WORKING PAPER SERIES

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WORKING PAPER
N. 75
APRIL 2018

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BETWEEN CASH, DEPOSIT AND BITCOIN: WOULD WE LIKE A CENTRAL BANK DIGITAL CURRENCY?

MONEY DEMAND AND EXPERIMENTAL ECONOMICS

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April, 11th , 2018

Abstract

The aim of this paper is to analyse the demand of a central bank digital currency (CBDC). Using a financial portfolio approach and assuming that individual preferences and policy votes are consistent, we identify the drivers of the political consensus in favour or against such as new currency. Given three different properties of a currency – where the first two are the standard functions of medium of exchange and store of value and the third one is the less explored function of store of information – and three different existing moneys – paper currency, banking currency and cryptocurrency – if the individuals are rational but at the same time can be affected by behavioural biases – loss aversion - three different groups of individuals – respectively lovers, neutrals and haters – emerge respect to the CBDC option. Given the alternative opportunity costs of the different currencies, the CBDC issuing is more likely to occur the more the individuals likes to use a legal tender, and/or are indifferent respect to anonymity; at the same time, the probability of the CBDC introduction increases if a return can be paid on it, and/or its implementation can guarantee at least the counterparty anonymity.

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

Keywords: Central Bank Digital Currencies, Cash, Bitcoin, Cryptocurrencies

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1. Introduction

Do we would like a central bank digital currency (CBDC)? Should the demand of such as currency be relevant and which drivers could explain it? The macroeconomic interest of these questions becomes evident observing two recent and parallel trends in the advanced economies: on the one side the puzzling resilience of the public paper currency, notwithstanding the wide diffusion of the cashless payment technologies in advanced economies; on the other side a particular innovation is characterizing such as diffusion, i.e. the issuing of the so called crypto currencies, where cryptographic techniques are used to protect the identity of the exchangers that operate peer to peer via an electronic network without a trusted authority that managed it (blockchain technology). **Motivation**

Today the only public money available to all citizens is the paper currency, that still represents a relevant share of the money supply in the advanced economies. In 2015 per capita holdings of paper currency on GDP has been about 20 percent in Japan, 11 percent in Switzerland and in the Euro area, 8 percent in the US (Jobst and Stix 2017). Even more puzzling, the paper currency circulation gone up in the recent years and can be observed in several and heterogeneous economies (Jobst and Stix 2017, Berentsen and Schar 2018a), as well as inside and outside the issuing country if we are looking at a global reserve currency (Feige 2012, Judson 2012). **Cash**

On top of that, most of the paper currency in circulation are large denomination banknotes, notwithstanding recent review of the paper currency denomination structures are reversing such as policies. For example on May, 4th , 2016 the ECB Governing Council decided to stop the issuance of €500 banknotes around the end of the 2018, and on November 8th 2016 the Indian government surprisingly announced a legal tender status taking off that targeted the 86% of the currency then in circulation in order to implement a radical demonetization policy (Dharmapala and Khanna 2017). The individual preferences toward cash seem to be also consistent with the increase in corporate cash (Graham and Leary 2017, Faulkender et al. 2017). **Cash: facts**

Yet the public utility of the paper currency is increasingly disputed, given that it has been claimed (Rogoff 2017) that paper currency has at least two important drawbacks: on the one side it facilitates the growth of the illegal economy, with the corresponding losses in terms of missing tax revenues, without mentioning other social negative spillovers; on the other side it hampers the effectiveness of the monetary policy, being the basis of the existence of the zero lower bound on the nominal interest rate. **Cash: cons**

It is worth recalling that the benefits of paper currency issuing are essentially two: the State gains the seignorage revenues, given that it acquires goods and services in exchange for paper currency, and the seignorage revenues are still relevant (Rogoff 2017); the anonymity of the paper currency can protect the individual privacy rights against the risk that a State – both democratic or dictatorial – can misuse the information that can be collected using the payment system. **Cash: pros**

At the same time the recent wave of innovation in the private payment systems has been characterized by the issuing of the so called crypto currencies. The crypto currencies represents a private supply of means of payment, that are produced and distributed using decentralized transfer system, i.e. the so called blockchain or peer to peer technologies (or distributed ledger technology DLT) (Halaburda 2016, Bech and Garratt 2017, Chiu and Koeppl 2017, Huberman et al. 2017); it is worth noting that the blockchain technology can shape industrial and commercial networks different from the payment systems (Cong and He 2018). The usage of the crypto currencies as medium of exchange is so far limited: the use of **Crypto**

Bitcoin proxied by the average number of daily transactions is equal to 250 thousands, while established electronic payment systems such as Visa handled almost 100 billion transactions (Bruhl 2017). At the same time, since the introduction of Bitcoin more than one thousand crypto currencies have been registered (Bruhl 2017). These developments can have implications for the conduct of both monetary and banking policies (Bohme et al. 2015, Bech and Garratt 2017), as well as for the tax policy design (Ahmed 2017).

CBDC

Beyond the resilience of the traditional public paper currency on the one side, and the emerging interest for new private electronic currencies on the other side, a natural question arises: is it any role for a public digital currency? It has been claimed that (Bordo and Levin 2017) that the issuing of a central bank digital currency (CBDC) could transform all the aspects of the monetary system, serving as a costless medium of exchange, secure store of value and stable unit of account, benefiting the consumers (Moghadam 2018, Berentsen and Schar 2018b). In general the CBDC introduction could have deep consequences in the implementation of both monetary and banking policies (Raskin and Yermack 2016, Niepelt 2017), but the issue needed to be tackled in a complete and systematic way, taking into account that the CBDC issuing can be designed in different ways, regarding for example the level of privacy and/or the possibility of having interest bearing mechanisms (Lober 2017), and/or the possibility to issue cryptocurrencies (Berentsen and Schar 2018b), both in advanced and emerging countries (Camara et al 2018).

