Central Bank Digital Currency: Case of Armenia

CBA Working Paper 2023/8

by Erik Vardanyan*

June 26, 2023

* The views expressed in this paper are those of the author(s) and do not necessarily represent the views or policies of the Central Bank of Armenia.

Central Bank Digital Currency: Case of Armenia

Erik Vardanyan*

June 26, 2023

Abstract

The introduction of Central Bank Digital Currency (CBDC) as a new form of money has fueled intensive discussions among economists. The overwhelming majority of central banks around the globe are researching the expediency of introducing CBDC into their economies. Motivations for CBDC issuance vary across central banks, depending on countries' characteristics. Along these lines, this research aims to investigate the suitability of CBDC issuance in Armenia. For that purpose, a series of exercises were conducted, including an analysis of international CBDC developments, an investigation of the local payment landscape, and surveys of private financial institutions to understand their views on payment infrastructure development in Armenia. An agent-based model was developed to simulate the potential adoption of CBDC in Armenia. A consideration of all outcomes yielded the conclusion that, based on the current level of financial market development in Armenia, limited use cases for retail CBDC have been identified thus far. However, the various technological innovations considered for CBDC hold potential for a wide range of financial market enhancements in specific areas.

JEL: C15, C63, E42
Keywords: CBDC, payment infrastructure, financial institution, agent-based model

Acknowledgement: I would like to thank my colleagues at the Central Bank of Armenia for their feedback and support throughout the research process. Their contributions have been invaluable in helping to conduct a survey and collect necessary data for the research.

* The views expressed in this paper are those of the author(s) and do not necessarily represent the views or policies of the Central Bank of Armenia.

Contents

1 Introduction

Most of the world's central banks are currently investigating the feasibility of issuing central bank digital currency (CBDC) in their jurisdictions. A survey conducted by the Bank for International Settlements [A. Kosse and I. Mattei, 2022] reveals that 86% of central banks are involved in CBDC-related research activities. The majority of the projects are at the research or proof of concept stage. Few central banks (e.g., Bahamas, Jamaica, Eastern Caribbean Central Bank [IMF, 2022]) have launched their own digital currencies so far. The Central Bank of Armenia is not an exception in the process and is undertaking similar research initiatives to shed light on the necessity of CBDC issuance in Armenia. Since it is hard to disentangle CBDC from payment infrastructure, the Central Bank of Armenia is studying the necessity of CBDC issuance within a broader agenda of payment infrastructure modernization. Prioritization of the research on CBDC has been reflected in the Central Bank's 2021 Strategy[1], which compels the bank to form a position on the necessity of issuing its own digital currency. The research described in this paper is the first step in that direction.

The main objective of this research is to reveal use cases of CBDC for the Armenian economy, as well as to evaluate possible impacts of CBDC introduction on the payment system. For that aim, both local and international developments were analyzed. During 2022, a series of discussions took place between a central bank dedicated working group and representatives of banking and payment institutions of Armenia. Participants shared their views on the future of the payment system of the country and challenges for development. Since the concept of CBDC is new and contains profound uncertainty, its possible design, architecture, technology, and implications were not directly discussed with private sector representatives. Instead, current payment infrastructure development bottlenecks were reviewed, which at later stages enabled the working group to correlate the identified challenges with potential CBDC designs in order to assess their effectiveness and suitability. Thus, according to received inputs, the current payment system has experienced dynamic transformation during the last decades. However, current economic relationships demand more flexible, innovative and functional payment solutions. The financial sector representatives emphasized a series of development challenges currently faced by the system, with the most profound ones being obsolete infrastructure, lack of standardized data management procedures and limited interoperability between systems.

The second part of the paper is devoted to an exercise of a potential CBDC adoption simulation. An agent-based model is developed to simulate different scenarios of CBDC adoption and analyze the implications of each for the payment system of Armenia. The simulations reveal that, in the case of strong demand for CBDC (the cases where CBDC has solid use cases and solves issues of payment infrastructure where conventional means are insufficient), economic agents substitute commercial bank money and cash with CBDC and the digital currency becomes the main payment instrument. However, if CBDC is introduced as just an alternative payment mean without proper use cases, at most it replaces some portion of commercial bank money with little impact on cash circulation. In such a case, though cash usage declines in the short run after CBDC introduction, cash returns to its pre-CBDC level in the long run.

[1] https://www.cba.am/en/sitepages/acstrategy.aspx

Overall, with task-centered architecture, a CBDC could undoubtedly address some of the current bottlenecks of the payment infrastructure. However, given the nature of raised issues and the availability of alternative solutions, the opportunity costs and economic impact of such intervention are unknown. Thus, at this stage, solid use cases for CBDC as a new payment mean have not been found. However, given rapid technological development in the information technologies, innovations that have the potential to effectively address specific aspects of the system in question should continuously be monitored.

2 International and Local Developments

In today's fast-paced world, payment systems frequently fall short in terms of efficiency, speed, affordability, convenience, and security. With consumers' sentiments constantly evolving and markets undergoing rapid digitalization, the payment infrastructure is facing mounting challenges. Existing solutions in the payment system often lack convenience and appear outdated. A vivid illustration of current payment limitations can be found in the realm of cross-border transactions. In this context, transfers often require several days to reach the recipient, while imposing a hefty 6.3% cost on the sender [WB, 2021]. Those drawbacks have triggered private initiatives to develop alternative solutions like decentralized finance, cryptocurrencies, stablecoins etc. These technologies are already competing with traditional finance, providing suitable services for a large share of consumers.

In addition to their applications in finance, new digital technologies are finding utility in various sectors such as governance, law, healthcare, tourism, and more. State authorities also try to adopt new digital technologies to increase efficiency of bureaucratic processes. Central banks are looking at these ideas too. The emergence of cryptocurrencies, particularly stablecoins, has sparked discussions among central bankers regarding the need for CBDC issuance [Zhang and Huang, 2022]. The former are decentralized network systems operating alongside the traditional payment infrastructure, and they often exhibit functions of money.

Given that the relevant literature may give different definitions of CBDC and to avoid misinterpretations, first let us state the definition of CBDC[2] applied in this research. Thus, CBDC is the direct liability of a central bank, and it is the digital representation of existing fiat currency of a central bank. The public often mixes the concept of CBDC with cryptocurrencies, like Bitcoin, Ethereum, Solana, etc. Despite some possible similarities, these two concepts are different by nature. Unlike CBDCs, cryptocurrencies are issued by private entities and are not regulated by any state authority. Moreover, cryptocurrencies, despite the name, are rarely used as payment means; they are, rather, positioned as investment assets [IMF, 2023]. In sum, a CBDC is not a new currency but a digital version of existing cash money, and they are always 1:1 mutually convertible.

[2]Generally, the literature distinguishes two types of CBDC: retail and wholesale. Wholesale CBDC is central bank money accessible to financial institutions and used for settlement between them, while retail or general-purpose CBDC is central bank money available to a wide range of economic agents (consumers, firms, financial institutions, government, etc.) and used by them in their everyday transactions. Throughout this paper, the term "CBDC" is used with reference to the retail version, unless otherwise stated.

