interest rate and credit channels. For example, adopting a remunerated CBDC would strengthen the pass-through from central bank policy rates to the broader economy, potentially amplifying the effects of central banks' decisions. Furthermore, as argued in the previous chapter, moving from bank deposits to CBDC holdings would result in tighter credit conditions, and may ultimately disrupt financial stability. The next subchapters focus on the transmission effects of a retail, interest-bearing CBDC. This choice is driven by the fact that, among the different options, a remunerated CBDC is the one most likely to interact directly with monetary policy toolkit and influence the transmission channels. Unlike a non-remunerated CBDC, whose functions would be similar to those offered by cash, a remunerated CBDC introduces an additional central bank policy rate, which would enable central banks to transmit monetary policy faster to the non-banking sector. Consequently, changes in i_{CBDC} would generate stronger and faster responses in aggregate demand and inflation. However, it is important to specify that a non-remunerated CBDC would not be neutral, especially in stress situations. When $i_{bank\ deposits}$ approaches 0 or becomes negative, a CBDC, offering 0 interest, may become a preferred option for households. Would that be the case, a non-

remunerated CBDC could cause massive outflows from bank deposits, resulting in higher risk of digital bank runs and financial instability.

For the aforementioned reasons, the following analysis takes into account a remunerated CBDC, as it provides the clearest framework for assessing the evolving nature of central banks' role in monetary policy transmission mechanism.

2.2. Interest Rate Channel in a CBDC Economy

As underlined previously, the monetary policy works primarily through the interest rate channel, whereby, for example, a restrictive monetary policy leads to a decrease in output. As opposed to economic growth, inflation takes more time to adjust to a given monetary policy decision.

If designed correctly, CBDCs would strengthen the interest rate channel. They would compete with bank deposits, with non-banking sector selecting the option that offer the best rate of return. This would favour a direct pass-through to the non-banking sector, since central banks adjust the CBDC interest rate, without going through commercial banks. This bypassing of the banking sector could reduce transmission lags and enhance the precision of monetary interventions. Therefore, economic response would be faster as compared to the traditional model and, as more people hold money in form of CBDC, central banks would be able to influence the demand for money via the CBDC rate, which, would lead to faster and more accurate forecasts about real economic variables. This direct influence on liquidity preferences of the non-banking sector would also allow central banks to monitor shifts in money demand in real time, leading to more timely and effective policy adjustments. For instance, considering a restrictive monetary policy, central banks could raise official interest rates, as well as interest rates on CBDCs, signalling the change directly to households and firms[73]. This direct mechanism would result in higher credibility and reduce uncertainty, potentially strengthening the expectation channel of monetary policy. Moreover, by offering an interest-bearing CBDC, CBDC may crowd out deposits paying low interest rates, strengthening competition in deposit market and forcing commercial banks to align more closely to central bank policy measures.

[73] Mitali Das, Tommaso Mancini Griffoli, Fumitaka Nakamura, Julia Otten, Gabriel Soderberg, Juan Sole, and Brandon Tan (2023), *Implications of Central Bank Digital Currencies for Monetary Policy Transmission*, available at: https://www.imf.org/en/Publications/fintech-notes/Issues/2023/09/15/Implications-of-Central-Bank-Digital-Currencies-for-Monetary-Policy-Transmission-538517

At the same time, remunerated CBDCs may also present some drawbacks for the channel under analysis. The design features are a critical factor to address since they have different implications for the interest rate transmission channel (Figure 20). They would compete with bank deposits and if, for example, $i_{CBDC} > i_{bank\ deposits}$, households would prefer CBDC holdings to bank deposits, potentially leading bank deposits falling to 0 (if no limits are imposed) and banks would be "forced" to raise the deposit rates in order to attract more customers[74]. This would imply that central banks would be competing with the banking sector, and potentially having a new and even more important role in the financial system than the current one. Depending on its interest rate, a CBDC has different effects on the interest rate transmission channel. Thus, based on the conclusions drawn so far, the different implications for the interest rate channel are summarized in Figure 19.

$i_{CBDC} > i_{bank\ deposits}$	Strong competition → financial disruption
$i_{CBDC} < i_{bank\ deposits}$	Minimal competition → channel strengthening
Tiered interest rates	Managed competition → stable bank funding
Holding limits	Lower risk of digital bank runs

Figure 19: Effects of CBDC characteristics on interest rate channel

The ultimate effects in the overall interest rate mechanism, in case of a monetary restriction, would be as follows:

$$i_{OFF} + i_{CBDC} \uparrow \Rightarrow CBDC\ returns \uparrow \Rightarrow i_{bank\ deposits} \uparrow\uparrow \Rightarrow i_{bank\ loans} \uparrow\uparrow \Rightarrow I \downarrow\downarrow \Rightarrow Y \downarrow\downarrow$$

Note that since bank deposits would compete with CBDC, as i_{CBDC} increases, banks' response would be more aggressive than in the traditional case. Thus, the $i_{bank\ deposits}$ would increase more, such increase would be transmitted to clients, that would have to pay higher interest rate on loans. In other words, the cost of capital increases sharply, and, as a result, investment spending, aggregate demand and GDP would fall more than in the traditional case (Figure 20).