CBDC Facts

The CBDC issuing is an option that both academics and central bankers are nowadays 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). At the same time it is worth noting that such a topic implies the need to consider both the economic and the political economy perspectives (Tucker 2017), as well as the role of the technological innovations (Velde 2017).

Research Question

The aim of this paper is to propose a primer that can be used to analyse the CBDC demand. Using a portfolio approach and assuming that individual preferences and voting are consistent, it is possible to identify the drivers of the political consensus in favour or against such as new currency. The CBDC – being at the same time a public and virtual medium of exchange – should be completely different on the one side from the existing forms of virtual monies, which are issued from private regulated firms (banks) and private unregulated entities (blockchain network), and on the other side from the paper currency. In other words the existence of a CBDC should change the possibility of each agent to allocate her/his funds – thereafter her – given her financial preferences.

Outline

Therefore the key question arises: how the existence of a CBDC should change the portfolio allocation in an advanced economy? In order to address such a question, we propose a simple theoretical framework, where individuals choose their portfolio allocation when a new medium of exchange – i.e. the CBDC – is introduced, starting with rational citizens and then taking into account the possibility behavioural biases – i.e. loss aversion. We assume three different properties of a currency – medium of exchange, store of value and store of information – and that three different moneys – paper currency, banking currency and cryptocurrency – already exist. Finally, assuming that the individual votes on the policy option of issuing a CBDC are consistent with the financial preferences, the political consensus on the new currency is evaluated shedding light on its drivers.

Cash & Politics

It is worth noting that decisions on the monetary circulation can produce political consequences, as it has been studied – for example – in the case of India’s 2016 demonetization (Bhavnani and Copelovitch 2018).

The remainder of this paper is organized as follows. Section Two describes the basic framework, Section Three introduces the possibility of behavioural biases, and Section Four presents the political outcomes. Section Five concludes.

2. The Demand for CBDC

Consider a population with a continuum of individuals, each of them free to choose his/her – thereafter her – financial portfolio composition. Any available financial asset can be potentially use as a medium of exchange, i.e. any individual can use it to finalize an exchange being alternatively the payer or the payee. In other words any financial asset can be used as money, other things being equal.

Our attention is focused on the individual demand for money. Owing to innovation, the demand for money is likely to change. Let us assume that the State decides to issue a E-Currency – a CBDC - that shares with the traditional (paper) currency two features: a) it is a legal tender, i.e. the State guarantees its role as medium of exchange (safe asset) and b) no return it is payed, while the main difference is that c) it is distributed via centralized electronic networks, and then it have not the anonymity property, which characterized the paper currency, which is distributed via decentralized physical exchanges. **CBDC**

The E-Currency issuing could be implemented by giving the public access to accounts at the central bank, which is already technically feasible (Bech and Garratts 2017), but without any lending option. In other words the E-Currency is a public debt- card; the public nature – legal tender – differentiate it from the electronic banking money, which is issued by private entities. Our E-Currency is a central bank digital currencies, i.e. electronic central bank money exchanged in a centralized manner (Jobst and Stix 2017).

Our analysis differs from a previous work (Hendrickson et al. 2015) that considers the economics of the policymaker perspective in allowing or not the coexistence between legal tender currencies versus cryptocurrencies, where the preferences of the traders are exogenous, as well as the drivers that give rise to such preferences. Here we try to explore such drivers in explaining the probability of success of a CBDC policy from a political economics point of view. **CBDC demand**

For each individual in the population the E-Currency share π in her portfolio can be different from zero. Therefore, the overall demand for money will represent a share of the overall portfolio, being an individual component of it.

In general the demand for E-currency in nominal terms can be analyzed starting from a standard approach à la Baumol (Baumol 1952), which is still currently used to empirically model the demand for currency (El Hamiani Khatat 2018). We assume that, in a given period, any individual holds cash as an inventory of the medium of exchange, that can be given up when exchanges have to be finalized. In our framework the individual will choose among different kind of cash; we define cash as a financial asset that can be used as a medium of exchange. **Demand for money**

For the sake of simplicity and without any loss of generality, we assume that there isn't uncertainty in the exchange series – i.e. a steady stream of transactions occur - and so we can zoom on the transactional demand for cash, given that our aim is to compare alternative currencies.

Holding cash implies an expected opportunity cost which is equal to the level of return r. The return includes any possible gain – including the non interest gains - in holding assets different from cash.

Opportunity Costs

Respect to the traditional demand for cash, we assume that using cash can spread information on the money holder. In other way we assume the existence of expected privacy costs in using money for exchanges. The privacy costs can be associated with the value of each transaction, as well as with the number of implemented transaction.

Privacy Costs

The relevance of the privacy costs is linked to the so called demand for trustlessness (Pagnotta and Buraschi, 2018). In general the trustless networks produce exchanges in a manner that does not require that the involved players either know or trust each other; in a complete trustless exchange the privacy costs are zero. It has been noted (Pagnotta and Buraschi 2018) that the demand for trustlessness – that we can call demand for anonymity – is likely to be correlated with the demand for censorship resistance. i.e. the players like networks that prevent any third party for imposing any particular restriction, where such as property was originally born to prevent any imposition in terms of network contents (Perng et al. 2005).

Demand for Trustlessness = anonymity

Another difference respect to the traditional demand for cash is that having different types of medium of exchanges, their safeness can be different. The safeness of a medium of exchange depends on its probability to be accept in a transaction. In other words for any kind of cash we can identify its expected liquidity costs l.

