CENTRAL BANK DIGITAL CASH AND CRYPTOCURRENCIES: INSIGHTS FROM A BAUMOL- FRIEDMAN DEMAND FOR MONEY

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Abstract

The aim of this paper is to analyse the ongoing changes in the supply of alternative media of payments (MOP). The comparison between old – cash and deposits – and new – cryptocurrencies and central bank digital currencies – MOPs will be based on a novel definition of money – naming it à la Baumol and Friedman – where a MOP has three properties: the first two are the standard functions of medium of exchange (liquidity costs) and store of value (opportunity costs) and the third one is the novel function of store of information (privacy costs). Given such as properties and the fact that the evolution of the different MOPs is likely to depend on the individual preferences, the relevance of experimental economics is highlighted.

JEL Classification: B22, D72, E41, E42, E52, E58, G38, G41, K42

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1. Introduction

Would we like a **central bank digital currency** (CBDC)? Would there be demand for such a currency and which drivers could explain that demand? The macroeconomic interest of these questions becomes more evident if we observe two other recent and parallel trends in the advanced economies: the puzzling resilience of state-issued paper currencies despite the wide diffusion of cashless payment technologies in advanced economies and an innovation that characterizes this diffusion of cashless payment technologies – the emergence of cryptocurrencies. In cryptocurrencies, cryptographic techniques are used to protect the identity of those exchanging the currency. Those exchanges occur peer to peer via an electronic network that is not managed by a trusted authority (i.e., blockchain technology).

Today, the only type of money available to everyone in society is **paper currency**, which still represents a relevant share of the money supply in advanced economies. In 2015, per capita holdings of paper currency relative to GDP was about 20 percent in Japan, 11 percent in Switzerland and the eurozone, and 8 percent in the US (Jobst and Stix 2017). Even more puzzling is the fact that the circulation of paper currencies has risen in recent years in several heterogeneous economies (Jobst and Stix 2017, Hesselink and Hernandez 2017, Berentsen and Schar 2018a). In fact, the circulation of global reserve currencies has increased inside and outside the issuing countries (Feige 2012, Judson 2012).

In addition, most of the paper currency in circulation is in the form of **large-denomination banknotes**, even though recent reviews of paper-currency denomination structures have resulted in the reversal of such as policies. For example, on May 4, 2016, the ECB's Governing Council decided to end the issuance of EUR 500 banknotes around the end of the 2018. On November 8, 2016, the Indian government surprisingly announced a change in legal tender that targeted removal of 86 percent of the country's paper currency then in circulation in order to implement a radical demonetization policy (Dharmapala and Khanna 2017). Individual preferences with regard to cash also seem to be consistent with the increase in corporate cash (Graham and Leary 2017, Faulkender et al. 2017).

However, the public utility of **paper currency** is increasingly disputed. Some researchers claim that paper currency has at least two important drawbacks (Rogoff 2017). On the one hand, it facilitates the growth of the illegal economy with corresponding losses in terms of missing tax revenues and other socially negative spill-overs. On the other hand, it hampers the effectiveness of monetary policy, as it is the basis for the existence of the zero lower bound on the nominal interest rate.

There are essentially two **benefits to issuing paper currency**. First, the state gains the seigniorage revenue, given that it acquires goods and services in exchange for paper currency and that there is some seigniorage (Rogoff 2017). Second, the anonymity of a paper currency can protect the individual against the risk that the state – whether democratic or dictatorial – could misuse the information that can be collected regarding the use of a payment system.

At the same time, the recent wave of innovation in private payment systems has been characterized by the issuance of **cryptocurrencies**. Cryptocurrencies are private supplies of means of payment that are produced and distributed using a decentralized, peer-to-peer transfer system, which is known as the blockchain technology (or distributed ledger technology, DLT) (Halaburda 2016, Bech and Garratt 2017, Chiu and Koeppl 2017, Huberman et al. 2017, Abadi and Brunnermeir 2018, Casey et al. 2018). Notably, the **blockchain** technology can shape industrial and commercial networks in ways that different from the payment systems (Cong and He 2018), including initial coin offering (ICO) sales (Howell et al. 2018).