[74] *Ibid.*

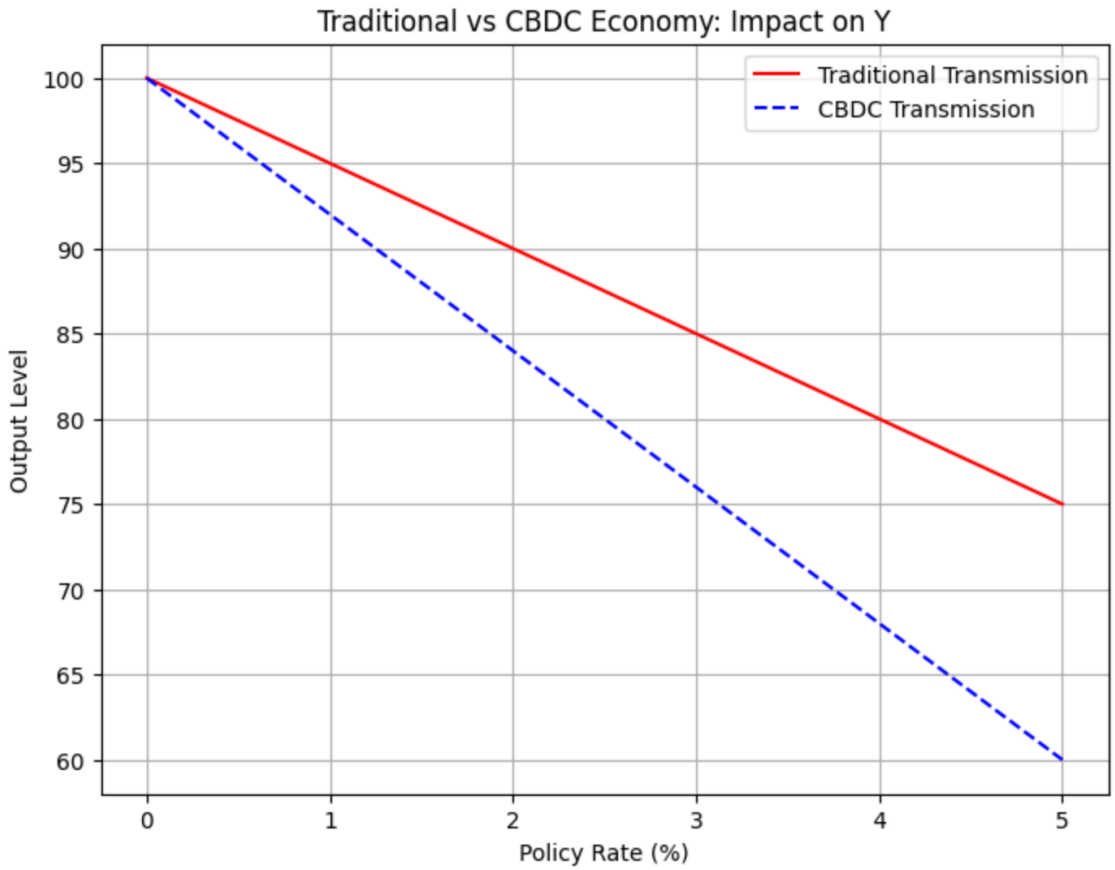

Figure 20: impact of monetary policy on Y: Traditional vs CBDC economy

2.3. Credit Channel and Bank Intermediation

Banks would compete with central banks and rates offered via CBDCs. This would cause banks to consider a more diverse source of funding since, as of today, deposits comprise most of the banks' liabilities. Indeed, a CBDC would cause bank deposits to fall (in case no limits are imposed and $i_{CBDC} > i_{bank\ deposits}$) and the effect on the banks' balance sheet may follow either of 2 scenarios.

Scenario 1: banking sector compensates the lower deposits in favour of wholesale funding (secured and unsecured borrowing). This would allow banks to keep the total value of liabilities unchanged and grant the same amount of loans. Despite this, borrowing from other financial institutions in the money market implies higher rates and higher risk exposure than traditional bank deposits. The effects on balance sheet are seen in Figure 21.

Banks Balance Sheet			
Assets		Liabilities	
Balances at central bank	=	Deposits	↓
Financial Assets	=	Secured borrowing	↑
Loans	=	Unsecured borrowing	↑
Fixed Assets	=	Total Liabilities: =	
Total Assets: =			

Figure 21: banks' balance sheet. Scenario 1

Scenario 2: deposits decrease but banks are not able to compensate for the lower amount of bank deposits. Thus meaning that the decrease in deposits is larger than the increase in wholesale funding, causing loans (assets) to fall by the difference between decrease in deposits and increase in wholesale funding. In turn, the size of the banks' balance sheet would shrink because of the lower assets and liabilities (Figure 22).

Banks Balance Sheet			
Assets		Liabilities	
Balances at central bank	=	Deposits	↓↓
Financial Assets	=	Secured borrowing	↑
Loans	↓	Unsecured borrowing	↑
Fixed Assets	=	Total Liabilities: ↓	
Total Assets: ↓			

Figure 22: banks' balance sheet. Scenario 2

More CBDCs holdings would bypass traditional banks since savers would hold deposits directly with the central bank (account-based CBDC). Particularly, during periods of economic stress, safe CBDC holdings would quicken digital bank runs: so, potentially, this might weaken the role of banks in credit creation, resulting in the so-called bank disintermediation. Credit channel might be potentially weakened if that was the case. However, as in the case of interest rate channel, it all depends on the design choices central banks opt for. Figure 23 provides a summary of different implications for credit channel.

No limits	Bank disintermediation risk ↑
Holding limits	Prevent massive digital bank runs
Tiered remuneration	Lower returns on large CBDC holdings → favour bank deposits

Figure 23: Different Implications for Credit Channel

Despite the risks analysed above that banking sector faces with its introduction, a CBDC, if designed correctly, could strengthen the bank lending channel. Indeed, since wholesale funding tends to be more sensitive to official interest rates than bank deposits, increase in wholesale funding might transmit the change in interest rates to the broader economy faster than with rates on bank deposits, which tend to be more insensitive to changes in policy rates[75].

The transmission chain in credit channel would be as follows:

$$i_{OFF} + i_{CBDC} \uparrow \Rightarrow i_{MM} \uparrow \Rightarrow Reserves \downarrow \Rightarrow Bank\ deposits \downarrow\downarrow \Rightarrow Bank\ Loans \downarrow\downarrow \Rightarrow I \downarrow\downarrow \Rightarrow Y \downarrow\downarrow$$

As shown, the "turning point" corresponds to bank deposits, as in the case of interest rate channel. With no CBDC, reserves would fall because banks demand less reserves from central banks, but, in this case, the decline would be even more severe because i_{CBDC} has a direct impact on bank deposits, creating a direct deposit outflow channel. Therefore, the fall in deposits is larger than in the traditional case and consequently, the stronger decrease would be transmitted to bank loans, investment spending and output.

[75] *Ibid.*

2.4. Exchange Rate Channel and Cross-border Transactions

Introduction of CBDCs would produce most effects in the interest rate and credit channel. The impact on the exchange rate channel may become more relevant in the future, when central banks decide to implement CBDCs to settle cross-border transactions. As of today, central banks, both those that have introduced (final or pilot version) and those that are still studying the design features of their own digital currency, are available for use only on the national territory. Adopting a CBDC may enforce national sovereignty since citizens may convert their crypto-assets holdings to CBDCs, potentially amplifying not only the exchange rate channel, but all of them[76].

Indeed, conversion of huge amounts would cause an increase in the demand for domestic currency, leading to an appreciation of it in the foreign exchange market. Upward shift of demand would lead to a new equilibrium point, with increased units of domestic currency and higher exchange rate. However, this would be the case only if no strict limits are imposed on CBDC holdings.

While the easy conversion between cryptocurrencies and CBDCs may seem advantageous, it also exposes central banks to a higher degree of sovereignty risk, since it would be more difficult to manage liquidity and capital flows from the global markets of cryptocurrencies to the domestic central bank-issued money, and vice versa.

