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Preliminary Draft

CRYPTOCURRENCIES, CENTRAL BANK DIGITAL CASH, TRADITIONAL MONEY: DOES PRIVACY MATTER?♦

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Abstract

The aim of this paper is to analyze the demand of both traditional and new media of exchange – as cryptocurrencies and central bank digital currencies – proposing a novel specification of the demand for money. 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 privacy (anonymity value). The proposed framework is tested using a laboratory experiment. Our results show that anonymity matters, but less of the other two properties; at the same time, the presence of anonymity increases the overall appeal of a MOP, particularly if the individuals are risk prone; given anonymity, the sacrifice ratio between liquidity risk and opportunity cost are relatively high.

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

Keywords: Money, Cryptocurrencies, Central bank Digital Currency, Cash, Baumol, Friedman, Experimental economics

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1.Introduction

Which is the current shape of the demand for money? More precisely, which drivers could explain the demand of both traditional and new media of exchange – already existing, as the cryptocurrencies, or still in the pipeline, as the central bank digital currencies?

The macroeconomic interest of these questions becomes more evident if we observe three 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). At the same time, the issuing of central bank digital currencies (CBDC) is an option that is increasing taken in consideration.

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 seignorage 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 and 2018, Kahn et al. 2018, Mancini-Griffoli et al. 2018, Lagarde 2018), also for a law point of view (Ricks et al. 2018). 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).

In order to address such as questions, the aim of this article is twofold. We propose a novel specification of the demand for money that mixes the standard Baumol framework with a Friedman forward looking intuition. In such specification 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 privacy. The relevance of the new specification is tested using a series of laboratory experiments.

The remainder of this paper is organized as follows. Section Two describes the novel demand for money, while Section Three presents our experiment. Section Four concludes.

2. 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 privacy. 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 or investment 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 any currency can spread different level of information on the money holder. In other words, we assume that money is also a store of privacy. In fact if any kind of money can be considered a "store of memory" (Kocherlakota 1998, Fernandez-Villaverde 2018), a crucial difference between different medium of exchange relies on the fact that any currency can be considered a disseminator of information. Consequently individuals consider the privacy (transparency) risks inherent in using a given currency for trading, given that any exchange can disseminate

[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:

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

information 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). It is worth noting that the demand of such as medium of exchange seems to be extremely sensible to news about regulatory actions (Auer and Claessens 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

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

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 proposed (Ardizzi et al. 2014, 2016, Seitz et al., 2018) 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). On this respect, to analyse the economics of cryptocurrencies is not sufficient to explore the standard reasons for holding a medium of exchange (Cong et al. 2018) – the transaction motive and the investment motive – but the role of anonymity have to be considered.

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.

To describe the Baumol-Friedman demand for money, we can use a standard portfolio model in which alternative currencies are present (Santomero and Seater 1996) and each individual subjectively cares about illiquidity risks, opportunity-cost risks and private risks. In every period, each individual receives an income Y that she can store in a portfolio where the assets are different consumption goods, alternative MOPs and a financial asset that cannot be used as a medium of exchange. Each asset is associated with its own utility, which is proxied by its net expected return. The individual seeks to optimize her portfolio allocation and defines, among other choices, the optimal quantity for each asset, including the alternative MOPs.

More specifically, the individual uses her income to buy an amount G of j different consumption goods:

$$Y = \sum_{j=1}^{J} G_J \, .$$

A series of consumption expenditures (exchanges) occurs at discrete intervals during the focal period. As we are considering a monetary economy, the individual has to use an MOP to finalize those exchanges.

Between the exchanges, the individual holds different kind of assets. First, she holds an inventory of the various consumption goods. Each good in that inventory is associated with an expected rate of return of r_{Gj}, which captures its utility. That expected return can be either positive or negative, and may include, for example, the likelihood of spoilage. Second, the individual holds the unspent income in two kinds of financial assets: a savings (investment) asset S, which cannot be used as medium of payment, with an expected rate of return of r_S; and the alternative MOPs, with their respective expected returns r_{Mi}, which are used to proxy the opportunity costs of holding money.