The usage of cryptocurrencies as medium of exchange has thus far been limited. Bitcoin, for example, is involved in around 250,000 daily transactions, while established electronic payment systems, such as Visa, handle almost 100 billion (Bruhl 2017). Notably, however, more than 1,000 cryptocurrencies have been registered since the introduction of Bitcoin (Bruhl 2017). These developments may have implications for monetary, banking and tax policies (Bohme et al. 2015, Ahmed 2017, Bech and Garratt 2017, Schilling and Uhlig 2018).

Given the resilience of traditional paper currencies on the one hand and the emerging interest in new private electronic currencies on the other, a question naturally arises: Is it necessary to have a public digital currency? Bordo and Levin (2018) suggest that a **central bank digital currency** (CBDC) could transform all aspects of the monetary system, as a CBDC could serve as a costless medium of exchange, a store of value and a stable unit of account, all of which would benefit consumers (Moghadam 2018, Berentsen and Schar 2018b).

In general, the introduction of a CBDC could have significant **consequences** for the implementation of both monetary and banking policies (Barrdear and Kumhof

2016, Raskin and Yermack 2016, Niepelt 2017). Therefore, the issue needs to be addressed in a complete and systematic way, taking the fact that CBDCs can be designed in different ways into account. For example, the level of privacy, the possibility of interest-bearing mechanisms (Lober 2017), and the possibility of issuing cryptocurrencies (Berentsen and Schar 2018b) in both advanced and emerging countries (Camara et al. 2018) need to be considered.

The issuance of a CBDC is an **option** that both academics and central bankers are carefully considering (Fung and Halaburda 2016, Skingsley 2016, Danezis and Meiklejohn 2016, Bordo and Levin 2017, Bech and Garratt 2017, Hileman and Rauchs 2017, Lowe 2017, Segendorf 2017, Coeurè 2018). Nevertheless, this topic requires consideration of both the economic and the political economy perspectives (Tucker 2017), as well as the role of technological innovation (Velde 2017).

The aim of this paper is to analyse the **demand for a CBDC**. A CBDC, which would simultaneously be a public and virtual medium of exchange, should be completely different from existing forms of virtual monies, which are issued by private regulated firms (banks) and private unregulated entities (blockchain networks), and from paper currencies. In other words, the existence of a CBDC should change the possibilities each agent has to allocate her/his funds (hereafter “her”) given her financial preferences.

In this regard, the key question is the following: How would the existence of a CBDC change portfolio allocations in an advanced economy? In order to address this question, we propose a **novel specification** of the demand for money in line with the tradition of Baumol and Friedman, in which a medium of payment (MOP) has **three** properties: the first two are the MOP’s standard functions as a medium of exchange and as a store of value, while the third one is a novel function as a store of information.

The remainder of this article is organized as follows. Section Two describes the novel demand for money à la Baumol and Friedman and its application to the alternative MOPs: cash, banking money, cryptocurrencies and central bank digital currencies. Section Three highlights the relevance of experimental economics in exploring how the individuals would like the different MOPs. Section Four concludes.

2. Evaluating Alternative Currencies: The Baumol-Friedman Demand for Money

Consider a population with a continuum of individuals, each of whom is free to choose her financial portfolio. Any available financial asset can potentially be used as a medium of exchange (i.e., any individual can use it to finalize an exchange as a payer or a payee). In other words, a series of assets can be used as an MOP, all else equal.

Now, given income and wealth, let us assume that individual preferences are heterogeneous with respect to the crucial properties of an MOP as a medium of exchange, a store of value and a store of information. These three properties capture the different risks that holding a financial asset as an MOP can entail at any given moment.