Considering the above case (no limits imposed), the effect on the exchange rate channel would be the following:

$$i_{OFF} + i_{CBDC} \uparrow \Rightarrow i_{MM} \uparrow \Rightarrow Demand_{CBDC} \uparrow \Rightarrow Demand_{Domestic} \uparrow\uparrow \Rightarrow Supply_{Foreign} \uparrow \Rightarrow E \uparrow\uparrow$$
$$\Rightarrow NX \downarrow\downarrow \Rightarrow Y \downarrow\downarrow$$

As previously argued, a CBDC increases the demand for domestic currency but, in this case, the increase in $Demand_{domestic}$ would be greater since there is a third type of domestic money. $Supply_{Foreign}$ would remain the same (shift has the same magnitude as in the traditional case) since we assume CBDCs can be only used in the domestic economy. This is shown in Figure 24, in case there is no CBDC, the new point of equilibrium B would result in exchange rate appreciation. On the other hand, point C shows what discussed earlier: the magnitude of demand shift would be larger than in the traditional case, leading to an even stronger appreciation of domestic currency and a new equilibrium point with more units of domestic currency. In turn, the greater magnitude of such effects will be transmitted also to net exports, aggregate demand and GDP.

[76] *Ibid.*

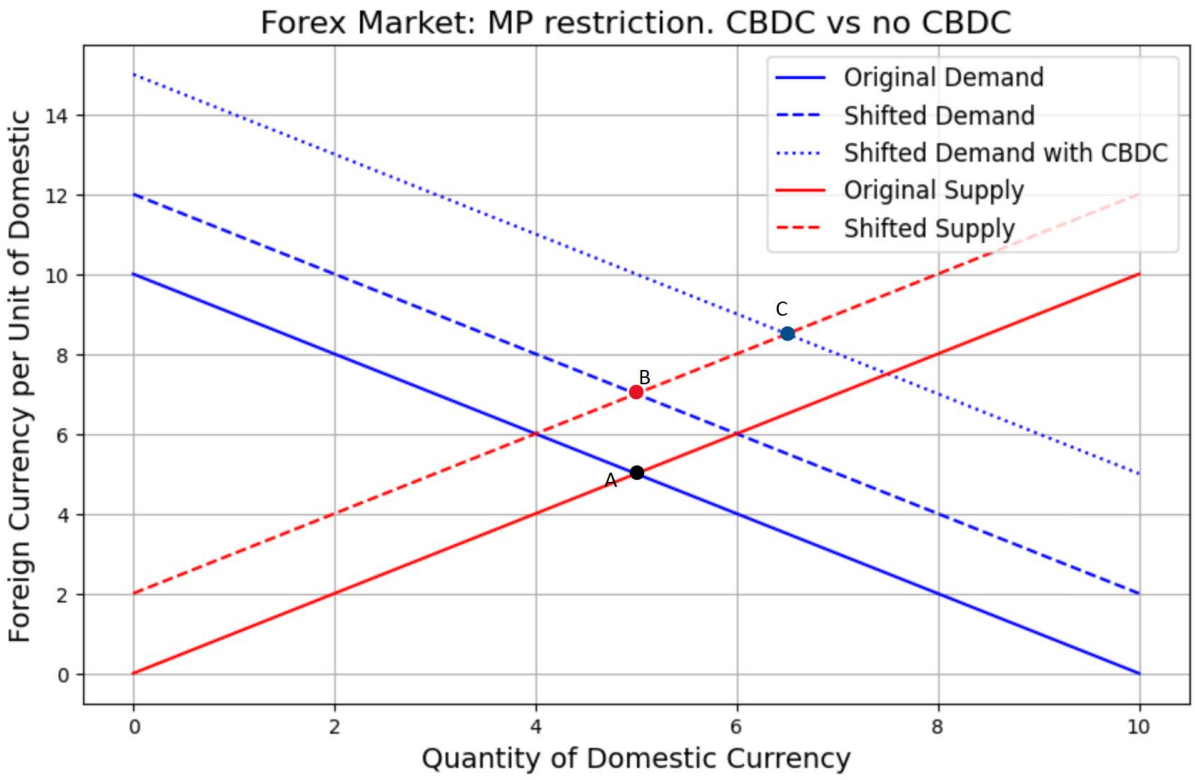

Figure 24: Forex market in Traditional vs CBDC Economy

However, the impact on the exchange rate channel may be even greater if, in the future, CBDCs would be used to settle international transactions. As discussed in Subchapter 1.5, this is what China expects and the main reason China was the first, among the major economies in the world, to introduce its own digital currency. Its clear objective is to dominate the future market for currencies, in a more digital realm[77].

[77] Rosa and Larsen, *Smart money*, p.95

2.5. Overall Impact of CBDCs on Monetary Policy Transmission

Previous subchapters have analysed the impact of a retail and remunerated CBDC introduction in each of the transmission channels. Interest rate and credit channel would be by far the most influenced ones since they both depend on the role of bank deposits. By contrast, exchange rate channel is less affected, especially due to current design features of CBDC, that allow its circulation only at national level: this channel might be subject to future developments if CBDCs were to be used also to settle cross-border transactions. As last, the least affected channel would be the asset price channel since a CBDC does not directly affect the economic factors in it, such as discount factor or expected profits. CBDCs would mainly affect liquidity conditions and bank deposits. Based on the analysis carried out so far, the impact of CBDC on the different transmission channel can be summarized as follows (Figure 25).

Transmission channel	Impact of CBDC
Interest rate channel	Strong (competition with bank deposits and direct pass-through to non-banking sector)
Credit Channel	Strong (less bank deposits, higher risk of bank disintermediation)
Exchange Rate Channel	Limited (may be stronger in the future in case of higher adoption in international trade)
Asset Price Channel	Weak (no direct impact on asset valuation)

Figure 25: Effects of CBDCs on different transmission channels

Transmission mechanism with CBDC becomes faster and stronger: changes in policy rates are passed directly from central bank to households and firms, with a reduced role for banks' intermediation. Investment spending, aggregate demand and GDP react faster and stronger to given changes in policy rates. As a consequence, bigger inflationary effects will be experienced, meaning that inflation will respond more sharply. For instance, considering the usual tightening monetary policy, increase in policy rates set by the central bank, could lead the level of prices to fall faster than in the traditional setting.

Thus, i_{CBDC} would become the fourth rate determined by central banks, in addition to those on MROs and SFs, expanding the monetary policy toolkit at their disposal.