Liquidity Costs

Therefore, given one kind of cash, we have the overall value T of the transactions, the cash holding π, the return r, the privacy costs p, the liquidity costs l. In the given period any individual will implement $\frac{T}{\pi}$ exchanges, the privacy costs will be equal to $b(\frac{T}{\pi}+\pi)$ while the liquidity costs will be equal to $l(\frac{T}{\pi}+\pi)$. The average cash holding will be $\frac{\pi}{2}$, and the corresponding opportunity cost will be $r\frac{\pi}{2}$. The overall cost C of the cash holding will be:

$$C = r\frac{\pi}{2} + b(\frac{T}{\pi}+\pi) + l(\frac{T}{\pi}+\pi)$$

The cost minimization will imply:

$$\frac{\partial C}{\partial \pi} = \frac{(r+2b+2l)\pi^2 - 2(l+b)T}{2\pi^2} = 0$$

And then:

$$\pi^* = \sqrt{2}\sqrt{\frac{(l+b)T}{r+2(l+b)}}$$

The optimal cash holding will be directly associated with the value of the transactions and inversely associated with the opportunity costs. The effects of changes in both privacy and liquidity costs are driven in two opposite direction by the number of transaction, that triggers an increase in the cash holding, and by the dimension of the cash holding, that pushes the individual in reducing it.

It is worth noting that our demand for cash so far mimics the features of a standard demand for money, both in normal (Gerdesmeier 1996, Sriram 1999) and in extraordinary times (Dreger et al. 2016, Jung 2016):

$$\pi = \Omega(Y, r, u)$$

With Y denotes a set of transaction variables – as income and wealth – while r is a set of rate of return on alternative assets and u are the individual preferences. Usually the transaction variables are positively associated with the demand for money, whereas the rates of return represent the opportunity cost, that is negatively associated with the demand for currency, and the individual preferences are homogeneous.

CBDC drivers

Now, given income and wealth, let us assume that the individual preferences are heterogeneous respect to the three crucial properties of a currency: medium of exchange, store of value and store of information. The three properties capture the different risks that the holding of a financial asset can imply in any given moment.

Currency properties

First of all we assume that any individual cares about the liquidity costs, which are associated with the probability that the asset cannot be traded, i.e. used as a medium of exchange and transformed in other goods and services. We assume that the issuer type influences the shape of the liquidity costs. When the currency is a legal tender, we assume that in a given territory it is the safer asset, being the obligation for each trader to accept in any exchange between both public and private traders; in other words any trader cannot refuse to accept the legal tender as payment. The legal tender, which is also the unit of account, minimized the expected liquidity costs. It is the public nature of the medium of exchange that guarantees the complete acceptability; the driver of such as property can its capacity to supply a common knowledge (Schnabel and Shin 2018).

Liquidity Costs

We assume that the legal tender property of the outside money internalizes the public gains that such feature implies, as the monetary policy effectiveness, and/or the seignorage gains (Rogoff 2017), notwithstanding it has to be acknowledged the properties of the private inside money (Diamond and Rajan 2001) at least as a portfolio diversification device.

Our definition of a safe asset zooms on its liquidity properties (Greenwood et al. 2016), rather than on the property to preserve its expected value – as for example in Caballero and Farhi 2017.

Safe Asset

Regarding such as second property of a financial asset – i.e. its expected value – we acknowledge its relevance for the individuals, using as its proxy the real expected return of each portfolio asset, which summarizes the standard opportunity costs, i.e. the purchasing power expected gains/losses. Assuming that inflation is likely to be different from zero and that deflation is unlikely the opportunity costs of holding legal tender are positive. A positive expected return characterized a store of value (profitable) asset.

Opportunity Costs

Finally a currency is also a store of information: the individuals consider the privacy (transparency) risks that using a given currency for trading can imply, given that any exchange can disseminate information on the exchangers. In general anonymity characterizes an asset as a store of information.

Privacy Costs

Among the individuals that like the currency anonymity a relevant group are the people that appreciate such as property being motivated by illegal reasons, given that an anonymous currency can be an effective device to implement money laundering operation. The attention to the study of money laundering has progressively increased, recognizing the importance of money laundering in the development of any law violation that generates revenues. At the same the growth of the crypto currencies has been associated with illegal activities (Foley et al. 2018).

Illegal Driver

In fact, the conduct of any illegal activity may be subject to a special category of transaction costs, linked to the fact that the use of the relative revenues increases the probability of discovery of the crime and therefore the likelihood of incrimination. Those transaction costs can be minimized through an effective money laundering secrecy action, a mean of concealment that separates financial flows from their illegal origin; the specific economic function of this instrument is to transform potential income into effective purchasing power (Masciandaro 1999). Inside the general framework of the economics of money laundering (Masciandaro et al. 2007, Unger 2007, Schneider and Windischbauer 2008) a currency demand approach has been recently proposed (Ardizzi et al. 2014, Ardizzi et al. 2016) which zooms on the relationship between an anonymous medium of exchange – i.e. cash – and the illegal component of its demand.

On this respect it is a matter of fact that also the electronic peer to peer currencies has been associated with the risks of money laundering (Brayans 2014), given that the crypto currencies seem to be especially effective for conducting illegal transactions (Hendrickson et al. 2015).

We assume that the expected transparency risks are associated with the distributional property of any given currency, that can be centralized or decentralized, where the latter minimizes the privacy risks. The decentralized system – or peer to peer system – characterized both the paper currencies – physical peer to peer network - and the crypto currencies – electronic peer to peer network, via the blockchain technologies.

Information & Currency Distribution

In our model we postulate that only the crypto currencies used the blockchain technology as platform. The blockchain mechanism can be characterized as follows: all the transactions are publicly recorded using the payer´s and the payee´s public email addresses, but such addresses do not need to reveal any information on the exchangers, being pseudonym based (Bech and Garrett, 2017).

Crypto & Blockchain

Therefore we assume that using the cryptocurrencies guarantee the counterparty anonymity and – at least partially - a full third part anonymity. It is worth recalling that a significant share of crypto currencies adopters so far sought the anonymity property, that wasn't available through the alternative electronic media of exchange (Bohme et al. 2015).

Our assumptions take stocks of the debate on the third party anonymity (TPA): the TPA is for sure a property of the paper currency, while the existence or not of such as property in the case of the blockchain transfer is controversial (Bohme et al. 2015) and the crypto currencies as been defined a quasi-anonymous medium of exchange (Hendrickson et al. 2015). At the same time is it unclear how much individuals actually value anonymity of either sort (Bech and Garrett 2017, Athey et al. 2017).