Another source of misconception is a lack of understanding of the underlying technology applied in digital assets. Most private cryptocurrencies are distributed ledger technology (DLT) based, while this is not necessarily the case for CBDCs. In fact, only 20% of retail CBDC projects explicitly claim application of DLT technologies[3]. Thus, some known CBDC projects such as OpenCBDC (Project Hamilton) in the US [Lovejoy et al., 2022] and Digital Pound in the UK [BoE, 2023b] do not employ DLT technologies. In general, DLT enables the network to operate without relying on a centralized regulatory authority for system control and transaction validation, the feature which lies at the heart of decentralized finance. By utilizing a decentralized model, cryptocurrencies aim to address situations where trust may be lacking among participants. On the other hand, CBDCs, irrespective of chosen architecture, are ultimately centralized systems with central banks being the sole issuer and ultimate controller of the digital currency. DLT technologies, such as blockchain, possess several useful traits making them appealing for digital currencies. Those are security, transparency, immutability etc. The permissioned blockchain[4] could be considered the most suitable for CBDC development; however, these technologies still have issues with interoperability, scalability, and speed, which limits their widespread consideration at central banks.

Apparently, the emergence of stablecoins can be considered the biggest trigger of CBDC initiatives. As a specific version of private cryptocurrencies, stablecoins are more suitable as means of payment, widening their usage by consumers. For instance, they are often used for cross-border transactions, where the solutions offered by traditional infrastructure are burdensome and costly. As could be inferred from the name, the main feature of stablecoins is the relative stability of their price. Private entities issuing stablecoins try to ensure coin value stability by backing them with fiat money, commodity or financial instruments. Issuers of stablecoins declare a 1:1 exchange rate with one of the reserve currencies (usually the US Dollar, but there are a few associated with the Euro, the Swiss Franc, etc.) and try to ensure this rate with market operations. Tether (USDT), USD Coin, and Binance USD are examples of well-known stablecoins. Despite the pledge, not all stablecoins' pegs are credible and not always so. For instance, the TerraUSD stablecoin decoupled from its 1 USD peg and lost 98% of its value in May 2022 when the market expressed concerns about the validity of the stablecoin's underlying economic model.

It is important to note that, currently, three forms of money are present in the market. Those are 1) cash money, 2) commercial bank reserves held in central bank accounts and 3) commercial bank deposits. Here, only the first two are central banks' money, while bank deposits are commercial banks' money and do not represent liabilities of a central bank. In fact, most of the money available to the public is in non-cash commercial bank money. As of the start of 2023, cash comprises only 40% of money in the economy of Armenia, while in developed countries it is 5%-10%. By withdrawing cash from their bank accounts, consumers seamlessly convert their commercial bank

[3] https://cbdctracker.org/

[4] There are permissionless and permissioned blockchains. In both cases, the ledger is recorded and kept at all entities of the network, enabling accuracy of data and cryptographic security. Permissionless blockchains allow any entity to validate new transactions and add them to the main chain, while in the permissioned case only a limited number of entities allow validation. Presumably, a central bank (and/or central bank dedicated entities) will have the authority of transaction validation in a CBDC system.

money into the central bank one. Consequently, there is no non-cash central bank money available to consumers, and CBDC is called to fill this gap. The absence of credit risk attached to CBDC, unlike with commercial bank money, is considered one of the advantages of CBDC.

Motivations for CBDC issuance vary across economies. Depending on the level of payment system development and local economic priorities, motivations for CBDC research engagement are different. In developed countries, CBDC project undertakings are often motivated by payment infrastructure development and monetary and financial stability policy enhancement, while for developing nations the motivation is financial inclusion and payment infrastructure development [A. Kosse and I. Mattei, 2022]. In general, several advantages are associated with CBDCs [BoE, 2020]. Some of them are briefly listed below:

- Financial inclusion enhancement
- Payment infrastructure advancement and cross-border payment facilitation
- Capacity building and knowledge accumulation
- Development of a domestic alternative to foreign digital currencies: fight against digital dollarization
- Enhancement of monetary policy transition mechanism
- Facilitation of transition to cashless society; reduction of costs associated with cash circulation
- Shadow economy reduction
- Programmability of money

With benefits come costs and risks. Some of those are listed below:

- CBDC can disrupt commercial banks' intermediation (by substituting deposit accounts at commercial banks with CBDC accounts, consumers will decrease lending resources in the economy) and may lead to bank deleveraging (limiting their money creation role in an economy and making loans more expensive for consumers).
- CBDC can increase financial stability risks, as CBDCs will always be procyclical due to risk differentiation. Thus, with CBDCs, financial cycles may amplify.
- Programmability of money can limit CBDC convenience for consumers and harm credibility of the system.
- There is a risk that, by issuing CBDC, central banks may disrupt the payment service provision market by indirectly competing with private service providers
- Privacy and security risks

As motivations and objectives of CBDC differ across jurisdictions, the types and extent of cost-benefit ratio vary as well. However, one thing is apparent: the introduction of CBDC to an economy will be associated with a trade-off. As such, before introducing CBDC, authorities should thoroughly assess the expected benefits of CBDC and the amount of associated risk they are willing to bear. By now, almost all major central banks are engaged in CBDC research projects, but few have committed to launching one in the near future[5] [DNB, 2017]. Hence, the continuous endeavors of central banks can be characterized as enhancement of banks' expertise in this emerging field of knowledge and proactive development of contingency plans for the potential issuance of CBDC, if the need arises. Such efforts can be seen, for instance, in the UK [BoE, 2023a] and in Canada [BoC, 2020].

Payment infrastructure advancement, capacity building and financial inclusion could be identified as the most suitable motivations for CBDC issuance for the Armenian economy, so let's discuss them in more detail.

2.1 Payment Infrastructure Development

Evidently, the one motivation uniting all CBDC projects in any jurisdiction is payment system development. Currently, the high pace of digitalization forces central banks to think about the future of payment systems and architecture needed to meet new demand. In many economies, the payment infrastructure consists of legacy systems that have limited capabilities for transformation. Thus, in many countries CBDC research initiatives are good reasons to revisit domestic payment infrastructure.

One illustration of the inconvenience of current payment systems is cross-border transactions. It can often take several days for funds to become accessible to the recipient, as money traverses multiple correspondent bank accounts across different jurisdictions. Moreover, those transfers can come at a significant cost for senders [BIS, 2021]. For instance, the international average cost of remittance sending is about 6.3%.[6] This is quite a high number considering the present-day availability of a variety of technological solutions [Bindseil and Pantelopoulos, 2022]. Several CBDC initiatives mention facilitation of cross-border payments as a motivation driving their research and development efforts. Nevertheless, a lot of ground needs to be covered in this dimension since issues with cross-border CBDC interoperability, international standardization and cybersecurity have not yet been resolved.

Generally, CBDCs can be distinguished into two types by architecture: direct and indirect (two-tier system). Under the direct architecture, central banks themselves issue, distribute and provide CBDC-related services to the public, while in the case of the two-tier type, central banks only issue and redeem CBDC and licensed entities (e.g., commercial banks, payment service providers, fintech etc.) are distributors and service providers. Among central banks, the indirect architecture is widely regarded as more suitable for the issuance of CBDC, primarily due to its associated lower disruption to the banking system. Moreover, by their very nature private entities are more specialized for consumer service provision than central banks [Auer and Böhme, 2020]. The indirect model has more potential to spur innovation. The CBDC infrastructure

[5] https://www.centralbanking.com/fintech/cbdc/7957236/sweden-does-not-yet-need-cbdc-inquiry-finds/

[6] https://remittanceprices.worldbank.org/

may develop innovative solutions for the market. Here, CBDC can be viewed as a new infrastructure which makes central bank money more accessible for the general public. Moreover, current domestic payment infrastructures are often fragmented and have limited interoperability. In this regard, CBDC infrastructure can serve as a platform linking all services.