Finally, it is important to remark that CBDCs are instruments which have to managed very carefully. Their design should be meticulously analyzed, since the several options available employ different benefits to the economy, but also leave the room for potentially severe economic downturns.

Chapter 3: Empirical Analysis of the Impact of CBDC Introduction on Inflation Rates

3.1. Research Design and Hypothesis

As seen previously, the introduction of a CBDC causes economic responses which are faster and more aggressive than in the traditional case. The third chapter focuses on the ultimate impact of CBDCs to the economy, in particular to inflation rates.

Only countries in which CBDCs have been officially launched (no pilot versions) are included in this study. According to the Atlantic Council, these countries are: Nigeria, Jamaica and the Bahamas[78].

The analysis considers inflation rates, from 2005 to 2023, for the relevant countries. The research design aims at estimating the potential impact of CBDC introduction on inflation rates. The decision to adopt a time-series regression model comes from the need to isolate the effects of CBDC introduction, while taking into account inflation persistence. A dummy variable is created to indicate the presence of a CBDC. Considering a 95% confidence interval, the hypothesis to be tested is whether CBDC have had an ultimate impact on the inflation rates experienced by the countries under analysis. Model used will be the following:

$$\pi_t = \beta_0 + \beta_1 \pi_{t-1} + \beta_2 \, CBDC_t + \epsilon_t$$

Where

π_t = inflation rate at time t

β_0 = intercept term

β_1 = lagged inflation effect

π_{t-1} = inflation rate at time t-1

β_2 = change in inflation after CBDC introduction

$CBDC_t$ = dummy variable. 1 if CBDC was introduced at time t; 0 otherwise.

ϵ_t = error-term at time t

[78] CBDC tracker, available at: https://www.atlanticcouncil.org/cbdctracker/

And the hypotheses to be tested:

$$H_0 : \beta_2 = 0$$

$$H_1 : \beta_2 \neq 0$$

The inclusion of lagged inflation controls for path dependence and autocorrelation common in inflation data. The regression was run separately for each country to account for national differences in inflation dynamics and contextual effects of CBDC introduction. Note that relationship between CBDCs and inflation is influenced by a wide range of factors. While the analysis aims to isolate the effects of CBDC introduction on inflation rates in the various countries, it is crucial to take into account that other macroeconomic variables (e.g. global economic conditions, fiscal policies, etc…) may also play a significant role. The analysis adopts a straightforward econometric model to identify any correlation between CBDC introduction and economic stability, but results should be interpreted with caution and in the context of broader economic dynamics.

3.2. Nigeria case

The following Table was created collecting data from World Bank regarding the inflation rates experienced by Nigeria over the years, from 2005 to 2023.

Year	Inflation Rate	Lagged Inflation Rate	CBDC Dummy
2005	17.86%	15%	0
2006	8.23%	17.86%	0
2007	5.39%	8.23%	0
2008	11.58%	5.39%	0
2009	12.54%	11.58%	0
2010	13.74%	12.54%	0
2011	10.83%	13.74%	0
2012	12.22%	10.83%	0
2013	8.50%	12.22%	0
2014	8.05%	8.50%	0
2015	9.01%	8.05%	0
2016	15.7%	9.01%	0
2017	16.5%	15.7%	0
2018	12.1%	16.5%	0

2019	11.4%	12.1%	0
2020	13.25%	11.4%	0
2021	16.95%	13.25%	1
2022	18.85%	16.95%	1
2023	24.66%	18.85%	1

Figure 26: data for Nigeria

As shown the inflation rate in Nigeria has been highly volatile driven by domestic structural weaknesses and external economic shocks. Inflation declined sharply from 17.86%, in 2005, to 5.39%, in 2007, guided by improved monetary policy implementation and relative stability in oil markets. However, inflation increased substantially after 2008 Global Financial Crisis, reaching 13.74% by 2010 due to oil price volatility, currency depreciation and expansionary fiscal policies[79]. From 2011 to 2014, inflation remained relatively stable, supported by high oil revenues and a relatively tight monetary stance[80]. The trend reversed between 2015 and 2017, when inflation reached 16.5% due to oil price collapse, recessions and depreciation of the domestic currency. Although it declined slightly in 2018 and 2019, it increased again in 2020, after Covid-19 Pandemic, which disrupted supply chains and led to greater fiscal and monetary expansion. Inflation then reached 18.85% in 2022 and increased even more in 2023, to 25%, approximately[81].

β_0 $(intercept)$	0.073
β_1	0.369
β_2	0.068
Standard error (β_2)	0.023
p-value	0.010
R-squared	0.544
Confidence Interval	[0.018; 0.118]

[79] International Monetary Fund (2011), *Nigeria: Staff Report for the 2010 Article IV Consultation*, available at: https://www.imf.org/external/pubs/ft/scr/2011/cr1157.pdf

[80] Central Bank of Nigeria (2014), *Monetary Policy Review*, available at: https://www.cbn.gov.ng/out/2015/mpd/mpr%20february%202014.pdf

[81] World Bank (2020), *Nigeria Development Update,* available at: https://thedocs.worldbank.org/en/doc/d1daaa57ec66a5105378ee54c1460d3d-0360012020/original/Nigeria-Development-Update-Presentation-June-2020.pdf

Figure 27: Nigeria results

It is worth noticing β_2 coefficient, which measures how much inflation changed after CBDC introduction, is 6.8%. The key point of this analysis is the p-value, which is 0.01, below the 0.05 threshold for statistical significance. This allows us to reject the null hypothesis $H_0 : \beta_2 = 0$ and conclude that the results obtained are statistically significant. This conclusion is also supported by the 95% confidence interval for β_2 , indicating that the introduction of CBDC is associated with an inflation increase between 1.8% and 11.8% with 95% confidence. The model also includes a lagged inflation coefficient of 0.369, suggesting that inflation is moderately persistent. Approximately 37% of the π_{t-1} carries over into the current period, highlighting the importance of taking into account inflation dynamics over time. As last, R-squared indicates that this model explain 54.4% of the variation in inflation rates, suggesting a very strong correlation between CBDC and inflation rate.