Crypto anonymity

We assume that the degree of anonymity depends on the distribution properties, where the peer to peer or decentralized system (paper currency and blockchain) guarantee higher degree of anonymity. The electronic nature can characterized both the decentralized and centralized payment system networks. In fact it has been claimed that if the blockchain technology is adopted by a centralized government – i.e. decentralization and blockchain are features that can be separated – the anonymity is gone (Kakushadze and Russo 2018).

In our framework we associate the distributional feature of a currency with the anonymity property. It is worth noting that here the distributional feature other summarizes two technical characteristics – accessibility and form – that can be separately analyzed (Bech and Garratt 2017).

Further we do not associated the distributional feature with gains and/or losses in terms of efficiency – i.e. transaction costs - given that on this topic the debate is still in a state of flux; while someone assumes for granted that the crypto currencies are low cost payment platforms (Hendrickson et al. 2015), for others the opposite seems to be true (Lowe 2017, Kaminska 2017, Yermack 2014), then in general it seems so far not clear if consumers benefit from using electronic decentralized systems (Bohme 2015).

Crypto other properties

In any case the circulation of currencies with uncertain properties – as the crypto currencies can be considered – could be explained using the general assumption that in some circumstances the existence of good and services with such features can increase on average the consumer surplus via the resulting overall competition among producers (Berg and Binsbergen 2017).

Finally it is worth noting that we could enlarge without problem our taxonomy, assuming that other private payment technologies which are at the same time not supplied by banks and are not based on blockchain mechanisms (shadow payment system) can enjoy – at least partially - the anonymity property (Gapper 2017).

Other currencies

Summing up, the financial assets that can be used as currencies are different respect to three main properties: 1) the issuer, that can be a public or a private entity; 2) the existence of an overall expected return; 3) the distribution network, that can be either centralized or decentralized.

In our economy, before the introduction of the E-Currency, in allocating her portfolio each individual can choose between the traditional paper currency, and two types of private assets that can be used as currencies: banking currency and crypto currency.

Currency Taxonomy

The three traditional key features of the paper currency are the role of the State as issuer, the absence of a nominal return and anonymity . The importance of such as drivers has been tested in the empirical analysis of the recent rising demand for paper currency (Jobst and Stix 2017), finding that the paper currency demand has been was mainly driven by higher level of uncertainty (legal tender effect) and lower level of the interest rates (expected return effect). while the absence of the anonymity effect has been explained with methodological difficulties, as well as well with the sample features. Finally the paper currency isn´t electronically distributed.

Both the banking currency and the crypto currency are not legal tender, have a (different) real expected return, but only the crypto currency is distributed via a decentralized network, guaranteeing a certain degree of anonymity. It is worth noting that, being the banking currency issued by a regulated firm, we could assume that its safeness is greater respect to the crypto currency.

Currency Comparisons

Regarding the expected return, the crypto coins are characterized by a value that changes, with ups and downs (Bech and Garratt 2017, Liew and Hewlett 2017, Chuen et al. 2017), in some cases with financial anomalies (Caporale and Plastun 2017, Caporale et al. 2018) and in general with a complex volatility (Catania and Grassi 2017) , while the banking currency traditionally yields a nominal return, which is relatively low and stable.

On this respect, the specialness of the crypto currencies is associated with the drivers of its value: unlike physical commodities it has no a positive direct utility due to practical use and it is not a liability of anyone, then it does not have any future dividends; its expected return relies exclusively on expectations of future demand with the corresponding increase of the resale value, given a supply that is supposed to be prospectively fixed – in the case of the Bitcoin the maximum amount is 21 million, and as November 27th 2017 16.7 million bitcoins have been issued (Bruhl 2017). The other drivers of the demand for crypto currencies are likely to be a loss of trust in the public authorities – it isn't a legal tender – and/or the desire among the exchangers to hide their identities (Niepelt 2016).

Respect to the E-Currency, both the private currencies have not a public issuer and lower opportunity cost risks. The banking currencies are private liabilities, while the crypto coins are not the liabilities of anyone (Bech and Garratt 2017).

Table 1 summarizes the three features of the four different currency types:

TABLE 1: CURRENCY TYPES

CURRENCY TYPES	SAFE ASSET (legal tender = low liquidity costs) SAFENESS	STORE OF VALUE ASSET (store of value asset = low opportunity costs) PROFITABILITY	STORE OF INFORMATION ASSET (decentralized distribution= low privacy costs) ANONYMITY (TRUSTLESSNESS)
E-CURRENCY (CBDC)	YES	NO	NO
PAPER CURRENCY	YES	NO	YES (full) (technology: decentralized physical chain)
BANKING	NO low	YES low	NO

CURRENCY			
CRYPTO CURRENCY	NO high	YES high	YES (partially: quasi anonymous) (technology: blockchain, pseudonym based, decentralized electronic chain)

The specialness of the E-Currency depends on being both an electronic and a public currency. For a portfolio diversification point of view, an increasing share of E-Currency triggers expected benefits respect to both the paper currency (less transaction costs) and the private coins (less liquidity costs), but also expected costs comparing it with on the side with the paper currency (more transparency costs) and the crypto currencies (more transparency costs and more opportunity costs) and the private currencies (more opportunity costs).

CBDC

The individual heterogeneous preferences are summarized in a parameter *t*, that represent the individual type and captures her/his – thereafter her – degree of *aversion* toward the introduction of the E-currency (*E-currency aversion*), which is common knowledge.

CBDC aversion

The heterogeneity among individuals may arise from any driver that can affect personal preferences, for example from their ideology and culture to the nature and origin – legal or not – of their income and wealth. The degree of aversion summarizes three possible individual and specific features: 1) Public issuing aversion ; 2) opportunity loss aversion; 3) transparency aversion.