As mentioned earlier, cross-border payments can often be challenging and inconvenient for economic agents. Therefore, several CBDC research initiatives are primarily focused on developing solutions to ensure easy and secure ways to conduct international transactions. In this arena, significant progress has been made under the BIS Innovation Hub[7] initiative. Within different projects economies try to work out solutions for fast international transaction settlements using their local CBDCs. For example, Project Dunbar [BIS, 2022] connects the Central Bank of Australia, the Central Bank of Malaysia, the Monetary Authority of Singapore, and the South African Reserve Bank. The project has developed a multi-currency common settlement platform allowing direct payment in different currencies between transacting parties. Similar projects include Project Mariana [BIS, 2023], an automated market-maker for wholesale CBDC transactions between Switzerland, Singapore, and the Euro system, Project Jura [BIS, 2021], a single DLT platform for wholesale CBDC transfers between French and Swiss commercial banks, Project mBridge [Auer et al., 2021], another multi-CBDC platform linking economic parties in Hong Kong, Thailand, China, the United Arab Emirates and more.

Interoperability is another important aspect of future payment infrastructure, often not well addressed in the digital currency literature. Most of the CBDC projects concentrate on the development of isolated systems with only their native currency in circulation. However, despite keen global interest in digital payment innovations, it is less likely that consumers will abruptly shift to new solutions. On the contrary, new payment means like CBDCs will coexist alongside traditional forms of payment like cash, debit/credit cards, and e-money [Auer and Böhme, 2020]. If introduced, CBDC systems would probably even face limited economy of scale at the initial stages. Therefore, alongside core CBDC development, more emphasis should be placed on digital currency interoperability with other systems (e.g., crosswise interoperability between domestic CBDC, foreign CBDC, local and foreign conventional systems). This is crucial, since it is often even harder to ensure interoperability between two different DLT-based systems [Belchior et al., 2023]. Isolated and not directly interoperable CBDC projects around the world spur commercial interest[8] to develop digital platforms for CBDC integration across different jurisdictions [Bokolo, 2022]. In sum, to increase the utility of CBDC in an economy, the CBDC should be developed not as a new means of payment but rather as a new infrastructure—a national infrastructure, which will allow economic agents to have access to central bank money for quick and secure settlement. Under this paradigm, CBDC will be a platform with the potential to interlink all payment systems in a country.

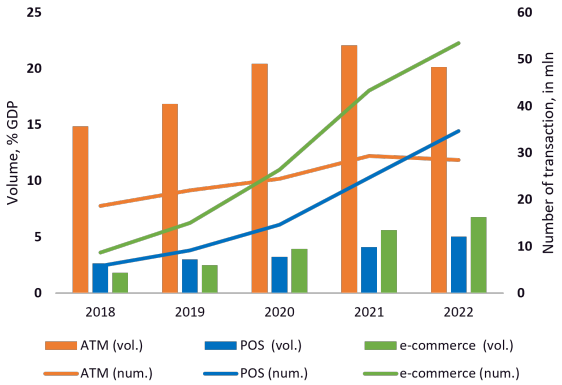
[7] https://www.bis.org/about/bisih/about.htm

[8] https://www.swift.com/news-events/news/cbdcs-interoperability-5-key-takeaways-our-ground-breaking-experiments

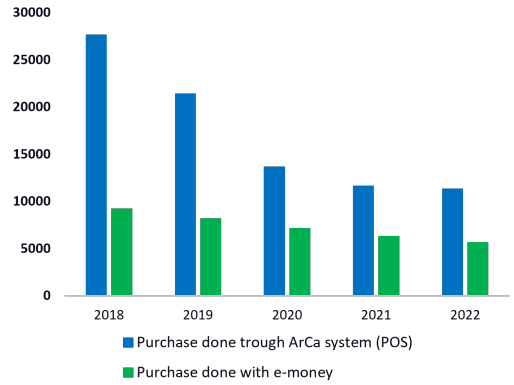
2.2 Financial Inclusion and Cashless Society

Non-cash transactions in Armenia have been steadily increasing in recent years[9]. Notably, the number of transactions has been increasing faster than the volume, which illustrates the fact that non-cash operations have become more accessible for consumers, who employ non-cash means of payment for day-to-day small purchases (Graphs 1 and 2). Despite the positive dynamics of non-cash, a substantial share of the population is still heavily cash-dependent, especially the elderly and people in rural areas. In turn, the issuance and maintenance of cash implies significant costs for a state and the financial sector to bear.

Graph 1: ArCa system statistics



Graph 2: Average purchase amount, AMD



Here, the introduction of CBDC is motivated by two aspects. First, in economies with the continuous decline of cash, it can ensure an alternative to banks' payment infrastructure with the public having direct access to the retail central bank money. This may be useful, for instance, in times of downturn, when consumers would like to keep their money in more secure means. Second, with the introduction of CBDC, central banks may aim to facilitate the creation of a cashless society. The public digital currency infrastructure has the potential to promote the inclusion of financially excluded individuals into the financial system. For the Armenian economy, these two motivations are legitimate. Enhancing financial inclusion would not only reduce cash management expenses but also provide broader financial access to a larger segment of the population. Nevertheless, considering that the volume of currency in circulation in Armenia is rising alongside cashless payments[10], prior to CBDC issuance one should thoroughly investigate the reasons behind people's adherence to cash.

With the introduction of CBDC, countries aim to make financial services more accessible for people. In some economies, opening a bank account can be challenging. Financial, bureaucratic, and geographic factors can serve as major obstacles to financial inclusion [Allen et al., 2016]. The World Bank's Global Findex Database for 2021[11] reports that 45% of the adult population in Armenia does not have a bank account, while this figure is 32% for peer countries, and 4% for developed nations. So, there is certainly room for improvement, and all pros and cons could be evaluated to understand whether the introduction of CBDC is a good choice for financial inclusion facilitation n Armenia.

[9] Armenian Card (ArCa) system statistics (a unified card payment system, which enables operations by local ArCa payment cards, as well as Visa and MasterCard international payment cards)

[10] https://www.cba.am/am/SitePages/statmonetaryfinancial.aspx

[11] https://www.worldbank.org/en/publication/globalfindex

It is important to note that, regardless of design choice for CBDC and the architecture of a future payment system, there will always be people who will prefer cash for its physical nature and associated anonymity. Therefore, the introduction of a CBDC should not be considered a complete substitute for cash, but rather a complement to existing payment instruments [Auer and Böhme, 2020].

2.3 Capacity Building

The ongoing research on central bank digital currency undertaken by many central banks is itself a great channel to gain new knowledge and revisit the payment system infrastructure. Since the emergence of new digital technologies in the field of communication and payment, central banks have been investigating the possibility of internalizing some of these innovative solutions to better fulfill their mandates. The CBDC is one, but not the only, direction of the research. New technologies like DLT can be used in database management, insurance, supply chain management, identity management, compliance and legislative control, cybersecurity, health services and more.