The first two properties of a currency are highlighted in all standard theories of money demand, and they correspond to the transaction motive and the speculative motive of money holding, respectively. They were discovered by Keynes: "Let the amount of cash held to satisfy the transactions (…) be M1, and the amount held to satisfy the speculative motive be M2. Corresponding to these two compartments of cash, we then have two liquidity functions L1 and L2 (J.M. Keynes, 1936, p.168)" (Brady 2018).

First, we assume that all individuals care about the **illiquidity costs**, which are associated with the probability that the asset cannot be traded (i.e., used as a medium of exchange and transformed into other goods and services) and with the costs of trading the asset – also in terms of time. In other words, the illiquidity costs depend on **two** drivers, which are likely to be intertwined: **acceptability** and **efficiency**. The illiquidity costs are associated with the standard **precautionary motive** to hold money.

Second, all else equal, we assume that the **issuer type** can influence the illiquidity costs. When a currency is a legal tender, we assume that it is the safer asset in a given country in normal times, as each trader is obliged to accept it in any exchange (public and private). In other words, a trader cannot refuse to accept the legal tender as payment.

The legal tender, which is also the **unit of account**, minimizes the expected liquidity costs. The public nature of this medium of exchange guarantees its complete acceptability, and the driver of this property is its capacity to supply common knowledge (Schnabel and Shin 2018).

In a sense, the legal-tender property of **outside money** internalizes the public gains that such a feature implies, such as monetary-policy effectiveness and/or seigniorage gains (Rogoff 2017). At the same time, the properties of private inside money (Diamond and Rajan 2001) have to be acknowledged, at least as portfolio-diversification devices.

Our definition of a **safe asset** focuses on the asset's liquidity properties (Greenwood et al. 2016) rather than on its ability to preserve its expected value (i.e., the stability of the asset's value), as in Caballero and Farhi (2017). Nevertheless, the stability of value is a feature that increases the currency's acceptability, all else equal.

For the sake of simplicity and without any loss of generality, we assume that there is no uncertainty in the **exchange series**, such that a steady stream of transactions occurs. Therefore, we can zoom on the demand for money, given that our aim is to compare alternative currencies.

We acknowledge that the second property of a currency as a **store of value** (i.e., the standard **speculative motive** for holding money) is generally relevant for individuals. Individuals use as its proxy the real expected return of each portfolio asset, which summarizes the corresponding purchasing power as well as expected gains and losses.

Holding an MOP implies an expected opportunity cost equal to the overall excess level of return. The excess return can be calculated by comparing the total return associated with holding other assets with the return on the MOP.[1]

Finally, with respect to the traditional demand for money, we assume that the use of cash can spread information on the money holder. In other words, we assume that money is also a **store of information**. As currency is a disseminator of information, individuals consider the privacy (transparency) risks inherent in using a given currency for trading, given that any exchange can disseminate information

[1] We use a standard formula for this return and assume that for any MOP *j*, the return can be divided into two components: the capital gain (loss) from the change in the MOP's price P and a yield component Y that reflects any kind of cash-flow return. The total expected return (ER) for the MOP j at time t is calculated as:

$$ER_{j,t} = \frac{P_{j,t} - P_{j,t-1}}{P_{j,t-1}} + Y_{j,t} \,.$$

on the exchangers. In other words, we assume the existence of expected privacy costs – or **anonymity** costs – when using money for exchanges. These privacy costs can be associated with the value of each transaction and with the number of transactions.

The relevance of the privacy costs in motivating the demand for money is highlighted in a statement **Milton Friedman** made during an interview:

> I think the Internet is going to be one of the major forces for reducing the role of government. The one thing that's missing but that will soon be developed is a reliable e-cash, a method whereby on the Internet you can transfer funds from A to B without A knowing B or B knowing A.[2]

The relevance of privacy costs is linked to the demand for **trustlessness** (Pagnotta and Buraschi, 2018, Kahn 2018). In general, trustless networks produce exchanges in a manner that does not require the players to either know or trust each other. In a completely trustless exchange, the privacy costs are zero. Pagnotta and Buraschi (2018) note that the demand for trustlessness, which we can call the demand for anonymity, is likely to be correlated with resistance to censorship. In other words, players like networks that prevent third parties from imposing restrictions, in order to prevent any imposition in terms of network contents (Perng et al. 2005).