CBDC aversion: drivers

Having an E-Currency share π in her portfolio can influence the utility function of each individual, which can be different across individuals. Using the utility function introduced in Alesina and Passarelli (2015) and used in Favaretto and Masciandaro (2016), let $V(t_i, \pi)$ be the description of the preferences of the individual i :

$$V(t_i, \pi) = B(t_i, \pi) - C(t_i, \pi) \qquad (1)$$

Where $B(t_i, \pi)$ and $C(t_i, \pi)$ are respectively the individual benefits and costs. We assume that for each individual the abovementioned comparative benefits in in having E-Currency are increasing and concave in the E-Currency share:

CBDC pros

$$\frac{\partial B(t, \pi)}{\partial \pi} > 0 \quad \frac{\partial B^2(t, \pi)}{\partial \pi} < 0 \qquad (2)$$

We assume that the benefits of having an electronic safe asset - i.e. less transaction costs respect to the paper currency and less liquidity costs respect to the private coins - is increasing but at a decreasing rate with its share.

At the same time we assume that the individual comparative costs in in having E-Currency - more opportunity costs respect to the private coins and more transparency costs respect to the decentralized payment systems, i.e. paper currency and crypto currency - are increasing and concave in the E-Currency share:

$$\frac{\partial C(t,\pi)}{\partial \pi} > 0 \quad \frac{\partial C^2(t,\pi)}{\partial \pi} \geq 0 \qquad (3)$$

Finally recalling that the individuals are heterogeneous with respect to their degree of E-currency aversion , they can be indexed such that more adverse individuals bear higher marginal costs and/or enjoy lower marginal benefits from having the E-Currency in their portfolios :

CBDC cons

$$\frac{\partial B_\pi(t_i,\pi)}{\partial t_i} \leq 0; \ \frac{\partial C_\pi(t,_i\,\pi)}{\partial t_i} \geq 0 \qquad (4)$$

Given the assumption from (1) to (4), the equilibrium is interior, i.e. the E-Currency share is non negative:

$$\frac{\partial B(t_i,0)}{\partial \pi} > \frac{\partial C(t_i,0)}{\partial \pi} \qquad (5)$$

For each individual the utility is increasing in the E-Currency share and the optimal E-Currency share $,\pi^*$ is such that marginal benefits match marginal costs:

$$\frac{\partial B_\pi(t_i,\pi)}{\partial \pi} = \frac{\partial C_\pi(t_i,\pi)}{\partial \pi} \qquad (6)$$

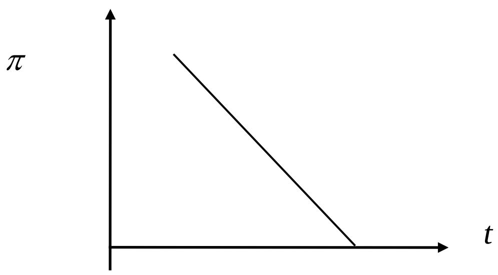
And that:

$$\frac{\partial \pi^*}{\partial t_i} < 0 \qquad (7)$$

In words, the optimal degree of E-Currency will be depend on the personal degree of E-currency aversion $\pi^*(t_i)$, i.e. the more the individuals dislike the public nature of the issuer and/or to have opportunity costs and on the contrary like the anonymity gains, the less will be the E-Currency share in their portfolios (Figure 1).

CBDC & aversion

FIGURE 1 AVERSION AND E-CURRENCY SHARE

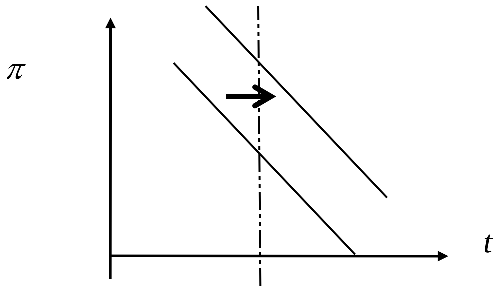


It is worth noting that:

Drivers

Any shock that modify the drivers that influence both the benefits and costs in having E-Currency will change the optimal share, given the individual aversion; for example, given its legal tender status, any policy that increases the efficiency and the security of the public digital currency (Bordo and Levin 2007) will increase the optimal E-Currency share (Figure 2):

FIGURE 2 LEGAL TENDER GAINS AND E-CURRENCY SHARE



Similarly an increase in the E-Currency share will occur if a return can be paid on it. In fact, as with other kinds of electronic money, it could be technically possible to pay interest on a central bank digital currency, as it is possible today to pay interest on the reserves of the commercial banks (Bech and Garratt, 2017, Bordo and Levin 2017, Segendorf 2017).

The same is true if the E-Currency implementation would reduce the transparency costs, for example allowing E-currency exchanges where the payer unknown to payee but the central bank have all information, having counterparty anonymity without third-party anonymity (Segendorf 2017). Given the individual sensibility respect to the transparency costs, if the existence of CBDC would be a device to isolate the demand for privacy due to illegal reasons, the CBDC issue can be an effective strategy against money laundering and all the correlated illegal activities (Bordo and Levin 2017).

3. CBDC Demand and Loss Aversion

Loss Aversion

Now we assume that with loss aversion, and for every portfolio choice, losses loom larger than gains, and both are evaluated with respect to a given *status quo*. Let $z > 0$ be the parameter which captures loss aversion and let π^{SQ} be the *status quo* E-Currency share. Given condition (5), the status quo E-Currency share is non negative so we can analyze in general how a given portfolio allocation can change if a shock occurs ; on top, if we assume that the E-Currency can be arbitrarily small we can also mimic the specific real world situation of the E-Currency introduction.