One of the significant advantages brought about by cryptocurrencies, stablecoins, and CBDCs is the facilitating of reexamination of existing legacy payment systems. Now, central banks around the globe put more effort into upgrading their payment infrastructure. Thus, recent advancements in retail payment systems in several economies may already provide some advantages attributed to CBDC (e.g., broader access, higher speed of transactions, affordability, etc.). Some examples of those systems are instant payment services like FedNow in the US[12], PIX in Brazil[13], and RIX-INST in Sweden[14].

In a nutshell, regardless of the final decision on CBDC issuance, the research in the field per se yields new knowledge and skills needed to build a modern payment infrastructure. Thus, efforts in this direction should be continued.

3 Discussions with Local Financial Institutions

It goes without saying that the issuance of CBDC cannot be a goal in itself. It should target bottlenecks in the existing payment system. Therefore, at the initial stage of investigation on the expediency of CBDC issuance, use cases of CBDC should be identified for the local economy. The ultimate design and architecture of the future payment system can be depicted based on the latter. Since the CBDC, once issued, will, one way or another, affect all aspects of economic life and the financial system in the country, it is important to hear local stakeholders' views on the development of the future payment system. The successful development of the latter is possible only in collaboration with the private sector. Furthermore, communications with the private sector are doubly beneficial since they may reveal obstacles for infrastructure development not apparent to the regulator. With that in mind, a series of bilateral meetings with representatives of financial institutions was organized by the Central Bank of Armenia in mid-2022. Executive and IT management personnel of 12 local commercial banks and five payment service providers (PSP) participated in the meetings.

[12] https://www.frbservices.org/financial-services/fednow
[13] https://www.bcb.gov.br/en/financialstability/pix_en
[14] https://www.riksbank.se/en-gb/payments--cash/the-payment-system---rix/

It is important to note that discussions were not around CBDC design choices or functionalities. That would be counterproductive, considering the uncertainties surrounding CBDCs and the limited involvement of the private sector in CBDC research. Instead, discussions were aimed at identifying current bottlenecks to payment infrastructure development, as well as determining the private sector's views on future payment system architecture, such that specialists at the central bank could afterwards, by assessing the various opinions expressed, consider possible CBDC design choices in the context of the issues raised and make a final decision on the suitability of CBDC for the Armenian economy. Nevertheless, as a matter of fact, a few representatives of local financial institutions were aware of the concept of CBDC.

Regarding the issues raised by the participants, the majority of them referred to the absence of a unified national identification system as one of the bottlenecks to payment system development. Each financial institution develops its own KYC (know your customer) system, which is often not trusted by other institutions and not compatible with similar processes of others. For instance, oftentimes a customer undergoes double KYC procedures at a bank and at a PSP, despite the two institutions collaborating with each other and the bank being an account provider for the PSP. According to several private sector participants, the introduction of a standardized identification system would ensure a level playing field for all, since the development of such a system imposes a heavy financial burden on smaller players. Therefore, participants were positive about the expected launch of the national identification system.

The lack of proper data management is yet another drawback of the current financial system of Armenia. The discussions suggest that little consumer activity data is collected and/or used to improve financial service quality. Presumably, this is the main reason for the absence of provision of personalized financial services. The latter implies higher utility for a consumer. On the contrary, currently the competition among digital applications is primarily focused on the extensive margin, with the aim to incorporate as many services as possible within mobile applications.

Commercial bank representatives noted that they use multiple state-run databases (e.g., the state registry, e-Governance infrastructure implementation agency[15], Nork[16], The Compulsory Enforcement Service of RA[17]) available to them for potential clients' credit worthiness assessments. However, access to those databases is often disrupted due to technical issues, which negatively impacts business processes. On the other hand, discussion participants expressed their desire to have access to other state databases as well, such as data from the registry office, data on bankruptcy, and list of the dead.

Based on the discussions and follow-up communication with private financial institutions, it was inferred that information on the cost of cash maintenance and online payment service provision is lacking. However, this is one of the critical issues to clarify, given that the cost of cash maintenance is the first measure of opportunity cost of any CBDC project. In fact, most of the local financial organizations position themselves as price takers with regard to the similar payment services in the market. Few organizations have assessed the actual costs associated with payment services.

It is important to note that the period of meetings coincided with considerable legislative changes, which might have introduced some biases to the financial sector

[15] https://www.ekeng.am/en/

[16] https://nork.am/

[17] https://cesa.am/en/home/

representatives' responses (especially in the case of PSPs). According to the new legislation[18], all consumers of PSPs must ensure their wallets are associated with bank accounts. The aim of the new rules is to provide more transparency and accountability to the non-cash payment market. Nevertheless, the changes were not perceived uniformly. Some payment service providers (PSPs) have claimed that the new law has placed them at a disadvantageous bargaining position in relation to banks. Thus, according to the PSP representatives, the recent legislative changes, rather than new technologies, are the main shocks to their businesses. These are the primary influences of the changes in the business model.

Last but not least, all private sector participants viewed the need to upgrade financial infrastructure positively. Legacy systems currently in place lack functionality and do not meet the needs of the market. The participants felt that both wholesale and retail payment systems should be revisited. Commercial banks were willing to invest in payment infrastructure development projects. However, due to market fragmentation, the private sector looks to the central bank to coordinate efforts. Importantly, the ArCa card payment system was mentioned by all participants as a key retail payment infrastructure of Armenia, based on which the future upgrades could be implemented. Furthermore, open banking, banking-as-a-service, banking-as-a-platform, transition to the ISO 20022 messaging standard were mentioned as promising directions for the financial sector's future development.

In conclusion, the survey of private financial organizations has provided useful information about the current status of the payment sector and its development bottlenecks. Apparently, not all issues lie in the technical domain, and several can be resolved through regulatory interventions. The remaining issues can have multiple solutions, with design CBDC being one. At this point, it is hard to assess the opportunity cost of CBDC issuance. Nevertheless, to maximize value for money, it is crucial to position a potential CBDC not as a new payment instrument, but as a novel payment infrastructure that grants private entities direct access to central bank money. Under this paradigm, the retail payment aspect would represent only a fraction of the comprehensive functionality offered by the CBDC. Instead of solely focusing on retail transactions, the CBDC would encompass a broader range of features and capabilities.

4 Agent-Based Modeling: Simulating CBDC Adoption in Armenia

The success of any retail CBDC project heavily depends on its potential adaptation by the local economy. Thus, prior to issuance of its own digital currency, a central bank should make sure that the new means of payment have solid use cases and there is a substantial demand for it. There are multiple techniques to measure consumers' potential demand for the new product. Surveys, pilot projects and computer simulations can all serve as methodologies for demand estimation. The first two methods can provide more accurate estimates but are costly to set up. For that reason, at this stage computer simulations were considered as a viable option to answer some CBDC demand-related questions. Macroeconomic model simulation has its pros and cons as

[18] https://www.arlis.am/DocumentView.aspx?DocID=161736 (Arm)

well. Aside from cost efficiency, it is a powerful and flexible policy-making tool, with which one can test different hypotheses under a variety of settings. A researcher can impose extreme conditions on the tested economy to analyze all possible implications of a shock. This would be virtually impossible to obtain with surveys and project pilots, given that those involve working with a real economy.

