

MONETARY POLICY AND BANKING INTERMEDIATION IN CBDC ECONOMY

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ABSTRACT

Increased dissemination of information and communication technologies in the economy has led many central bankers around the world to consider the introduction of money in the digital form. In academic literature, various central bank digital currency (CBDC) issues, from technical design to political influence, are discussed, although until now, it has not been fully implemented in any country except the Bahamas. The central bank digital currency (CBDC) is an additional form of national currency that combines the properties of cash and bank accounts. This study mainly aims to provide a comprehensive analysis of monetary policy in the CBDC economy. To meet the aim of the study, the study applies an agent-based model that has six types of economic agents and complicated interaction algorithms. The various design parameters are employed to study the dynamics of endogenous variables. Model simulations suggest that CBDC introduction leads to reduced macroeconomic volatility and price stability. Furthermore, the study provides evidence of the increased efficiency of the interest rate channel of the monetary policy transmission mechanism and the negative consequences of possible banking disintermediation. Based on the results obtained, the study concludes that the CBDC impact the economy through changes in the monetary base, strengthening the structural liquidity deficit, banking disintermediation, and increasing the fiscal policy capabilities. The proposed agent-based model provides a theoretical foundation for the further study of monetary policy and banking intermediation in the CBDC economy.

Keywords: *central bank digital currency, agent-based model, monetary policy, transmission mechanism.*

1. INTRODUCTION

Central bank digital currency (CBDC) can be issued on a centralized digital platform or with the implementation of blockchain technologies. Bech and Garratt introduced a widely

used taxonomy of CBDC and systematized its main characteristics (Bech & Garratt, 2017). Subject to the design, scope of application or interest accrue, CBDC could impact both bank intermediation and the effectiveness of the monetary policy (Auer et al., 2021).

Brunnermeier and Nippelt conclude that CBDC would not have an impact on economic dynamics (Brunnermeier & Niepelt, 2019), while Barrdear and Kumhof propose a substantial increase in aggregate output (Barrdear & Kumhof, 2021). Bian and Wang consider the significant reduction of bank lending and the strengthened government regulation in the CBDC economy (Bian et al., 2021).

A study by the Bank for International Settlements suggests that the retail deposits migration into the CBDC could lead to the loss of relatively cheap and stable resources by commercial banks (Bank for International Settlements, 2018). Meaning et al. conclude that the advantages of CBDC implementation would be outweighed by the negative consequences of bank disintermediation (Meaning et al., 2021).

Most of these studies employ the mainstream DSGE models where money effectively serves as a measure of value, and price rigidity allows to analysis only the short-run effects of monetary policy. To maximize the utility function of the representative agent one has to solve a complex system of nonlinear equations. Logarithmic linearization simplifies the computational process, but it narrows the possibilities to study the transmission of monetary policy (Fagiolo & Roventini, 2017; Sanchez-Roger & Puyol-Antón, 2021).

The global economic crisis of 2007-2008 demonstrated the limitations of mainstream macroeconomic models and revealed the opportunities of agent-based simulations (Bookstaber, 2017). The agent-based model traditionally includes a large number of agents with heterogeneous characteristics. The evolution of agent-based models in macroeconomics is provided by Haldane and Turrell (Haldane & Turrell, 2019).

One of the agent-based modelling advantages consists of the possibility to get aggregated dynamics of macroeconomic variables without imposing additional restrictions on the individual agents' behavior. Agents could be heterogeneous in their characteristics, while the simulated economic system could evolve, to reflect fundamental changes in the behavior of agents and resource constraints.

The purpose of the study is to provide a comparative analysis of the monetary policy efficiency and banking intermediation in the CBDC economy. It is important to distinguish

the temporary effect associated with the CBDC introduction and long-term changes in economic relations associated with the circulation of digital currency. The study hypothesizes that by issuing CBDC, the Central bank expands its liabilities, and partially substitutes commercial banks in settlement and cash servicing. Therefore, agents could reduce nonproductive costs and change the structure of their assets while commercial banks would experience increased competition and lower interest rates.

The rest of the paper is structured as described next. Section 2 gives a theoretical background on macroeconomic agent-based models related to monetary policy and lays out a set of building blocks of the developed model. Section 3 is focused on the agent-based model with CBDC and the results of data simulations. Section 4 is dedicated to the discussion of results and the generalization of factors determining the efficiency of monetary policy and banking intermediation in the long run. Conclusions follow in Section 5.