With loss aversion an increasing E-Currency share - $\pi > \pi^{SQ}$ - entails more benefits than costs, but higher expected costs yield psychological losses which amount to:

$$z(C(t_i,\pi) - C(t_i,\pi^{SQ})) \qquad (8)$$

Vice versa reducing the E-Currency share - $\pi < \pi^{SQ}$ - overall entails less benefits than costs, with psychological losses in terms of benefits – i.e. due to less public guarantees and/or less efficiency - which amount to:

$$z(B(t_i,\pi^{SQ}) - B(t_i,\pi)) \qquad (9)$$

Therefore the individual goal function with loss aversion $V(t_i, \pi / \pi^{SQ})$ is given by the basic utility $V(t_i, \pi)$ minus the psychological losses due to the departures from the *status quo* allocation:

$$V(t_i \pi / \pi^{SQ}) = V(t_i, \pi) - z(C(t_i, \pi) - C(t_i, \pi^{SQ})) if \pi > \pi^{SQ}$$

$$V(t_i \pi / \pi^{SQ}) = V(t_i, \pi) - z(B(t_i, \pi^{SQ}) - B(t_i, \pi)) if \pi < \pi^{SQ}$$

The optimal conditions are as follows:

$$B_\pi (t_i, \pi) = (1+z) C_\pi (t_i, \pi) if \pi > \pi^{SQ} \quad (10)$$

$$(1+z) B_\pi (t_i, \pi) = C_\pi (t_i, \pi) if \pi < \pi^{SQ} \quad (11)$$

Therefore for each individual it will be true that, given her level of aversion t_i, she will set her preferred E-Currency share π_i according to the following rule:

$$B_\pi (t_i, \pi) = (1+z) C_\pi (t_i, \pi) if t_i < t^S$$

$$(1+z) B_\pi (t_i, \pi) = C_\pi (t_i, \pi) if t_i > t^T \quad (12)$$

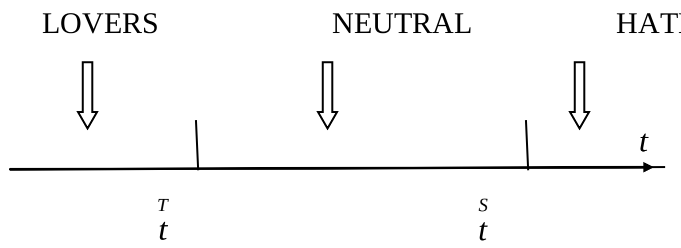
$$\pi = \pi^s if\ t^T < t_i < t^S$$

It is worth noting that $t^T and\, t^S$ with $t^T < t^S$ represents respectively a lower bound and a higher bound in the distribution of aversion that depend on the status quo portfolio allocation.

Therefore every population can be splitted in three different groups: E-Currency Lovers people - $if t_i < t^T$ - E-Currency Haters people - $if t_i > t^S$ and Neutral people - $if\ t^T < t < t^S$ (Figure 3).

Peoples

FIGURE 3 INDIVIDUALS: LOVERS, NEUTRAL AND HATERS



Each individual will express well defined E-Currency share preferences. With respect to the basic situation we are now assuming that i) each individual will evaluate any situation in terms of changes from the E-Currency share status quo; ii) any negative effect of a change with respect to the status quo are thought to loom larger than a positive effect of equivalent magnitude. The two assumptions are a simple application of the loss aversion principle (Kahneman and Tversky 1979, Tversky and Kahneman 1991), highlighting the fact that if there is a loss/gain asymmetry for individuals, inertia is more likely to occur, as we will see below.

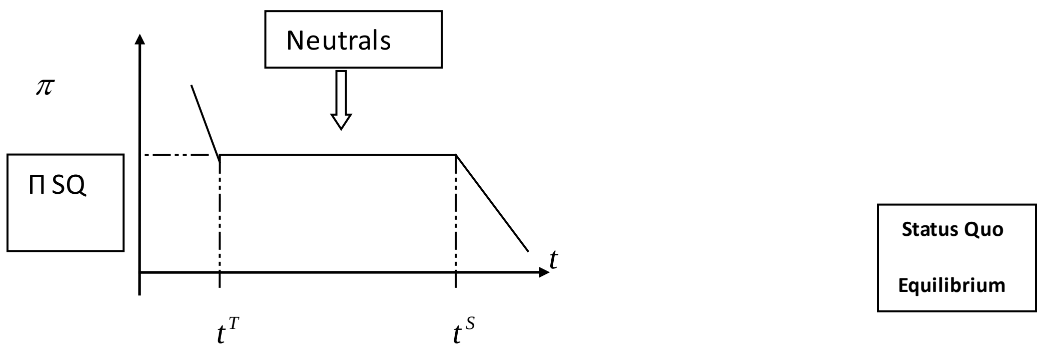
Given the preferences, for each individual the optimal E-Currency share will depend on her aversion t_i, having three possibilities: lover, neutral and hater. More precisely three different equilibria can arise (Figure 4):

$$\pi = \pi^{SQ} if\ t^T < t_i < t^S$$

$$\pi < \pi^{SQ} if\ t_i < t^T \qquad (13)$$

$$\pi > \pi^{SQ} if\ t_i > t^S$$

FIGURE 4 PEOPLE TYPES AND E-CURRENCY SHARE



The existence of loss aversion influences the portfolio decisions at least via a *Moderation (Status Quo) Effect*:

The E-Currency share outcome will be the status quo share π^{sSQ} if the individual is neutral. Further, given that the distance between $t^T and\ t^S$ is increasing in $z > 0$, the more the loss aversion is increasing the more likely the individual is neutral: a status quo bias – i.e. portfolio inertia - will emerge. In other words more loss aversion among individuals reduces the distance between their E-Currency share positions. As the individuals become more loss averse, neutral people increase in number and portfolio inertia is likely to increase. In other words being π^* the equilibrium E-Currency share, we have that increasing loss aversion triggers portfolio inertia, i.e. :

$$\pi^* = \pi^{SQ} \text{ if } z > 0 \qquad (14)$$

In words: the more that are individuals that disproportionally dislike the expected losses the less there will be change in the E-Currency share.

Preferences & Voting

4. Voting for CBDC Issuance

Now we assume that our individuals is a population of citizens that have to choose if and how to introduce the E-currency; the overall procedures can be summarized through a unidimensional policy $p \in R^+$. On top we assume that for each individual her optimal policy p can be proxied using her optimal E-currency share. Therefore haters vote for lower CBDC policies, i.e. against them; the opposite is true for lovers preferences.