The sensitivity of outcomes with regard to the imposed assumptions is one of the main drawbacks of modeling. Since reflection of all aspects of the real economy is neither a plausible nor required option, the model should capture only the parts of the economy needed to answer specific research questions, with the remaining aspects of the economy being deemed irrelevant. Therefore, the research should concentrate on the hypothesis to be tested and around which an economic model should be constructed. On the other hand, the weakness of the modeling can be turned into an advantage. The possibility of flexibly altering parameters of the model provides the opportunity to evaluate the system's sensitivity with regards to specific factors. In short, economic modeling does not aim to answer all questions, but it is a rather useful analytical tool to have in a policy-maker's toolkit.

With that in mind, a few questions were identified and addressed through economic modeling. Those are:

- In what time range could a central bank digital currency be adopted by society?
- What impact can CBDC introduction have on other payment means?

To answer the questions, the agent-based modeling (ABM) technique was employed. The choice of ABM is driven by its flexibility and traceability. This modeling technique enables the inclusion of multiple economic agents with distinct behavioral characteristics and the examination of system dynamics over a specific time period. In general, ABM models have gained significant popularity in sociology, healthcare, economics, etc. This type of model was widely applied during the COVID-19 pandemic to estimate the speed at which the virus spread across a population[19]. From our research point of view, it may seem odd at first, but there are significant similarities between the spread of technologies and viruses. As in the case of viruses, the spread of technology transmission depends on the number and intensity of personal interactions. Moreover, as the spread of new technology increases, the likelihood of new individuals becoming "infected" also rises.

As was emphasized, the model aims to describe the process of CBDC adoption by society. However, its flexibility allows further modification and augmentation to address other related questions. For instance, it allows for the modeling of financial stability and monetary policy relevant blocks to assess corresponding implications of CBDC introduction.

The ABM model development for the Armenian case was inspired by the work of Ramadiah, Galbiati, and Soramäki on this topic [Ramadiah et al., 2021]. The economic structure is generally in line with the referenced work, with several alterations to reflect Armenian economic characteristics. The modeling is done using the Python programming language with the application of the Mesa package for ABM modeling[20].

Here is a brief characterization of the ABM model: There are four economic agents in the model: consumers, merchants, a commercial bank, and a central bank.

[19] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8341708/
[20] https://mesa.readthedocs.io/en/stable/

In this model, time is discrete, and each time point represents a week. For the sake of simplicity, all quantitative values are reflected in thousands. For instance, one million in population in the model will be recorded as 1000. At each point in time, all agents interact with each other in accordance with preassigned rules[21]. Since the structure of the modeled economy is borrowed from [Ramadiah et al., 2021], one can refer to it for details on the economic structure and rules imposed. Nevertheless, there are several augmentations to the model, which are described below.

There are 2300 consumers in the economy. At each time-point, consumers are faced with a series of decisions to make. Those are whether to purchase or not, the amount of the purchase, the merchant from which to purchase, the type of the purchase (offline or online) and the means of payment (cash, bank card or CBDC). In the case of online purchases, a consumer has a bank card and CBDC wallet at his/her disposal. For the offline purchases, all three options are available.

Since people usually have differentiated approaches towards digital innovations, it was decided to split the modeled society into two groups. The first one, the so-called "progressive" sector represents people who are more willing to adopt an innovation like CBDC. Moreover, if available, they prefer to pay with non-cash means. This group represents younger and/or financially educated people. The second group, the "conservatives," eventually adopt CBDC but prefer cash in everyday transactions. The populations of the groups are roughly 1300 and 1000, respectively[22].

Initially, no consumer or merchant has CBDC, but as time goes by, they implement the innovation. At the initial stage, CBDC wallets are randomly distributed to a handful of consumers. This is comparable with the pilot stage of real-world CBDC projects, where a central bank randomly distributes some amount of CBDC to some consumers, to get feedback from the market[23]. At the later stages, the law of motion of CBDC adoption depends on parameters guiding the distribution across society. Importantly, since the use cases and level of necessity of CBDC is yet to be investigated, the precise measure for potential CBDC demand is unknown. To proceed, some nontrivial value were assigned to the CBDC in our model. Thus, it is assumed that there is a gap in the Armenian payment system, and the launch of a CBDC is intended to bridge this gap. Otherwise, CBDC issuance could be considered a goal in itself. Therefore, in the model, a consumer with all payment means available will prefer CBDC (with slight preference differentiation for the two consumer types) over other payment instruments. One can easily picture several real-life cases which can make CBDC potentially an appealing payment option. For instance, it could be more accessible and cheaper for consumers as a payment instrument, or it may provide access to other services not available with traditional payment means, etc. Nevertheless, the policy goals and technical features of the future CBDC are unknown and outside of the scope of this paper. Answers to those questions depend on near future economic and technological

[21]The scheme of main CBDC-related relationships between economic agents in the model is illustrated in Graph 1 of the Appendix of the paper.

[22]22According to Central Bank of Armenia statistics, there are more than 3 million cards held by Armenian consumers. But since the number of unique card holders is not observed, it was assumed that a representative holder has at least two cards (2.3 on average). https://www.cba.am/en/sitepages/default.aspx

[23]https://www.reuters.com/article/us-china-currency-digital-explainer-idUSKBN27411T

developments within Armenia and globally.

The probability of a consumer i downloading a CBDC wallet is determined by the probability function $b(w_{t-1})$, where w_{t-1} is the share of the CBDC wallet holders within the overall population at time $t-1$. The higher the share, the higher the probability of a consumer acquiring a CBDC wallet (1).

$$prob_i(openWallet_t) = b(w_{t-1}) \tag{1}$$

This mechanism is fairly straightforward. A consumer in real life has multiple information sources, such as friends, relatives, media, and social networks. The more common CBDC technology becomes, the more probable it becomes for the consumer to be aware of it.

At each point in time, each consumer meets with a merchant and makes a purchase if all conditions are met. Those are conditions relating to money amount and compatibility of technologies for both agents. For example, if the consumer decides to pay by CBDC but the merchant does not have the necessary infrastructure, the purchase does not take place. But if the infrastructure is in place but there are not enough means in the CBDC wallet, the consumer can top it up using his/her bank account. Importantly, for each consumer type so-called preference matrices were introduced. This is one notable augmentation to the reference model. The preference matrices contain weights for payment means. Higher weights correspond to the most preferable payment means for the given consumer type. The sequence of payment instruments is the following: CBDC, bank card, cash. So, for instance, a [1,1,2] preference matrix states that, for the corresponding consumer, cash is the most convenient payment means and will be the first payment choice of the consumer half of the time. Consequently, 25% of the time the consumer will prefer paying with CBDC and the remaining 25% with a bank card.