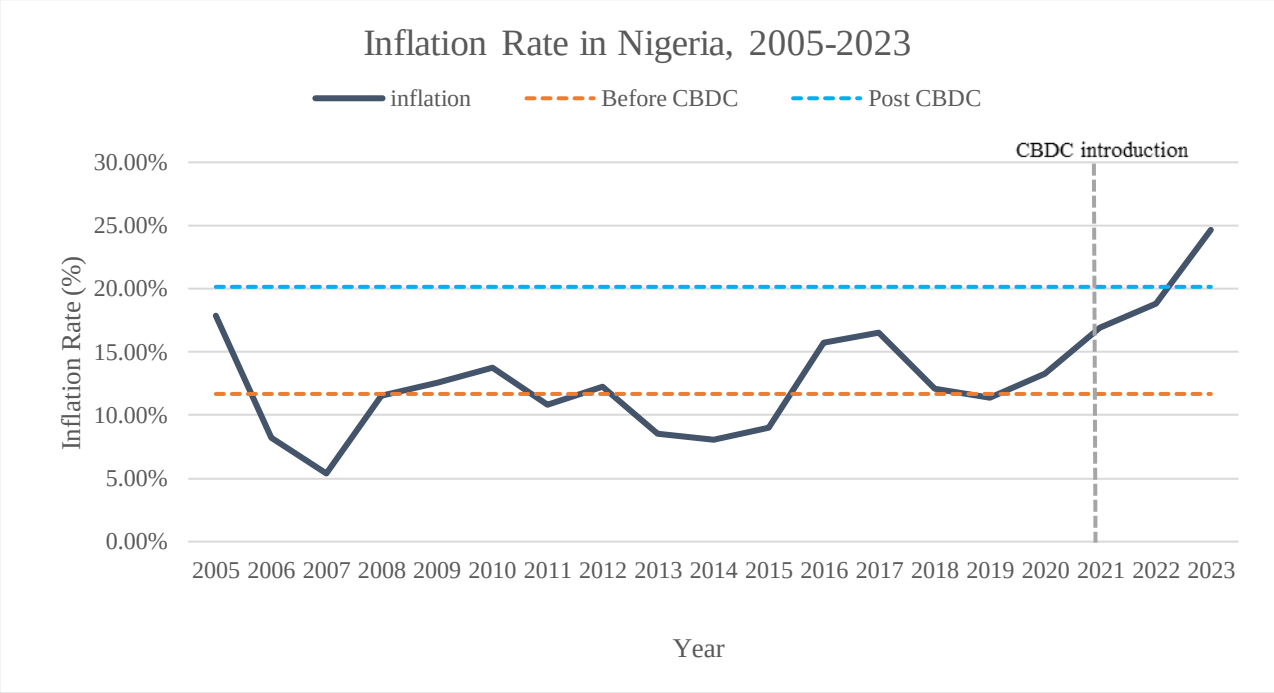

Figure 28: Inflation Rate in Nigeria

It is also important to analyse the relationship between residuals and predicted inflation. Figure 29 shows a scatterplot illustrating such relationship. Residuals are generally distributed symmetrically around 0, indicating model does not show systemic bias and that linear specification is appropriate. However, there is a slight spread in residuals for higher predicted inflation rates, potentially indicating

weak heteroskedasticity. Overall, the scatterplot suggest a reasonably good model fit, with no clear signs of non-linearity.

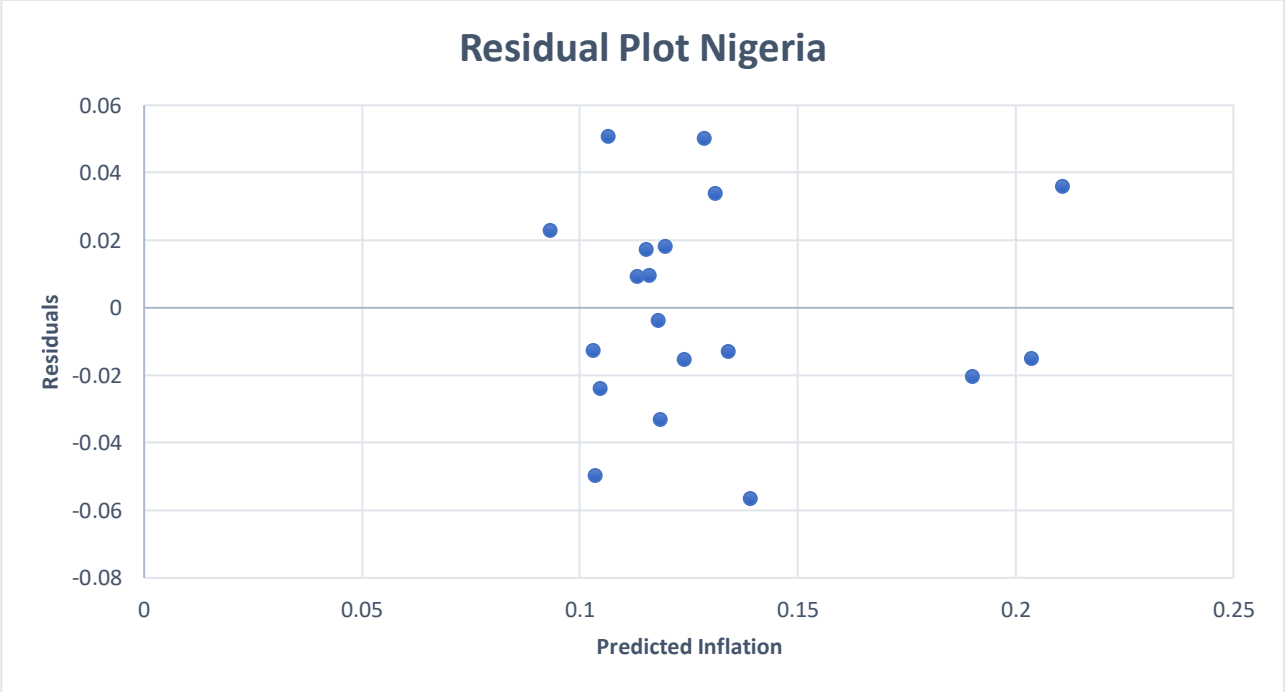

Figure 29: Residual Plot: Predicted Inflation vs Residuals for Nigeria

3.3. Jamaica case

The following Table was created collecting data from World Bank regarding the inflation rates experienced by Jamaica over the years, from 2005 to 2023.