2. METHODS

The agent-based model simulates the internal structure of an economy and allows to study its dynamics. Dosi et al. (2015) develop one of the first agent-based models with money where the banking sector attracts retail deposits and provides loans to production firm (Dosi et al., 2015). It concludes that monetary policy is most effective under relatively equally distributed social wealth, and the dynamics of interest rates determine the long-term growth rate and output volatility.

Gualdi et al. (2017) propose an agent-based model with a decentralized money market and heterogeneous inflation expectations (Gualdi et al., 2017). The introduction of a central bank with Taylor's rule would lead to equilibrium with low levels of inflation and output. Peters et al. develop an agent-based model that isolates the monetary transmission channels to study how monetary policy determines financial stability (Peters et al., 2018).

Giri et al. (2019) proposes an agent-based model to study the monetary policy under large-scale shocks (Giri et al., 2019). It supports the empirically observed negative impact of an unanticipated rate increase on economic activity.

Agent-based modeling requires extensive computational resources and program code that implemented algorithms of agents' interactions on different markets. Therefore, we propose the agent-based model based on the combination of existing models by Schasfoort et al. (2017), Caiani et al. (2016) and Dawid et al. (2019) from which we borrow main building

blocks and interaction algorithms. The model represents a closed economy that consists of six types of agents interacting on different markets: households, capital goods firms (type A) and consumer goods firms (type B), commercial banks, the central bank, and the government.

The key model properties are provided in Table 1. The interaction of agents is based on the protocol in a distinct sequence on the following markets:

- consumer goods market (households and consumer goods firms (type B)),
- capital goods market (capital goods firms (type A) and consumer goods firms (type B)),
- the labor market (households, firms, government),
- financial market (all types of agents).

Table 1: The building blocks of the agent-based model

Concept	Description
Labor supply	Heterogeneous quality of the labor force, the required wages are determined by labor market conditions
Number of agents	In bankruptcy, a new firm is established with no financial liabilities.
Price expectation setting	Linear extrapolation model
Firm pricing setting	Profit maximization based on demand estimation
Goods market interaction	Production based on actual demand, instant delivery of goods
Interest rate setting	Banks charge fixed markups to the discount rate, lending is restricted by compliance with prudential ratios.
Labor supply	Heterogeneous quality of the labor force, the required wages are determined by labor market conditions

Agents have their own set of individual characteristics, which are updated under adaptive expectations each period. The interaction occurs every period. The price is set as the cost of labor and the interest payments on loans increased by the markup. Firms seek to discover the lowest supplier prices available.

Firms of type A produce homogenous consumer goods by employing households and heterogenous capital goods manufactured by firms of type B. Both types of firms could apply for investments to commercial banks. The government collects taxes and provides public service. In addition, the government pays benefits to unemployed households. In our model, the Central Bank's responsibility is price stability while the government is responsible for full employment (Figure 1).

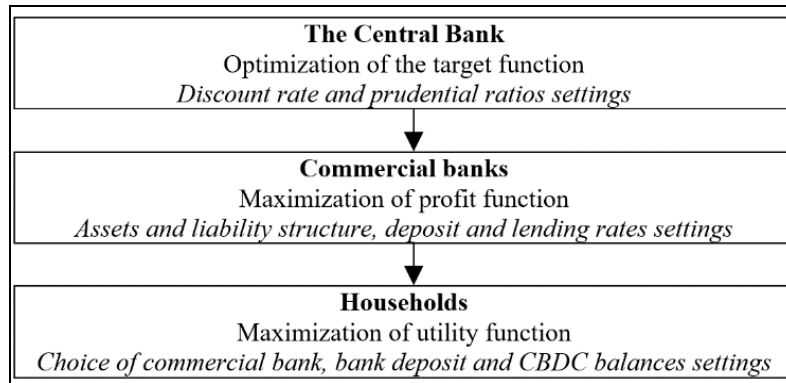


Figure1: Design of CBDC demand

Since firms mostly use non-cash payments in the real economy, the implementation of CBDC would have no critical impact on their production decisions. The short-term temporary effect could be associated with the reduction of banking service costs. Accordingly, the CBDC circulation would affect mainly the behavior of households, commercial banks, and the Central bank.