In a similar vein, at the beginning of the simulation, no merchant accepts CBDC and only some of them accept bank card payments. For each non-cash payment means, there is a rule for the corresponding technology adoption by the merchant. A bank card payment acceptance is guided by a probability function with a constant parameter, which ensures smooth adoption of the technology by all merchants (e.g., introduction of POS (Point-of-Sale) terminals). To be able to accept CBDC payments, the presence of bank card accepting infrastructure is a necessary precondition. However, the rules for CBDC POS terminal introduction are slightly different. Here, the adaptation takes place according to the probability function $h(z_{t-1})$. However, unlike the consumers' case, the parameter z_{t-1} is not a function of the whole population but rather the share of the corresponding merchant's consumers with sufficient amount of CBDC in their wallets, among all the consumers of the merchants (2). The idea is that, irrespective of the final payment instrument used, the merchant observes its consumers' payment possibilities as they approach to make a purchase. An increase in the share of consumers carrying CBDC increases the probability that the merchant will install a CBDC POS terminal.

$$prob_i(accepts_t) = h(z_{t-1}) \tag{2}$$

The private financial sector is represented by one commercial bank, which plays the role of an intermediary in the economy. Its main functions are deposit collection (including interest payments and services related to bank cards and cash withdrawals), loan provision and CBDC distribution. Considering the hypothesis to be tested, the introduction of one bank is sufficient to represent the whole banking sector under the assumption of perfect competition. However, the model allows incorporation of differentiated banking sectors to test other hypotheses as well. For instance, the question of the impact of a concentrated banking sector on CBDC distribution is a legitimate research question and can be addressed in future research. However, this is outside of the scope of this research.

The CBDC system in our modeled economy is a two-tier one. The CBDC is the direct liability of the central bank, issued by it and transmitted to the commercial bank. While observing demand for CBDC from society, the commercial bank acquires the necessary amount from the central bank using their reserves held there [Juks, 2018]. A legitimate question arises here regarding the model's impact on the commercial bank's profitability, since part of the deposits would be converted into central bank money. Additionally, banks reserves declined as well, making them more vulnerable in times of crisis. However, the underlining assumption for the financial system is that the presence of a new payment infrastructure and internalized new technologies will open up new opportunities for financial institutions to innovate and offer new products generating new sources of profit.

The role of the central regulator is entrusted to the central bank, which holds several tools at its disposal: 1) it sets the maximum leverage requirement for a commercial bank; 2) it determines the cost of CBDC borrowing; and 3) it also sets the maximum CBDC top-up and cash withdrawal amounts. With regard to financial stability, the model allows for the incorporation of central bank objective function for dynamic regulation. This is another interesting avenue for future research. In this case, the central bank's regulations are constant over time. Finally, the last step of model preparation prior to simulation is parameter calibration and determination of initial condition. A comprehensive description of all parameters can be found in the Appendix of the paper. The parameters are set in such a way as to represent the Armenian economy.

4.1 Multiple Scenarios of CBDC Adoption

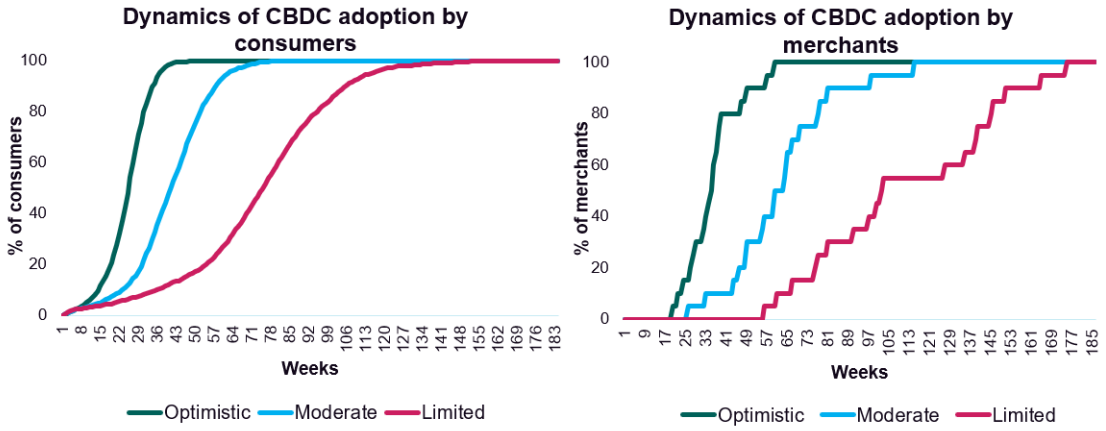
CBDC introduction will undoubtedly have profound implications for an economy's payment system. The long-run effects on competition, financial inclusion, financial system stability and security are yet unknown. The direction and the magnitude of the impact will depend on technological developments, design and architecture of the system, and on demand from financial institutions, the real sector, and society. In this part of the research, some of the questions pertaining to introduction of CBDC into the payment system will be addressed. More specifically, under certain assumptions, the substitution effects of CBDC will be analyzed.

As was discussed earlier, the potential level of demand for CBDC in real life is unknown. Therefore, differentiated scenarios for a comparative analysis of CBDC

introduction were defined. In general, the scenarios will differ in terms of the level of social preferences for CBDC. As assumed, the suggested CBDC, with its specific design and architecture, is attributed with nontrivial positive utility. Therefore, there is certain demand for it. The case where there is no considerable use case and demand for the CBDC does not have research validity. Therefore, this scenario is not considered here. The preference for CBDC for each scenario will differ only by a slight margin. Since the other parameters of the model are kept constant, any observable output differences would be attributed only to the marginal change in CBDC preferences.

Let's consider three scenarios of CBDC adoption. Under the first one (the optimistic one), a significant demand for CBDC is assumed, which fills a gap in the current payment system and provides positive externalities for the economy. In other words, here, traditional technologies face infrastructure issues and lack the ability to effectively cope with them. Under this scenario, in aggregate, in 35% of cases, consumers prefer to pay with CBDC. Smooth adoption of CBDC is observed for both types of consumers (with relatively slower pace for the "conservative" group). The second and third scenarios involve moderate and limited adoption. In these scenarios, the aggregate preference towards CBDC is around 27% and 18% respectively. It is important to note that under all three scenarios economic agents eventually adopt CBDC technology. However, not all of them actively use them. This outcome resembles some real-life cases. For example, despite being available to consumers for more than one year, the well-functioning Nigerian CBDC eNaira experiences sluggish adoption [[Ree, 2023]. Thus, according to our simulation, the average time for economic agents to adopt CBDC technology (having CBDC wallets and POS terminals, but not necessarily using them) may vary from one year (the optimistic adoption scenario) to four years (the limited adoption scenario) (Graph 3).

Graph 3: Timespan of CBDC adoption by agents under different scenarios



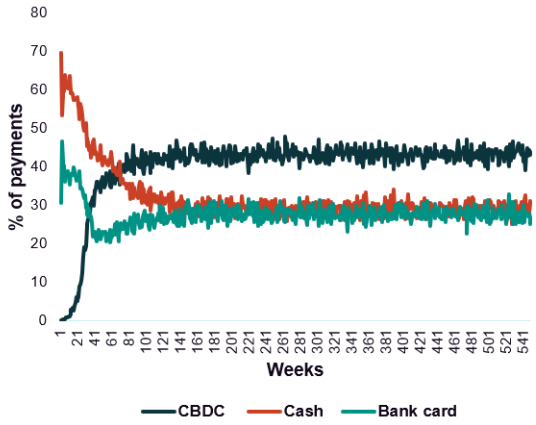
If adopted, CBDC will result in structural change in the financial market with the potential to alter consumers' payment behavior. Since, as a new technology, it should be in line with the three core principles of "do not harm," coexist, and provide innovation and efficiency [Auer and Böhme, 2020], CBDC should be viewed as an alternative payment means and should not position itself as a substitute for existing instruments, as far as there is a demand for the latter. However, the risk of disruption remains. CBDC introduction may result in some financial institutions finding themselves out of the market. The level of financial disintermediation can decrease substantially, with

adverse consequences for monetary policy implementation and financial stability.