Among the individuals that like the anonymity property are people who appreciate this property for **illegal reasons**, as an anonymous currency can be an effective device for money laundering. The attention paid to money laundering has progressively increased in recognition of the involvement of money laundering in various activities that violate the law. At the same time, the growth in cryptocurrencies has been associated with illegal activities (Foley et al. 2018).

In fact, any illegal activity may be subject to a special category of transaction costs owing to the fact that the use of the resulting revenue increases the probability of discovery and, therefore, the likelihood of incrimination. Those transaction costs can be minimized through effective **money laundering** – a means of concealment that separates financial flows from their illegal origins. The economic function of this instrument is to transform potential income into effective purchasing power (Masciandaro 1999). Within the general framework of the economics of money laundering (Masciandaro et al. 2007, Unger 2007, Schneider and Windischbauer 2008), a currency-demand approach has recently been

[2] NTUF (1999), https://www.youtube.com/watch?v=6MnQJFEVV7s.

proposed (Ardizzi et al. 2014, 2016) that zooms in on the relationship between an anonymous medium of exchange (i.e., cash) and the illegal component of its demand. In this respect, electronic peer-to-peer currencies – cryptocurrencies – have been associated with the risk of money laundering (Brayans 2014) given that cryptocurrencies seem particularly effective for conducting illegal transactions (Hendrickson et al. 2015).

We assume that the expected transparency risks are associated with the **distributional properties** of any given currency, which can be centralized or decentralized (the latter minimizes the privacy risks). The decentralized, or peer-to-peer, system characterizes both paper currencies (a physical peer-to-peer network) and cryptocurrencies (an electronic peer-to-peer network that functions via blockchain technologies).

Notably, the distributional feature summarizes two technical characteristics – **accessibility** and **form**. While these two characteristics can be analysed separately (Bech and Garratt 2017), they can both influence the illiquidity risks of any currency. In this respect, it is prudent to avoid any association between the distributional features and possible gains and/or losses in terms of **efficiency** (i.e., transaction costs) given that the debate on this topic is still in a state of flux. Some researchers assume that the cryptocurrencies are low-cost payment platforms (Hendrickson et al. 2015), but others believe the opposite is true (Lowe 2017, Kaminska 2017, Yermack 2014). Therefore, whether consumers benefit from using electronic decentralized systems is unclear (Bohme 2015). In any case, the circulation of currencies with uncertain properties, such as cryptocurrencies, can be explained using the general assumption that, under some circumstances, the existence of good and services with such features can increase the consumer surplus via the resulting competition among producers (Berg and Binsbergen 2017).

Cryptocurrencies use the blockchain technology as their platform. The **blockchain** mechanism can be characterized as follows: all transactions are publicly recorded using the payer´s and the payee´s public email addresses, but those addresses do not need to reveal any information on the exchangers, as they can be based on pseudonyms (Bech and Garrett 2017). Therefore, the general assumption is that cryptocurrencies guarantee the counterparty anonymity and, at least partially, **third-party anonymity**. Notably, a significant share of cryptocurrency adopters thus far have sought the anonymity property, which is not available through alternative electronic media of exchange (Bohme et al. 2015).