Commercial banks decide on the asset allocation and deposit rate based on the Central Bank benchmark policy rate and liquidity ratios. Given the rates offered by commercial banks and individual consumption parameters, households decide on the asset structure. The Central bank then aggregates market information and offers liquidity to commercial banks proportionally to distributed CBDC.

3. RESULTS AND DISCUSSION

With the progress in agent-based modeling, there is a growing number of software packages that enable the implementation of interaction algorithms in the given framework. Developed at the Bielefeld University the Eurace@Unibi model (Dawid et al., 2019) responds to the requirements of our study to analyze the CBDC economy. To generate individual models and implement simulation procedures, there is freely available special software called a virtual computing machine. Technical documentation and processing specifications can be found at https://github.com/ETACE/eurace_unibi. The values of the proposed model parameters are given in Table 2.

Table 2: The parameters of the agent-based model

Nº	Parameter	Value	Nº	Parameter	Value
1	Income tax	20%	6	Savings rate	10%
2	Depreciation rate	5%	7	Discount rate	2%
3	Firm markup	20%	8	Planning horizon of firms	10
4	Financial leverage	2.0	9	Number of periods	5000
5	Number of banks	20	10	Deposit margin	10%

We consider several scenarios of monetary policy based on assets allocation between commercial bank deposits and the CBDC account as well as different Central bank discount rates. The results of the model simulation are given in Table 3. The shift of household assets to the CBDC accounts leads to a slight decrease in macroeconomic volatility.

The transmission of monetary policy increases as the interest rate change results in a more significant deviation of the consumer price index, unemployment rate, and per capita GDP. Commercial banks demonstrate more exposure to Central Bank decisions and discount rate changes are more promptly reflected in the loan costs, credit activity, and the dynamics of production.

The impact of price stability on the economy can be conventionally reflected in the following causal relationships. First, a stable price level extends the planning horizon of households and firms, which is reflected in the growth of the long-term investment. Second, the predictability of prices reduces the risk premium on loans of commercial banks and debt securities, providing conditions for the mobilization of external financing.

In the CBDC economy, an improved monetary policy transmission mechanism leads to a more efficient allocation of resources in the economy and would cause minimal distortions in the financial market.

Table 3: Coefficients of variation for endogenous variables in agent-based model

Variable	CBDC in total Assets	Central bank discount rate				
		1%	2%	3%	4%	10%
Consumer price index	10%	0.0363	0.0338	0.0384	0.0354	0.0350
	30%	0.0313	0.0337	0.0290	0.0288	0.0341
	50%	0.0316	0.0330	0.0326	0.0377	0.0318
Rate of unemployment	10%	0.0776	0.0737	0.0788	0.0826	0.0979
	30%	0.0782	0.0738	0.0757	0.0769	0.1062
	50%	0.0800	0.0767	0.0780	0.0787	0.0994
GDP per capita	10%	0.3148	0.3223	0.3266	0.3494	0.3951
	30%	0.3216	0.3250	0.3227	0.3311	0.4076
	50%	0.3077	0.3221	0.3437	0.3402	0.3970

Economic agents get access to an additional means of payment that have no risk of default. The use of a CBDC account lowers bank switching costs for households, so the deposit market suffers from an interest rate increase because of reduced bank margins. The Central Bank provides settlement while commercial banks continue earning transaction processing. Additionally, commercial banks gain by cutting the cost of cash service infrastructure. Moreover, social welfare would be increased by the removal of mandatory insurance for assets on digital accounts.

The CBDC introduction improves the monetary policy transmission mechanism through other channels as well. First, the more efficient banks increase market share as a result of competition. Second, the Central bank could weaken its regulation by accepting other financial institutions to service digital accounts. Third, the shrinking interest margin leaves the deposit and credit policy of commercial banks more sensitive to monetary policy. Since commercial banks have access to an equivalent amount of assets on customers' accounts in CBDC, the Central bank obtains additional tools to influence the financial system.

CBDC introduction requires taking into account the historical background and current socio-economic situation in the country. High volatility and the absence of investment protection in private cryptocurrency could discredit the idea of digital money. The lack of government policy credibility intensifies under the decreasing social confidence, negative experience of previous reforms, as well as psychological traumas on the coronavirus pandemic background. The current political confrontation of major countries raises threats of cyberattacks on the CBDC platforms. National instant payment systems are the closest prototype of the CBDC with comparable functionality but don't impact bank intermediation.