Each medium of payment M_i is associated with its own rate of return r_{Mi}. Without any loss of generality, we assume that $r_s > r_{Mi} > r_{Gj}$. The individual implements any exchange using one of the available n different media of payment M_i, where the quantity of good j purchased using the medium i is G_{ji}, such that:

$$G_j = \sum_{i=1}^{n} G_{ji} \, .$$

To finalize the overall consumption expenditure for every good G_j, the individual implements a number of monetary exchanges Z_{ji} using the medium M_i. The probability that any medium M_i is accepted ranges from 0 to 1. In other words, each medium M_i is associated with perceived illiquidity costs. We assume that, in each exchange, such costs are equal to β_{ji} – a lump-sum cost that is independent from the value of the exchange.

At the same time, any medium M_i is characterized by its properties as a store of privacy (i.e., its degree of anonymity). We assume that the privacy costs associated with each medium

M_i can be proxied using the switching cost α_i, which captures the privacy losses associated with converting income in that medium of exchange. Again, we model such as losses as a lump-sum cost that is independent from the amount of the conversion. Exchanges occur between conversions and are evenly spaced. With N_{ji} representing the number of exchanges involved in buying good j with money i per conversion of M_i, we have:

$$Z_{ji} = T_j N_{ji}.$$

Given that consumption, exchanges and conversions are all evenly spaced, the profit function π of each individual can be expressed using the average values of the assets as follows:

$$\pi = r_s \overline{S} + \sum_i r_{Mi} \overline{M}_i + \sum_j r_{Gj} - \sum_i T_i \alpha_i - \sum_i \sum_j Z_{ji} \beta_{ji}.$$

For the first-order conditions, we can obtain the optimal average quantity of each alternative medium of exchange M_i:

$$\overline{M}_i = \left[\frac{\alpha_i}{2(r_S - r_{Mi})} \sum_j G_{ji} \right]^{1/2} - \sum_j \left[\frac{\beta_{ji} G_{ji}}{2(r_{Mi} - r_{Gj})} \right]^{1/2}.$$

Notably, given the income and consumption choices, the holding of each alternative money M_i is: i) directly associated with the anonymity risk per conversion, ii) inversely associated with the illiquidity risk and iii) inversely associated with the opportunity-cost risk.

In other words the money holding will be directly associated with i) the anonymity property, ii) the liquidity property and iii) the expected return property, which are respectively associated with the three causes - privacy motive, transaction motive and speculative motive – that can explain the demand for money.

3. The Experiment

In our framework, the individuals face portfolio decisions that involve value trade-offs, given that any of the 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. 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).

3.1 Measurement Method

Let $x^a = (x_1^a, x_2^a, x_3^a)$ indicate a payment method of an amount of a EUR , with three attributes x_1, x_2, x_3, where x_1 is the Illiquidity Probability (IP), x_2 the Expected Return (ER), and x_3 the Anonymity (ANM). The methodology consists of three major stages. First, we want to determine which of the three attributes the subjects value the most, and possible interactions among attributes. In order to do so, we select 18 media of exchange (points) of a EUR, with different levels of IP, ER, and ANM. For each of these media of exchange (MoE), we are interested in assessing the value the subjects attribute to them. We express this value in terms of cash, where the cash is a MoE with IP=ER=0 and ANM= YES. Hence, we elicit the cash indifference value z_i such that $x_i^a \sim z_i$ for i=1,…17. In other words, the subjects compare the an amount of cash – a MoE which is anonymous, with expected return but also any illiquidity risk – with alternative MoE, whose properties in terms of liquidity, return and anonymity are different.

In the second stage, we zoom on anonymity. In a sense we want to determine, when two MoE differ only in the anonymity dimension, how relevant is – if any - the preference for anonymity. Practically, we consider a portfolio with two MoE, $(0^a, 0^a, No^a)$ and $\left(0^b, 0^b, Yes^b\right)$ and elicit the optimal money allocation (a^*, b^*) between the two MoE . The bigger the positive difference between b*-a*, the higher the subjects' preference for anonymity is.