This brings us to the debate on third-party anonymity (TPA). TPA is a property of paper currencies, but whether this property exists in the case of blockchain transfers remains controversial (Bohme et al. 2015). Cryptocurrencies have been defined as **quasi-anonymous** media of exchange (Hendrickson et al. 2015). In this respect, some researchers claim that if the blockchain technology is adopted by a centralized government (i.e., the decentralization and blockchain features can be separated), then the anonymity aspect will disappear (Kakushadze and Russo 2018). At the same time, the extent to which individuals actually value anonymity of either sort is unclear (Bech and Garrett 2017, Athey et al. 2017). Finally, it is worth noting that the other **private payment technologies** that are not supplied by banks and are not based on blockchain mechanisms (i.e., shadow payment systems; Gapper 2017) enjoy – at least in part – the anonymity property.

In general, the holding of any financial asset that can be used as an MOP will depend on perceptions of the presence of the three properties in that asset among individuals.

3. Would We Like Central Bank Digital Currencies and Cryptocurrencies? The Role of Experimental Economics

In our framework, the individuals face portfolio decisions that involve value trade-offs, given that any of the four currency types can have different characteristics with respect to three above-mentioned properties: safeness, profitability and anonymity. The intuition in this regard is as follows. Given any effective or potential exchange between two players using an MOP, that medium can have three different values (properties) for each player: transaction (liquidity) value, which is inversely associated with the probability that the MOP is likely to be accepted in any exchange (illiquidity probability); speculative value, which is directly associated with the overall expected return of the MOP; and privacy (anonymity) value, which is inversely associated with the individual information required to use a given MOP (privacy risks).

The MOPs are heterogeneous, so that each of them is characterized by different properties. For example, in a given country and in normal times, a banknote is likely to have zero illiquidity risk, zero expected return and zero privacy risk.

The model can be tested in a laboratory experiment (Borgonovo et al. 2018). To the best of our knowledge, the money-demand features have previously been analysed in laboratory experiments in only two cases and exclusively for pedagogical reasons (Ewing 2004, Chen 2018).

In our experiment, the participants were students from various academic backgrounds. The experiment was computer based and it was run in English. It involved 30-minute sessions with three stages. Two experimenters were present in each session, one of whom read the instructions out loud. At the end of the instructions, the participants were asked to provide information on their age, gender and academic background.

The participants were then asked to price monetary portfolios that had different shares of the currency types and an increasing degree of diversification. The portfolios were composed to ensure that the participants would be familiar with the kind of questions that were asked, given that "the rationale is that the students should be actively and seriously involved in the decision problem" (Scheubrein and Zionts, 2006, p. 20).

Prior to the experiment, the experimenters described the building up of the alternative portfolios and the properties of the different types of currency. The key assumption was that the students had to select their preferred cash portfolios using liabilities issued by private banks with different properties. They were asked to select a series of portfolios in a three-stage sequence in which the possibility of portfolio diversification increased in each stage.

The experiment was repeated for 80 participants, giving a total of 1,440 responses. The data were treated using the methodology recommended in the literature on experiment design. More specifically, the data were fitted using a Poisson regression framework. The analysis reveals that the model is strongly statistically significant as a whole.

The preliminary results indicate that the coefficients of two variables – illiquidity risk and expected return – as well as their interaction term are strongly statistically significant. The coefficient of the third variable – anonymity – is weaker. The results suggest that the students valued illiquidity risk and return, while anonymity seemed to play a minor role.

Now we can examine the policy implications of this experiment given the features of the alternative currencies in the real world. In the real world, when allocating a portfolio, an individual can generally choose among traditional paper currencies and two types of private assets that can be used as currencies: banking currencies and cryptocurrencies.

The traditional key features of **paper currencies** are the role of the state as the issuer, the absence of a nominal return and anonymity. The importance of these drivers was recently tested in an empirical analysis of the rising demand for paper currencies (Jobst and Stix 2017), which found that this demand has mainly been driven by a higher level of uncertainty (a legal-tender effect) and lower interest rates (an expected-return effect). The fact that the anonymity effect was not found to be a driver was attributed to methodological difficulties and sample features. Finally, paper currency is not electronically distributed.