The policy outcome will depend on the voting rules. First of all, which should be the optimal policy if a social planner is in charge? The benevolent dictator would maximize the overall sum of individuals' preferences:

$$\int [B(t,p) - C(t,p)] dFt \qquad (14)$$

Where the first best CBDC policy will be define in order to equalize the average marginal benefits $\overline{B}_p(p)$ and the average marginal costs $\overline{C}_p(p)$, i.e. solving the equation:

$$\overline{B}_p(p) = \overline{C}_p(p) \qquad (15)$$

Social Planner

The social planner goal is to maximize the effectiveness of the CBDC issuing taking into account its relative properties as medium of exchange, store of value and of information. But the social planner solution is not necessarily the equilibrium solution if a voting regime is in action.

If for the sake of simplicity, we assume that the voting regime is governed via a majority rule, the selected CBDC policy will depend on the preferences of the median voter, i.e. it will be equal to p_m. Therefore the introduction of the CBDC will be more like if the median voter is a lover; the opposite is true if in the given individual preferences distribution the median voter is an hater. The distribution of the prefer ences among the citizens becomes crucial to define will the actual CBDC policy.

Median Voter

At the same time, given such as distribution, the likelihood of a CBDC establishment will increase whatever event will increase its expected gains and/or will decrease its expected costs.

Finally, if we introduce the loss aversion, we can assume that in the status quo situation the E-Currency doesn't exist, i.e. in our model such an assumption implies $p_{ST} = \pi_{ST} = \varepsilon$, where ε is infinitely small. Now we assume that the reference point for the citizens is the status quo situation, our assumption seems to be sufficiently robust, given that usually the debate on the pros and cons of introducing a CBDC is usually assessed against the existing payment system situation; it is a backward looking reference point (Alesina and Passarelli 2015).

Given the abovementioned three group of citizens – lovers, neutrals and haters in Figure 4 - if the median voter is the intermediate group, the policy outcome is the status quo, i.e. the CBDC is less like to be introduced.

Median Voter & Status Quo

5. Experiment Design

In our model the individuals face portfolio decision problems with value trade-offs, given that any of the four actual currencies can be differently characterized respect to three abovementioned properties: safeness, profitability and anonymity. The model can be tested in a laboratory experiment, taking into account the current cash payment habits (Rinaldi, 2017).

Subjects can be students from Bocconi University, coming from various academic backgrounds. The experiment can be computer based, run in English with 30 minute sessions of 3 stages, each of them of 8 subjects. Two experimenters can be present in each session, Instructions can be read aloud. At the end of the instructions the students can provide her/his – thereafter her – age, gender, academic background.

The subjects can be asked to price sequentially monetary portfolios that can have different shares of the currency types, with an increasing degree of diversification. The students can be paid a show-up fee of 100 Euros.

The portfolio can be composed in such a way that subjects are familiar with the kind of questions that have been 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).

Before the experiment the experimenters will describe the building up of the alternative portfolios and the properties of the different types of currency. The key assumption is that the students have to select their preferred cash portfolios, using liabilities issued by private banks with different properties. Subjects had to select a series of portfolios in a sequence of three stages, where in each stage the possibility of portfolio diversification increases.

In the first stage we have the Bank A, with a level of safeness which is equal to $p_A > 0$. The level of safeness is an indicator that measures the liquidity risks, i.e. the likelihood that the chosen currency is refused in a transaction as a medium of exchange. It can be considered an indicator of the trustworthiness of the bank.

Bank A issues two different kind of currencies: electronic coin and a saving card. Both liabilities can be used for transaction purposes; they have the same degree of safeness, being issued by the same issuer. For the same reason they have the same degree of anonymity, which is equals to zero (maximum level of privacy costs). The difference is that the saving card has a return r - which is certain and low – while the electronic coin is can be used for every amount, in every moment and in every exchange ; in other words, the expected transaction costs are lower using the electronic coin. Therefore in selecting each portfolio the students address a trade – off between operational efficiency and opportunity costs.

There is a series of portfolios. Each portfolio is a wallet which is composed of the two kind of currencies (electronic coin and the bank saving card), whose values are expressed in Euro. The students have an endowment of 100 Dollars, that they have to invest in the wallet. The exchange rate between Euro and Dollar is assumed to be constant and equal to 1. In each portfolio there is a different (increasing) level of the return percentage of the saving card. The initial portfolio 1 is fixed: being the return of the saving card equals to zero, the share of the two currencies are 100 and 0.

	PORTFOLIOS		ENDOWENT
PORTFOLIO and return *r %* on the debt card	ELECTRONIC COIN	SAVING CARD CASH	100 DOLLARS
1 return = 0	100	0	100
2 return= 0.25			100
3 return= 0.50			100
4 return= 0.75			100
5 return= 1.00			100
6 return= 1.25			100
7 return= 1.50			100
8 return= 1.75			100
9 return= 2.00			100

For each portfolio, subjects have to choose the preferred shares of the two kinds of medium of exchanges. They had to confirm their choices.

At the end of the first stage each subject *J* selects a series of his /her - thereafter her - optimal portfolio $P_j(x_1, y_1)$, where x_1 and y_1 are the selected values respectively of the electronic coin and of the private debt card. The selected portfolios signal the individual preferences in terms of opportunity costs (profitability).

In the second stage the subjects can introduce a share of crypto currencies in their portfolios. The Bank A can issue a crypto cash, with an increasing level of anonymity, the same efficiency of the saving card, but with zero return.