In the third stage, we want to understand in a context of anonymity - cryptocurrencies or central bank digital currencies, assuming credible anonymity for both types of MoE - how subjects trade-off between risk and return. Does it play the usual role or not? There are three types of MoE: the first two are the same as in the second stage. The third MoE is $(x_1; x_2; Yes)$ with three levels of IP and three levels ER. Hence, we create 9 portfolios and elicit the optimal money allocation (a^*, d^*, c^*) between the three MoE, $(0^{a*}, 0^{a*}, No^{a*})$, $(0^d, 0^d, Yes^d)$, (x_1^c, x_2^c, Yes^c). The third MoE is the only one that has a risk-return component different from zero. Hence, the higher the c*, the more the subject is willing to allocate money on the profitable, but risky MoE.

3.2. Study

3.2.1 Subjects and Incentives

The subjects were 98 from Bocconi University, with different background. Subjects were paid a flat fee of 10 EUR. At the end of the experiment, 10% of subjects could play for real one of the choices. We used the Prince method because it improves several aspects of existing incentive systems (Johnson et al., 2017). The incentive compatibility is very clear. Indeed, the choice question implemented for real is selected before the experiment starts, subjects' answers are framed as instructions to the experimenter about the real choice to be implemented at the end, the real and entire choice situation is in a sealed envelope. Subjects before starting the experiment picked one sealed envelope. At the end of the experiment, 10% of the subjects played for real (see Appendix A for a detailed description on how the envelopes have been constructed).

3.2.2 Procedure

The experiment was computer run with a minimum of three experimenters per session, with an average of 12 subjects per session. The experiment lasted one hour, on average: instructions were read aloud (see Appendix C for the instructions provided to the subjects), for twenty minutes, then subjects took a seat and could always read the instructions. The procedure to elicit the indifference values was made clear to the subjects, for each part. Once the bisection procedure for one

elicitation was over, the subjects moved to the next elicitation. The order of the elicitations within each part was random.

The experiment consisted of three parts. In all the three Parts, the elicitations were performed via a choice task. The choice task is known to be preferred to the matching one (Lichtenstein and Slovic, 1971, Bostic et al., 1990). The innovative aspect consisted in the fact that each step of the procedure to elicit the indifference value was visible to the subjects. The main reason for this was to make the experiment of a standard length.

In Part I, we used a standard bisection procedure to determine the 17 indifference values. As Table 1 shows, x_i^{100} is a payment method of 100EUR with *i*=1,…17. The 17 MoE of 100 EUR have been constructed by combining three levels of IP (0%, 1%, 10%), three levels of ER (0%, 5%, 20%), and two levels of ANM (Yes/No).

In Part II, we elicited, via an iteration procedure, the optimal money allocation (a^*, b^*) between the two MoE, $(0^a, 0^a, No^a)$ and $(0^b, 0^b, Yes^b)$. Subjects had to choose between two portfolios, Options A and B, which differed in the allocation of the 100EUR between the two MoE:

Option A:$((0^n, 0^n, No^n); (0^{b+10}, 0^{b+10}, Yes^{b+10}))$
Option B: :$((0^a, 0^a, No^a); (0^b, 0^b, Yes^b))$

where n=a-10, $a + b = 100$EUR . We started with a=10EUR. If subjects chose Option B, we kept adding 10 EUR until they switched to Option B. The experiment ended and then we stored the mid - point values, (a^*, b^*).