Year	Inflation Rate	Lagged Inflation	CBDC Dummy
2005	15.05%	13.55%	0
2006	8.56%	15.05%	0
2007	9.24%	8.56%	0
2008	22.02%	9.24%	0
2009	9.59%	22.02%	0
2010	12.61%	9.59%	0
2011	7.56%	12.61%	0
2012	6.87%	7.56%	0
2013	9.34%	6.87%	0
2014	8.27%	9.34%	0

2015	3.69%	8.27%	0
2016	2.35%	3.69%	0
2017	4.38%	2.35%	0
2018	3.74%	4.38%	0
2019	3.91%	3.74%	0
2020	5.23%	3.91%	0
2021	5.86%	5.23%	0
2022	10.35%	5.86%	1
2023	6.47%	10.35%	1

Figure 30: data for Jamaica

Between 2005 and 2023, Jamaica's inflation has been highly volatile. In 2005, inflation was 15.05%, but dropped in the following years before rising drastically to 22.02% in 2008 due to global food and fuel crisis. The trend then remained relatively stable until 2014, supported by restrictive monetary policy and IMF-supported fiscal policies[82]. A period of low and stable inflation followed from 2015 to 2019, reaching a historic low of 2.35% in 2016, reflecting the improved macroeconomic management and a shift to inflation-targeting. Later, inflation increased moderately during the Covid-19 period, and was followed by a sharp increase in 2022 (year of CBDC introduction) due to global commodity prices shocks[83].

$\beta_0\ (intercept)$	0.046
β_1	0.413
β_2	0.005
Standard error (β_2)	0.034
p-value	0.889
R-squared	0.181

[82] International Monetary Fund (2022), *Jamaica: 2022 Article IV Consultation-Press Release; Staff Report and Staff Statement.*

[83] World Bank (2022), *JAMAICA BOOSTING RECOVERY AND SUSTAINABLE ECONOMIC GROWTH SYSTEMATIC COUNTRY DIAGNOSTIC*, available at: https://documents1.worldbank.org/curated/en/099035010312218535/pdf/BOSIB09ab23d2d0710955702715362c5e50.pdf

Confidence Interval	[-0.066; 0.076]

Figure 31: Jamaica results

In this case, the estimated coefficient of β_2 indicates that, after CBDC introduction in 2022, the average inflation increased by 0.5%. However, this effect is not statistically significant, as indicated by a p-value of 0.889, which is much larger than 0.05 threshold. Consequently, we fail to reject the null hypothesis $H_0: \beta_2 = 0$. The 95% confidence interval for β_2 also includes 0, strengthening the conclusion. The estimate of 0.413 for β_1 coefficient suggests that inflation in Jamaica shows a moderate degree of persistence: approximately 41% of π_{t-1} carries over into time t. Additionally, model's R-squared value of 18.1% indicates that the regression model explains only a small portion of the variation of inflation rate in Jamaica, implying that other macroeconomic factors are likely to have been more influential.

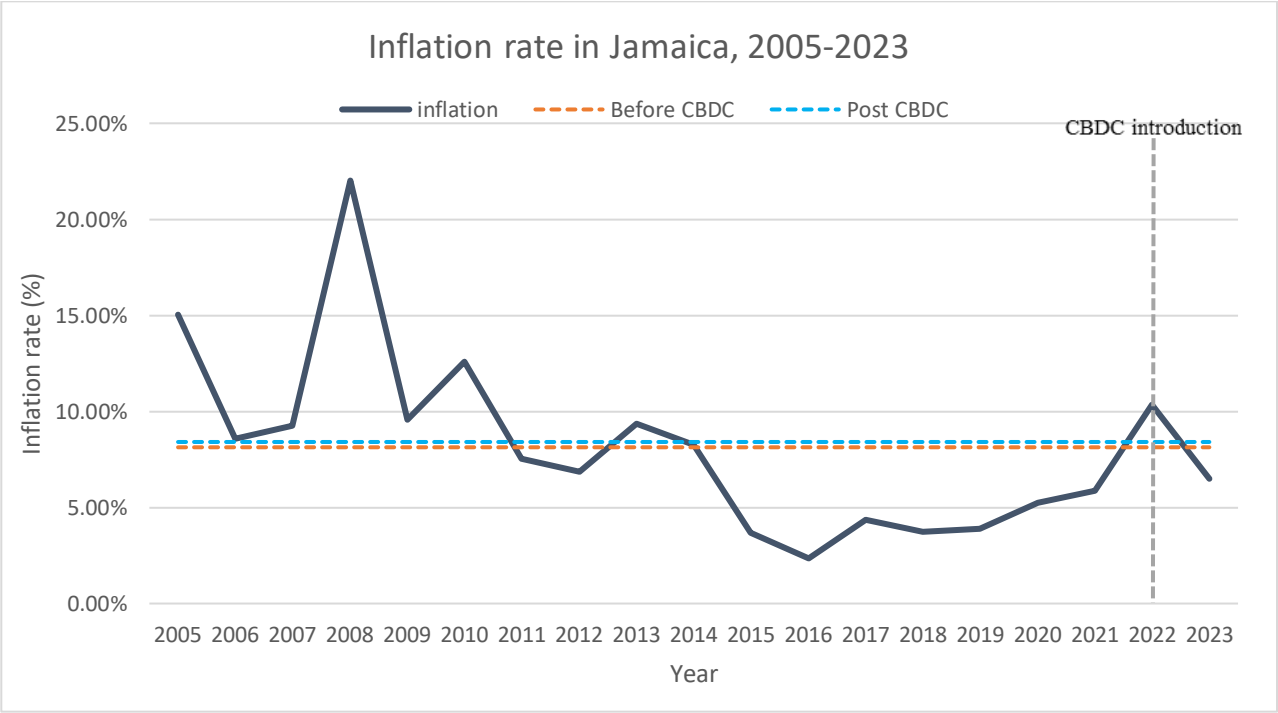

Figure 32: Inflation Rate in Jamaica

As regards residual distribution, the plot shows a generally random and symmetric distribution around 0, supporting the linearity assumption and suggesting that model is reasonably well-specified. However, there is one notable positive residual, 0.14 approximately, which occurred in 2008, coinciding with the Global Financial Crisis, during which Jamaica experienced a significant inflation increase due to sharp increases in international commodity prices, i.e. energy. This suggests the

predicted inflation was substantially lower than the experienced one, because of the external shocks not captured by the model.