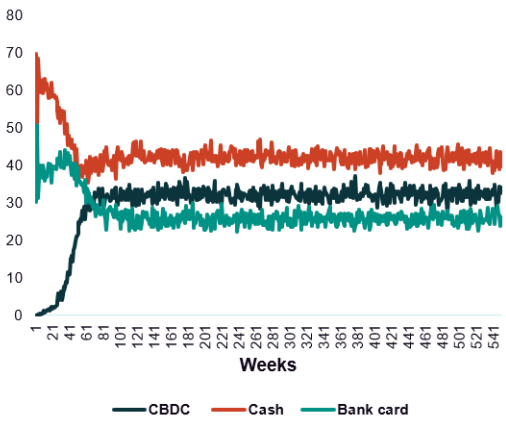
According to the optimistic scenario of our simulation, CBDC introduction equally substitutes cash and bank deposits (Graph 4). The graph illustrates the dynamics of shares of payment made by different payment means. Two years after CBDC introduction, cash and bank cards lose roughly half of their markets. Here, financial institutions have to drastically change their business models and provide more innovative solutions to deal with competition.

As one could expect, the simulation under the moderate adoption scenario implies less profound substitution of conventional payment means (Graph 5). Cash and bank cards lose almost a third of their markets. Interestingly, under the pessimistic adoption scenario, in the long run, CBDC substitutes only the bank cards and almost does not alter the value of cash transactions. The intuition behind this is that the people who are digitally educated and banked are those who find CBDC useful and become the ultimate beneficiaries of the innovation. Note that, during the initial two years, consumers actively acquire CBDC wallets and use CBDC for payments, substituting cash and bank cards. However, in the steady state, cash recovers, which is not the case for bank cards.

Graph 4: The optimistic adoption scenario

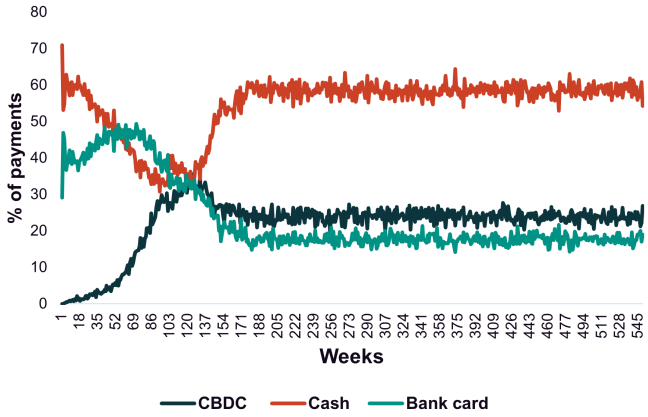


Graph 5: The moderate adoption scenario



Intuitively, it can be an illustration of possible concerns over the CBDC life cycle. At the initial stage, when the CBDC launch is accompanied by a promotional campaign (like cashbacks, subsidized products, access to special services, etc.), the new payment instrument can gain momentum and even force cash out of the market. Nevertheless, if real use cases are not addressed, the old steady state may recover with CBDC being marginalized. This is a depiction of the not well-thought CBDC introduction policy (Graph 6).

Graph 6: The pessimistic adoption scenario



In sum, under all three scenarios, CBDC replaces consumer deposits in commercial banks to some extent, leading to financial disintermediation. Since the intermediation implies bank's deleveraging, the commercial bank has less resources for loan financing. As a result, banking sector profit declines by one percentage point annually. Changes to loans and deposits in our simulation occur only with regard to their volumes and not to the associated interest rates. However, in the real-world banking sector, deleveraging would certainly be directly reflected in bank service prices and interest rates. Consequently, to cover accrued losses, banks would increase loan interest rates and become involved in financing more risky projects with eventual risk of consumers' financial exclusion and aggregate welfare decline. Therefore, CBDC-associated financial market contraction risks should be thoroughly calculated prior to the introduction of digital currency.

5 Conclusion

The expediency of issuing Central Bank Digital Currency is being studied by nearly all of the world's central banks. Despite the availability of various technical solutions, few countries have yet expressed willingness to issue retail CBDC in the near future due to financial stability concerns and uncertainty around the technology. CBDC feasibility research is being conducted at the Central Bank of Armenia as well. Within this work, the current market situation and financial infrastructure were studied. Additionally, the viewpoints of private sector stakeholders regarding the future of payment infrastructure and the existing development bottlenecks were gathered and analyzed. Market fragmentation, lack of standardized identification procedures, issues with data collection and management and lack of innovations in the financial infrastructure were identified by private financial institutions as the main bottlenecks affecting development. Those issues can be addressed with CBDC as well as with conventional technologies. Some of those issues can certainly be resolved through the introduction of a specially designed CBDC. However, so far, the opportunity cost of such intervention is unknown. Within this study, an agent-based model was developed to simulate a potential CBDC adoption in Armenia. Analysis of different scenarios indicates that CBDC adoption heavily depends on the presence of real use cases, meaning issues in the financial mar-

ket which cannot feasibly be addressed with conventional technologies. In a few of the real use cases identified, a CBDC issuance marginalizes commercial bank money and leaves cash circulation unimpacted. Given the results of the private financial institution survey and the ABM simulations, it was concluded that, given the current level of payment infrastructure development in Armenia, the introduction of a CBDC as an alternative payment instrument would have limited implication for Armenian society. However, the underlying technology can prove to be useful for a variety of financial market enhancements.

References

[A. Kosse and I. Mattei, 2022] A. Kosse and I. Mattei (2022). Gaining momentum – Results of the 2021 BIS survey on central bank digital currencies. *Bank for International Settlements Papers*, No 125.

[Allen et al., 2016] Allen, F., Demirguc-Kunt, A., Klapper, L., and Martinez Peria, M. S. (2016). The foundations of financial inclusion: Understanding ownership and use of formal accounts. *Journal of Financial Intermediation*, 27:1–30.

[Auer and Böhme, 2020] Auer, R. and Böhme, R. (March 2020). The technology of retail central bank digital currency. *Bank for International Settlements. BIS Quarterly Review*.

[Auer et al., 2021] Auer, R., Haene, P., and Holden, H. (2021). Multi-CBDC arrangements and the future of cross-border payments. *Bank for International Settlements Papers. Monetary and Economic Department*, No. 115.

[Belchior et al., 2023] Belchior, R., Riley, L., Hardjono, T., Vasconcelos, A., and Correia, M. (2023). Do You Need a Distributed Ledger Technology Interoperability Solution? *Distributed Ledger Technology: Research and Practice, Volume 2, Issue 1, Article No.: 1*, pages 1–37.

[Bindseil and Pantelopoulos, 2022] Bindseil, U. and Pantelopoulos, G. (2022). Towards the holy grail of cross-border payments. *European Central Bank. Working Paper Series*.

[BIS, 2021] BIS (2021). Extending and aligning payment system operating hours for cross-border payments. *Bank for International Settlements. Consultative report*.

[BIS, 2023] BIS (2023). Project Mariana: CBDCs in automated market-makers. *Bank for International Settlements*.

[BIS, 2022] BIS (March 2022). Project Dunbar – International settlement using multi-CBDCs. *Bank for International Settlements*.