There is a series of portfolios. Each portfolio is a wallet with the three kind of cash (electronic coin, saving card and crypto cash), whose values are expressed in Euro. The students have as usual an endowment of 100 Dollars, that they have to invest in the wallet. The exchange rate between Euro and Dollar is assumed to be constant and equal to 1. In each portfolio there is a different (increasing) level of the anonymity of the crypto cash . The initial portfolio 1 is fixed. The starting point is the last portfolio of the first stage, i.e. $P_j(x_1^9, y_1^9)$ and being the initial level of anonymity of the crypto cash equals to zero, the share of the first two currencies are the same of the abovementioned portfolio, while the share of the crypto cash is zero:

	PORTFOLIOS		ENDOWMENT

PORTFOLIO and level *b%* of crypto cash anonymity	ELECTRONIC COIN	SAVING CARD CASH	CRYPTO CASH	100 DOLLARS
1 b = 0	x_1^9	y_1^9	0	100
2 b = 0.10				100
3 b = 0.20				100
4 b = 0.40				100
5 b = 0.50				100
6 b = 0.60				100
7 b = 0.80				100
8 b = 0.90				100
9 b= 1				100

At the end of the second stage each subject J selects a series of her optimal portfolio $P_j(x_2, y_2, z_2)$ with three kinds of cash - electronic coin, saving card and crypto cash – with their preferred values, respectively x_2, y_2 and z_2 . The selected portfolios signal the individual preferences in terms of privacy costs (anonymity).

In the third and final stage the subjects can insert a safer asset in their portfolios. The Bank B is introduced; the Bank B is more safe that the Bank A, i.e $p_B = p_A + l$, with $l \geq 0$, and $l_{mas} = 100$. Bank B can issue an electronic coin with the same degree of efficiency of the coin issued by the Bank A, but with increasing degree of safeness *l*, without return and without anonymity.

There is a series of portfolios. Each portfolio is a wallet of the four kind of cash (electronic coin, saving card , crypto cash, safe coin), whose values are expressed in Euro. The students have the usual endowment of 100 Dollars, that they have to invest in the wallet. The exchange rate between Euro and Dollar is assumed to be constant and equal to 1. In each portfolio there is a different (increasing) level of the safeness of the safe cash . The initial portfolio 1 is fixed. The starting point is the last portfolio of the first stage, i.e. $P_j(x_2^9, y_2^9, z_2^9)$ and being the initial level of safeness of the safe cash equals to zero, the share of the first three currencies are the same of the abovementioned portfolio, while the share of the safe cash is zero. Then:

	PORTFOLIOS				ENDOWMENT
PORTFOLIO and level *l%* of safe cash safeness	ELECTRONIC COIN	SAVING CARD CASH	CRYPTO CASH	SAFE COIN	100 DOLLARS

1 l = 0	x_2^9	y_2^9	z_2^9	0	100
2 l = 5					100
3 l = 10					100
4 l = 15					100
5 l = 20					100
6 l = 60					100
7 l = 80					100
8 l = 90					100
9 l= 100					100

At the end of the third and final stage each subject J selects a series of her optimal portfolio $P_j(x_3, y_3, z_3, \pi_3)$ with four kind of cash - electronic cash, saving card, crypto cash and safe cash - with their preferred values, respectively x_3, y_3, z_3 and π_3. The selected portfolios signal the individual preferences in terms of safeness costs (safeness).

If we assume that the central bank issue its own CBDC with the following property – high efficiency, no return, no anonymity, full safeness - at the end of the experiment for each subject J we will have her optimal share of the CBDC, . the $\pi^*(t_i)$ of our model.

At the same time, the value of y_3 and z_3 can offer information on the possible crowding out due the introduction of a CBDC, given that the features of y and z mimic respectively the properties of the banking money and of the banknotes, at least in normal times.

It is worth noting that if the specialness of the crypto currencies is just in their technologies – i.e. the blockchain – and the only comparative advantage of such technologies rely just on the privacy costs, the specialness is likely to disappear the more the traditional players – banks and central banks – will implement the new technology.

Given the distribution of the $\pi^*(t_i)$ preferences, we could calculate the median voter choices.

The distribution of the $\pi^*(t_i)$ preferences could offer information also on the likelihood of loss aversion.

(Results of the experiment: yet to be written)

6. Conclusion

Exploring the link between individual liquidity preferences and CBCD issuing and business cycle can help in shedding light on the micro foundations of both normal time and extraordinary time phenomena – banking runs and financial instability (Haldane 2017), interest rate lower bounds (Rogoff 2017), precautionary cash trends (Graham and Leary 2017 and Faulkender et al. 2017) – and its consequences for the design of the two main tasks of the modern central banking: monetary policy and banking regulation.

Relevance

The existence of a relevant demand for E-currency would have implications for:

a) Monetary Policy: if we assume that the individuals are sensible to the technological properties – i.e. they completely dislike the physical form - the demand for E-currency would completely replace paper currency, and consequently the E-currency issuing has the potential to address and fix the zero lower bound constraint in the monetary policy implementation.

b) Banking Policy: In normal time, the more the opportunity cost discrepancies between the E-currency and the banking currency become smaller, the higher will be the risks to the business model of commercial banks, due the disintermediation. In extraordinary times - for example when bad news on the state of the banking health circulate - if we assume that the individuals can become extremely sensible to liquidity risks, a bank run is more likely to occur.

The aim of this paper has been to offer a primer in order to analyse the effects of the issuing of a central bank digital currency (CBDC). The analysis has been based on the assumption that the perspective of the CBDC issue influences the individual portfolio choices and consequently the voting in favour or against the introduction of such new currency.

Bottom Line

Given three different properties of a currency – medium of exchange, store of value and store of information – and three different already existing moneys – paper currency, banking currency and cryptocurrency – if the rational individuals can be also affected by behavioural biases – loss aversion - it has been shown that it is possible to disentangle in the population three different groups – lovers, neutrals and haters – respect to their preferences towards the CBDC introduction. Given the alternative opportunity costs of the different currencies, the CBDC issuing is more likely to occur the more the individuals likes to use a legal tender, and/or are indifferent respect to anonymity; at the same time, the probability of the CBDC introduction increases if a return can be paid on it, and/or its implementation can guarantee at least the counterparty anonymity.

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