In Part III, we elicited via an iteration procedure, the optimal money allocation (a^*, d^*, c^*) between the three MoE $(0^{a*}, 0^{a*}, No^{a*})$, $(0^d, 0^d, Yes^d)$, (x_1^c, x_2^c, Yes^c) where (x_1^c, x_2^c, Yes^c) have been constructed by combining three levels of IP (5%, 15%, 25%), and three levels of ER (*1*0%, 20%, 30%), always in an anonymous context (ANM=Yes). Subjects had to choose between

two portfolios, Options A and B, which differed in the allocation of 100 EUR between the three MoE. For example:

Option A:$((0^{a*}, 0^{a*}, No^{a*})\,; \left(0^{d+10}, 0^{d+10}, Yes^{d+10}\right); \left(5\%^{c-10}, 10\%^{c-10}, Yes^{c-10}\right))$

Option B: :$((0^{a*}, 0^{a*}, No^{a*}); \left(0^{d}\,, 0^{d}\,, Yes^{d}\right); (5\%^{c}\,, 10\%^{c}\,, Yes^{c}\,))$

where $a* + d + c = 100$EUR. a^* , elicited in Part II, was allocated in the first payment under both Option A and B. If subjects chose Option B, we kept increasing c by 10 EUR until they chose Option B, in which case we stopped, took the midpoint, and stored c^* . c^* can be interpreted as the fraction invested in the risky payment. Table 2 provides the elicitations in Part II and Part III. Appendix B provides a detailed description of the elicitation procedures for each Part.

Table 1. The 27 points with the mean indifference values (standard deviation) and the predicted value for an expected value maximizer.

i	Illiquidity Probability	Expected Return	Anonymity	Mean (SD)	EV
1	0%	0%	No	97 (11)	99
2	1%	0%	No	93 (10)	98
3	10%	0%	No	80 (15)	89
4	0%	5%	No	106 (5)	104
5	1%	5%	No	103 (9)	103
6	10%	5%	No	90 (13)	94
7	0%	20%	No	124 (10)	119
8	1%	20%	No	121 (12)	118
9	10%	20%	No	108 (17)	108
10	1%	0%	Yes	94 (12)	99
11	10%	0%	Yes	81 (14)	90
12	0%	5%	Yes	107 (8)	105
13	1%	5%	Yes	105 (13)	104
14	10%	5%	Yes	90 (14)	95
15	0%	20%	Yes	127 (14)	120
16	1%	20%	Yes	123 (12)	119
17	10%	20%	Yes	109 (16)	108

Table 2. The 10 portfolios, in Part II and Part III, for which we elicit the optimal money allocation, (a^*, b^*) and c*, respectively.

i	Portfolio	Optimal Allocation	Mean Values
18	$((0^a, 0^a, No^a); (0^b, 0^b, Yes^b))$	(a^*, b^*)	(18,82)
19	$((0^{a*}, 0^{a*}, No^{a*}); (0^d, 0^d, Yes^d); (5\%^c, 10\%^c, Yes^c))$	c*	28
20	$((0^{a*}, 0^{a*}, No^{a*}); (0^d, 0^d, Yes^d); (5\%^c, 20\%^c, Yes^c))$	c*	37
21	$((0^{a*}, 0^{a*}, No^{a*}); (0^d, 0^d, Yes^d); (5\%^c, 30\%^c, Yes^c))$	c*	46
22	$((0^{a*}, 0^{a*}, No^{a*}); (0^d, 0^d, Yes^d); (15\%^c, 10\%^c, Yes^c))$	c*	10
23	$((0^{a*}, 0^{a*}, No^{a*}); (0^d, 0^d, Yes^d); (15\%^c, 20\%^c, Yes^c))$	c*	18
24	$((0^{a*}, 0^{a*}, No^{a*}); (0^d, 0^d, Yes^d); (15\%^c, 30\%^c, Yes^c))$	c*	26
25	$((0^{a*}, 0^{a*}, No^{a*}); (0^d, 0^d, Yes^d); (25\%^c, 10\%^c, Yes^c))$	c*	8
26	$((0^{a*}, 0^{a*}, No^{a*}); (0^d, 0^d, Yes^d); (25\%^c, 20\%^c, Yes^c))$	c*	9
27	$((0^{a*}, 0^{a*}, No^{a*}); (0^d, 0^d, Yes^d); (25\%^c, 30\%^c, Yes^c))$	c*	16