[BoC, 2020] BoC (2020). Contingency planning for a central bank digital currency. *Bank of Canada*.

[BoE, 2020] BoE (2020). Central Bank Digital Currency. Opportunities, challanges and design. *Bank of England. Discussion Paper*.

[BoE, 2023a] BoE (2023a). The digital pound: a new form of money for households and businesses? *Bank of England. Consultation Paper*.

[BoE, 2023b] BoE (2023b). The digital pound: Technology Working Paper. *Bank of England. Consultation Paper*.

[Bokolo, 2022] Bokolo, A. J. (2022). Exploring interoperability of distributed Ledger and Decentralized Technology adoption in virtual enterprises. *Inf Syst E-Bus Manage 20*, page 685–718.

[DNB, 2017] DNB (2017). Central Bank Digital Currency in Denmark? *Denmark National Bank*, No. 28.

[IMF, 2022] IMF (2022). The Bahamas: 2022 Article IV Consultation-Press Release; Staff Report; and Statement by the Executive Director for The Bahamas. *Staff Report*, 1BHSEA2022001.

[IMF, 2023] IMF (2023). Elements of Effective Policies for Crypto Assets. *Policy Paper No. 2023/004*, PPEA2023004.

[Juks, 2018] Juks, R. (2018). When a central bank digital currency meets private money: effects of an e-krona on banks. *Sveriges Riksbank Economic Review*.

[Lovejoy et al., 2022] Lovejoy, J., Fields, C., Virza, M., Frederick, T., Urness, D., Karwaski, K., Brownworth, A., and Narula, N. (2022). A High Performance Payment Processing System Designed for Central Bank Digital Currency. *MIT. OpenCBDC*.

[Ramadiah et al., 2021] Ramadiah, A., Galbiati, M., and Soramäki, K. (2021). Agent-Based Simulation of Central Bank Digital Currencies.

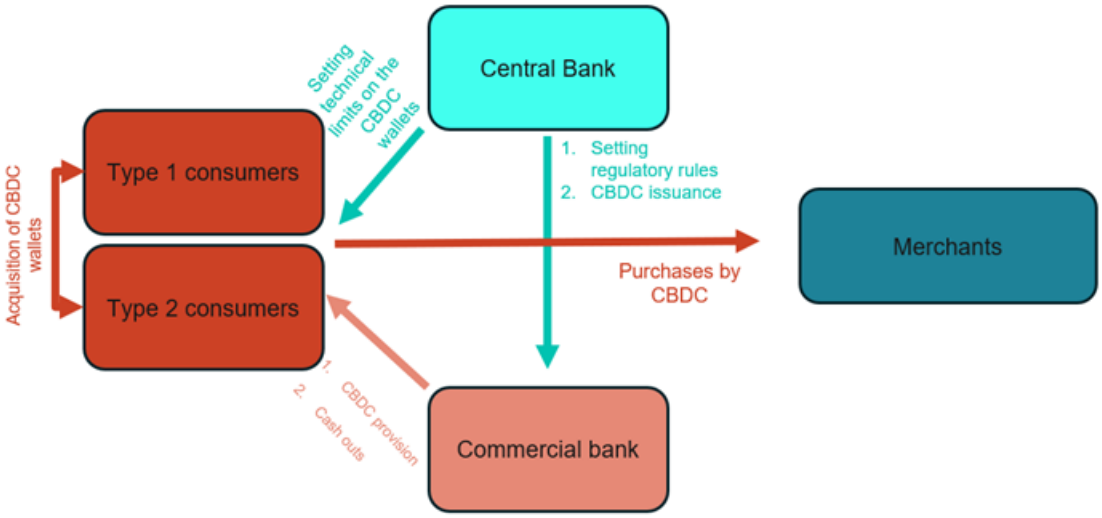
[Ree, 2023] Ree, J. (2023). Nigeria's eNaira, One Year After. *Working Paper No. 2023/104*, WPIEA2023104.

[WB, 2021] WB (December 2021). An analysis of trends in cost of remittance services. Remittance price worldwide. Quarterly. *World Bank. Remittance Prices Worldwide*, Issue 40.

[Zhang and Huang, 2022] Zhang, T. and Huang, Z. (2022). Blockchain and central bank digital currency. *ICT Express*, 8(2):264–270.

6 Appendix

Graph 1. CBDC-related interactions between economic agents



6.1 ABM Model Calibration

Table 1: Consumers

Parameter	Description	Value	Data Source
N_{cash}	Number of "conservative" people	1000	Approximation of eligible population of Armenia, model assumption
$N_{\text{non-cash}}$	Number of "progressive" people	1300	Approximation of eligible population of Armenia, model assumption
$P^a_{i,t}$	Distribution of weekly purchases	Empiric distribution	2020 RA Household's Integrated Living Conditions Survey anonymised microdata database, ArmStat
p_{online}	Share of online purchases	0.2	Model assumption
p_{purchase}	Probability of making a purchase in a given week	0.7	Model assumption
$b(w_{t-1})$	CBDC adoption function, where w_{t-1} is the share of population with CBDC wallets at $t-1$	$0.15 \times (w_{t-1})$	Model assumption
$[C, B, A] \sim f(.)$	Initial wealth distribution	See text	The CB of Armenia statistics on HH savings
κ	Exogenous wage	50 AMD	Approx. of weekly nominal wage, ArmStat
r_A	Return on non-liquid asset	$\frac{10.7\%}{52}$	Short-term government bonds rate, RA CB
τ	CBDC top-up horizon	2 weeks	Model assumption
τ_c	Cash withdrawal horizon	Every week	Model assumption
[optimistic, moderate, pessimistic]	Population's aggregate preferences of CBDC under different scenarios	[35%, 27%, 18%]	Model assumption

Table 2: Merchants

Parameter	Description	Value	Data Source
N_m	Number of merchants	20	Approx. of number of the profit taxpayers in RA
P_B	Initial share of merchants accepting bank card payments	0.2	Model assumption
P_K	Initial share of merchants accepting CBDC payments	$0.1 \times P_B$	Model assumption
$h(z_{t-1})$	CBDC adoption function, where z_{t-1} is the share of the merchant's consumers having CBDC at $t-1$	$0.2 \times (z_{t-1})$	Model assumption

Table 3: Commercial Bank

Parameter	Description	Value	Data Source
B_0	Initial volume of deposits	800 mln. AMD	On-demand deposits in RA by August 2022, RA CB
$K_{\text{bank},0}$	Initial CBDC borrowing	100 mln. AMD	Model assumption
X_0	Initial investment in risky assets	1000 mln. AMD	Computed from the model
$r_{B,0}$	Deposit interest rate	$\frac{8.24\%}{52}$	World Bank (WDI 2021)
$\uparrow$	Return on risky assets	$\frac{11.76\%}{52}$	World Bank (WDI 2021)
ε	Friction in liquidating	0.95	Model assumption
ϵ	Mark-up on the cost of borrowing CBDC	$\frac{0.5\%}{52}$	Model assumption

Table 4: Central Bank

Parameter	Description	Value	Data Source
β	Maximum allowed CBDC balance	100 AMD	Model assumption
β_c	Maximum cash withdrawal	30 AMD	Model assumption
Γ	Maximum leverage ratio	32.3	Model assumption
r	CBDC borrowing rate	$\frac{0.3\%}{52}$	Model assumption