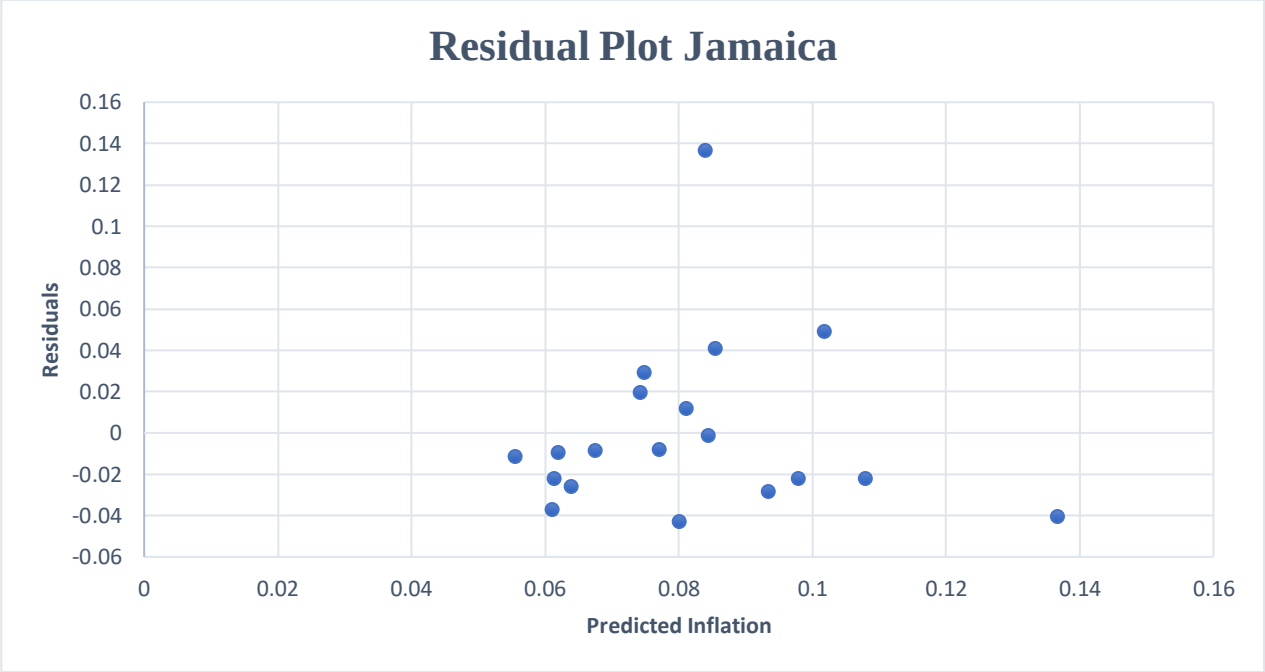

Figure 33: Residual Plot: Predicted Inflation vs Residuals for Jamaica

3.4. Bahamas case

The following Table was created collecting data from World Bank regarding the inflation rates experienced by Bahamas over the years, from 2005 to 2023.

Year	Inflation Rate	Lagged Inflation	CBDC Dummy
2005	1.59%	0.98%	0
2006	2.39%	1.59%	0
2007	2.49%	2.39%	0
2008	4.49%	2.49%	0
2009	2.06%	4.49%	0
2010	1.34%	2.06%	0
2011	3.2%	1.34%	0
2012	1.97%	3.2%	0
2013	0.72%	1.97%	0
2014	1.51%	0.72%	0
2015	1.86%	1.51%	0

2016	-0.35%	1.86%	0
2017	1.52%	-0.35%	0
2018	2.27%	1.52%	0
2019	2.49%	2.27%	0
2020	0.04%	2.49%	1
2021	2.9%	0.04%	1
2022	5.61%	2.9%	1
2023	3.05%	5.61%	1

Figure 34: data for Bahamas

For the period under analysis, the Bahamas inflation remained relatively low and stable, reflecting the country's fixed exchange rate regime, an economy which heavily relies on imports and a cautious monetary stance. From 2005 to 2015, inflation fluctuated within a narrow range, approximately between 1% and 3.2% with a temporary increase in 2008, coinciding with the Global Financial Crisis and the rising price of commodities. The country also experienced a period of deflation, in 2016, driven by weak domestic demand and low global commodity prices[84]. Following this period, inflation remained relatively stable at an average rate slightly above 2%, until the Covid-19 Pandemic which coincides with a drop in inflation to 0.04% in 2020, bringing economic contraction but a minimum inflationary impact because of reduced consumption and lower tourism revenues. However, by 2022, inflation increased significantly to 5.61%, driven by global supply chain disruptions and higher shipping costs. By 2023, inflation declined to 3.05%.

$\beta_0\ (intercept)$	0.017
β_1	0.142
β_2	0.008
Standard error (β_2)	0.008
p-value	0.341
R-squared	0.097

[84] Central Bank of the Bahamas (2017), *Annual Report 2016*, available at: https://www.centralbankbahamas.com/viewPDF/documents/2019-06-24-05-34-19-Annual-Report-2016.pdf

Confidence Interval	[-0.009; 0.025]

Figure 35: Bahamas results

Launching the new digital currency resulted in an average inflation increase of 0.8%. However, this estimated effect is not statistically significant, as indicated by the p-value of 0.341, much larger than 0.05, leading us to fail to reject null hypothesis $H_0 : \beta_2 = 0$. The 95% confidence interval for β_2 includes 0, further confirming that the effect of CBDC introduction on inflation is not statistically significant. The coefficient for lagged inflation of 0.142 suggests a relatively low level of inflation persistence, meaning that π_{t-1} is not significantly influential on current inflation rates. Moreover, the R-squared value of only 9.7% indicates that the model explains only a small portion of the variation in inflation, suggesting, as in the case of Jamaica, that other macroeconomic and structural factors had more influence on the inflation dynamics of the country under analysis.