Since CBDC shortens the settlement period, it requires less money to make the same transactions activity. Depending on the adaptation to the digital means of payment and the removal of restrictions on CBDC transactions, it can be expected a reduction of the monetary base. Since economic agents substitute cash and account balances on CBDC, commercial banks would lose an important source of liquidity. The smoothing money demand for regular payments would reduce excess investment in highly liquid assets. At the same time, to manage liquidity commercial banks need to additionally borrow from the Central Bank that would be reflected in higher interbank lending rates.

Despite the lack of a finalized accepted scheme of CBDC implementation, commercial banks would be the most affected economic agents. In the context of banking digitalization, the CBDC economy characterizes by reduced switching costs for customers, as well as decreased importance of traditional banking activities. Commercial banks challenge with downsized fundings and higher borrowing costs because of the outflow of balances from customer accounts and the attracting liquidity at market rates.

Since card payment organizations charge high merchant fees, sellers are interested in alternative forms of payment. As a result, there is the emergence of private cryptocurrencies

that provide secure payments and low costs. Big technological companies tend to wrap all customer payments on their ecosystem platforms. The long-term outcomes include the national payment system disintegration and the loss of state control as well as monopolization of the payment market.

Another important issue concerns digital dollarization that means the use of a foreign CBDC in parallel to or instead of a domestic currency. As transaction costs of using foreign CBDC would be significantly lower compared to foreign cash, individuals have more incentives to use it not only for savings but also for regular payments. The introduction of national CBDC and its further dissemination would reduce the attractiveness of private cryptocurrencies and foreign CBDC.

In the CBDC economy, the government gains new instruments to manage aggregate demand and increase the effectiveness of fiscal policy as it gets access to the individual accounts and all transactions. The mechanism design of social transfers would be more personalized in terms of size, target usage, and payment period. At the same time, one of the central issues in the CBDC introduction remains its accessibility.

The use of digital currency requires not only minimum digital literacy or availability of electronic devices with Internet access, but also the registered account on the CBDC platform. It also introduces new risks for the financial system. Under the traditional organization of monetary circulation, the role of the Central Bank consists of market regulation and supervision but in the CBDC economy, it would directly participate in the transaction processing and private data storage.

Bank runs could be more intensified because of a significant reduction in the cost of money withdrawals from the bank account. The failure of the CBDC infrastructure (technical disruption, internet shutdown, intentional hacker attack) would explode cash demand and increase the volatility of the financial markets.

4. CONCLUSIONS

The demand for CBDC depends on its simplicity of use, associated transaction costs, security, and ease of conversion to traditional forms of money. The CBDC introduction would lead to cash and bank deposits substitution. The effectiveness of the CBDC introduction depends on the legal framework and economic situation. In developing economies, CBDC would increase financial inclusion, and reduce the cost of the payment

infrastructure. In advanced economies, it would allow the Central bank to maintain control over the payment system and keep the power to implement monetary policy. If interest rates remain low, then economic agents are more likely to use digital currency.

We use agent-based model to study dynamics of macroeconomic variables under CBDC introduction. The proposed model consists of six types of agents that interact in different markets. The interaction algorithm allows consider the heterogeneity of the individual characteristics of agents, the possibility of dynamic development of the system as a whole. The shift of household assets to the CBDC accounts leads to a slight decrease in macroeconomic volatility.

The study concludes that the CBDC impact the economy through changes in the monetary base, strengthening the structural liquidity deficit, banking disintermediation, and increasing the fiscal policy capabilities. The effectiveness of monetary policy is enhanced by increasing competition and changing the liabilities structure of commercial banks.

The CBDC introduction would significantly change the role of commercial banks in the economy. Although balances on customer accounts do not determine lending activities, banks actively use it for liquidity management. Commercial banks would suffer from the loss of relatively cheap and stable funding resources, and the costs of customer service would increase.

There are criticisms and reasonable concerns about the usefulness of the CBDC introduction. The development of the national instant payment systems could be an alternative opportunity to improve the effectiveness of monetary policy and banking intermediation. In this regard, the potential effects of digital money on households and firms' behavior as well as commercial bank activities should be researched more deeply. The further development of the proposed agent-based model provides a theoretical framework for the study of monetary policy and banking intermediation in the digital economy.

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