Both **banking currencies** and **cryptocurrencies** are not legal tender. They both have real expected returns, but only cryptocurrencies are distributed via a decentralized network that guarantees a certain degree of anonymity. As banking currencies are issued by regulated firms, we might expect them to be safer than cryptocurrencies. In addition, Budish (2018) claims that, theoretically, cryptocurrencies are unlikely to be able increase their acceptability by showing more stability in their values given the intrinsic economic limits associated with the blockchain technology.

With regard to the **expected return**, the cryptocurrencies are characterized by values that rise and fall (Bech and Garratt 2017, Liew and Hewlett 2017, Chuen et al. 2017, Frunza and Guegan 2018, Gerlach et al. 2018). In some cases, their values change with financial anomalies (Caporale and Plastun 2017, Caporale et al. 2018, Liu and Tsyvinki 2018). In general, they are characterized by complex volatility (Catania and Grassi 2017, Klein et al. 2018). In contrast, banking currencies traditionally yield a nominal return that is relatively low and stable.

In this respect, the specialness of cryptocurrencies relates to the **drivers** of their value. Unlike physical commodities, cryptocurrencies have no positive (intrinsic) direct utility arising from the practicality of their use (for a discussion of bitcoin as a commodity money, see Klein et al. 2018 and Luther 2018). Moreover, they are not a liability for anyone (Bech and Garratt 2017), so they do not offer the potential for future dividends. Their expected return relies exclusively on expectations of future demand and the corresponding increase in the resale value, given a supply that is supposed to be prospectively fixed. In the case of Bitcoin, the maximum amount is 21 million. As of November 27, 2017, 16.7 million bitcoins had been issued (Bruhl 2017). Other likely drivers of the demand for cryptocurrencies are a **loss of trust** in the public authorities, as they are not a legal tender, and a desire among the exchangers to **hide** their identities (Niepelt 2016), as such players are highly sensitive to anonymity risks.

The basic properties of the cryptocurrencies can be modified, at least theoretically, by proposing **alternative payment technologies**, such as digital trade coins (DTC) (Lipton et al. 2018). In such cases, the holding of real assets – or the holding of government bonds (Kwon and Park 2018) – is intertwined with the use of the distributed ledger technology to address the problem of the stability of the store-of-value property.

Finally, individuals could use a CBDC. The specialness of a **CBDC** will depend on it being both an electronic and a public currency and, more importantly, on how such a CBDC is designed, at least in terms of the level of privacy and/or the possibility of interest-bearing mechanisms.

5. Conclusion

An exploration of the links among individual liquidity preferences, the issuance of CBDCs and the business cycle can help shed light on the micro foundations of both normal-time and extraordinary-time phenomena, including banking runs and financial instability (Haldane 2017), the lower bounds of interest rates (Rogoff 2017) and precautionary cash trends (Graham and Leary 2017, Faulkender et al. 2017). They can also highlight their consequences for the design of the two main tasks of modern central banking: monetary policy and banking regulation.

The existence of demand for a CBDC would have implications for:

a) Monetary policy: If we assume that individuals are sensible to the technological properties of electronic currencies (i.e., they completely dislike the physical form), then the demand for electronic currencies would completely replace the demand for paper currencies. Consequently, the issuance of electronic currencies has the potential to address the zero lower bound constraint of monetary policy implementation.

b) Banking policy: In normal times, the narrower the opportunity-cost discrepancies between electronic currencies and banking currencies, the greater would be the risks to the business model of commercial banks due to disintermediation. In extraordinary times, such as when bad news circulates about the state of the banking system, a bank run is more likely if we assume that individuals can become extremely sensitive to liquidity risks.

The aim of this paper has been to serve as a primer for analysing the effects of the CBDC issuance, using a novel specification of the demand for money à la Baumol and Friedman. In this specification, the medium of payment (MOP) has three properties: the first two are the MOP's standard functions as a medium of exchange and as a store of value, while the third is a novel function as a store of information. The proposed framework has been tested using a laboratory experiment.

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