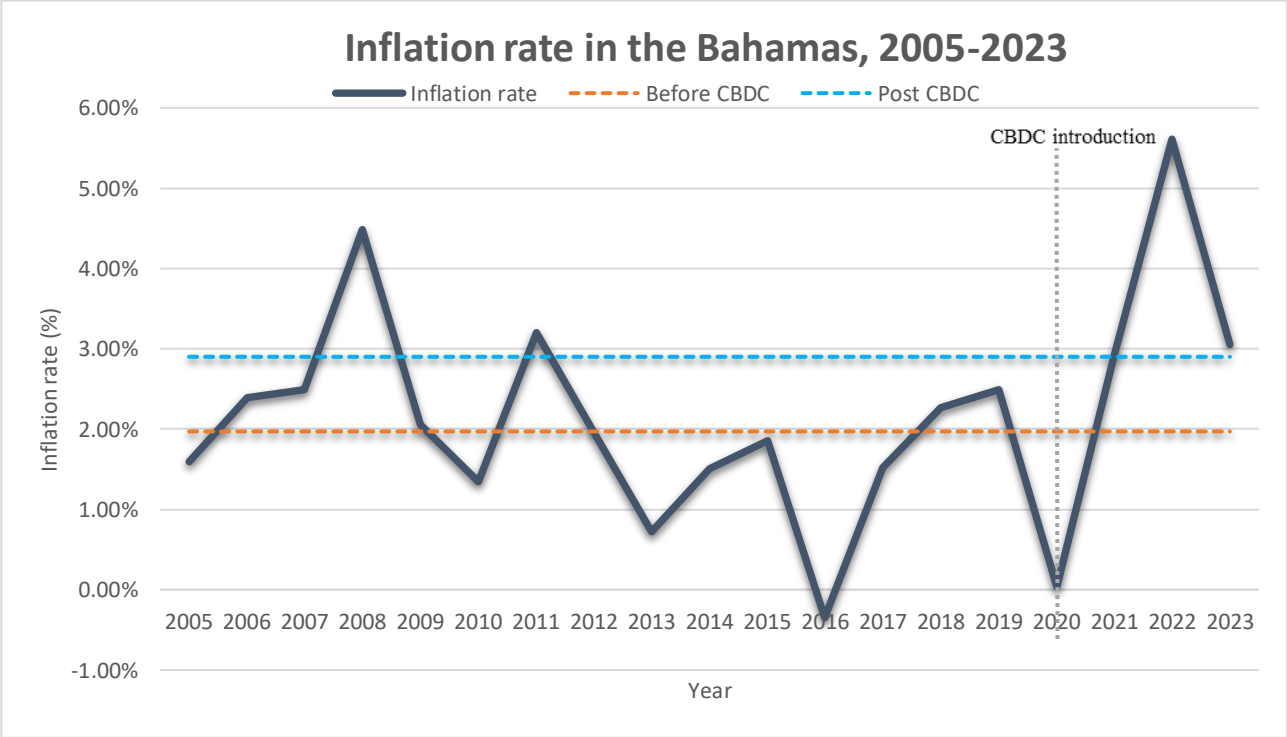

Figure 36: Inflation Rate in the Bahamas

The Residual Plot for the case of Bahamas indicates that the regression model performs adequately, with residuals distributed around 0 and showing no systemic pattern. The variance of residuals appears to be stable across the prediction range, supporting the assumption of homoskedasticity. Thus, the plot suggests that the model's linear specification is appropriate, and the prediction errors are generally low, despite few outliers.

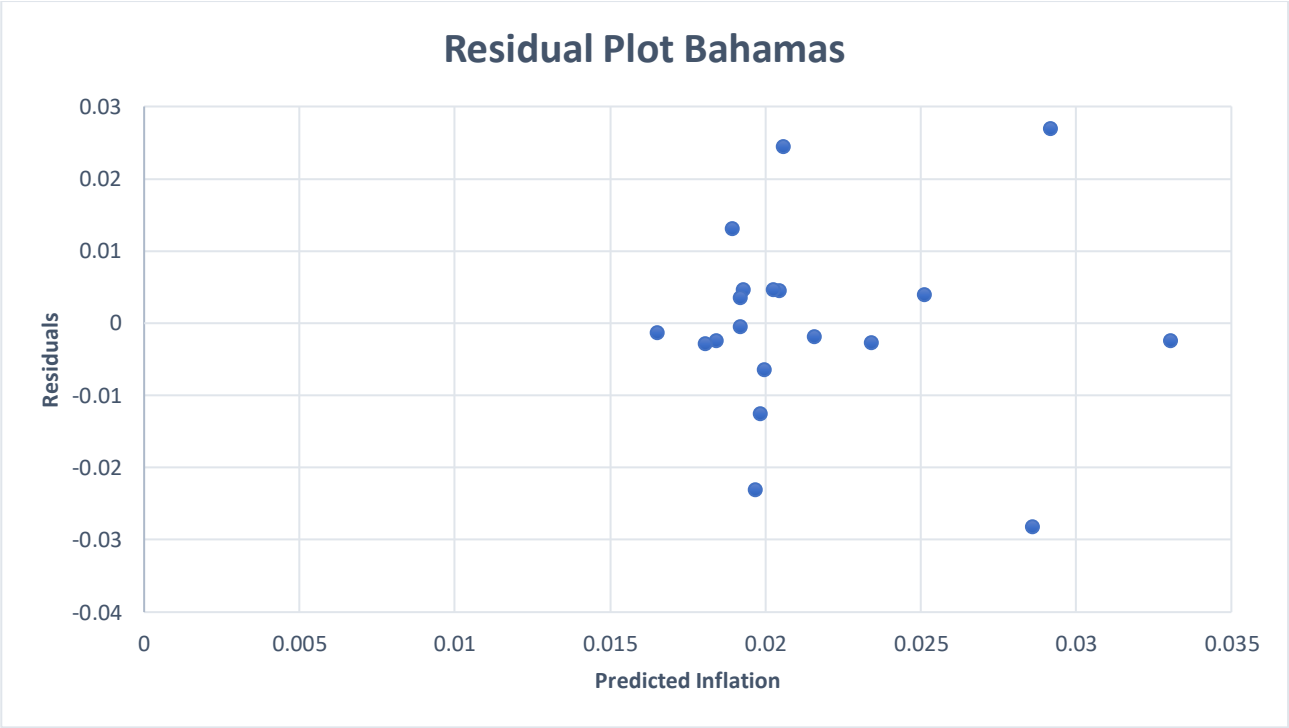

Figure 37: Residual Plot: Predicted Inflation vs Residuals for the Bahamas

3.5. Results

The study undertook in this final chapter aimed at measuring the impact of CBDC on the relevant domestic economies. Results indicate that CBDC influence on inflation varies by country.

The Nigerian case suggested that CBDC introduction may have contributed to changes in inflation rates (with 95% confidence).

However, for Jamaica and the Bahamas, the analysis did not reach statistical significance, suggesting that other factors might have been more influential. These findings highlight the importance of considering economic conditions of specific countries when assessing the effects of CBDCs.

Further research could better explore these relationships deeper and over longer time horizons to better understand the correlation between CBDC and economic stability.

Moreover, CBDCs have been introduced in recent years, meaning that data is still limited, to conduct a comprehensive study on the relationship between CBDCs and inflation rates.

Conclusion

Thesis has looked at different aspects of money and its evolution over time. CBDCs would represent a new phase for monetary history. In particular, depending on their design features, they might have severe effects on the global economy. Currently, they operate only at national level, meaning that their impact is limited in the forex market and international trade context.

Only Nigeria, Jamaica and Bahamas have introduced their ultimate version of CBDC and the regression model used has discovered that the null hypothesis $H_0 : \beta_2 = 0$ could be rejected only for Nigerian case, with 95% confidence.

CBDCs represent the next step of evolution in the monetary system. They are potentially a powerful tool that can be used by central banks, especially if we consider remunerated CBDCs. At the same time, they present very severe drawbacks if not designed carefully, such as increased volatility in inflation rates and liquidity conditions.

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