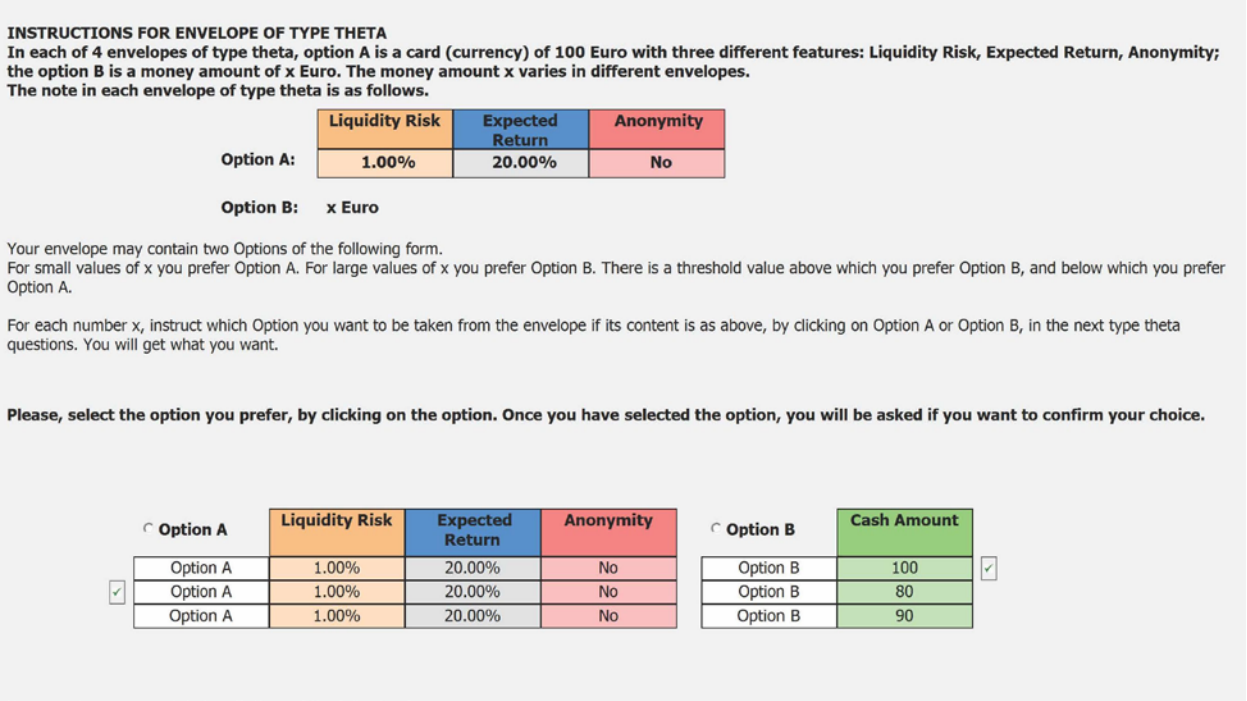

Figure 1. The screenshot of Part I, with the bisection procedure visible to the subjects.

3.3. Validity

To test for response error, we repeated a total 11 choice questions. Precisely, at the end of Part I, for each subject we repeated the third iteration (close to the indifference value) for 7 randomly selected elicitations. These elicitations can be different for each subject. At the end of Part III, for each subject we repeated the second iteration or the first one if the second one is not present for 4 randomly selected elicitations.

3.4 Statistical Analysis

The experimental setting for the first 18 questions is a full factorial design, with two factors , illiquidity risk and return, at 3 levels (No, Low, High), and a third factor, anonymity at two levels (Yes, No). The design has a total of $3^2 \times 2 = 18$ points. A full factorial design is an experimentation plan that allows to investigate the main and interaction effects of the three factors which can vary simultaneously. It contains all the possible 18 combinations of the three factors and it is represented by the hypercube in Figure 2. Each of the 80 participants provided an answer for each point, for a total of 1440 responses.

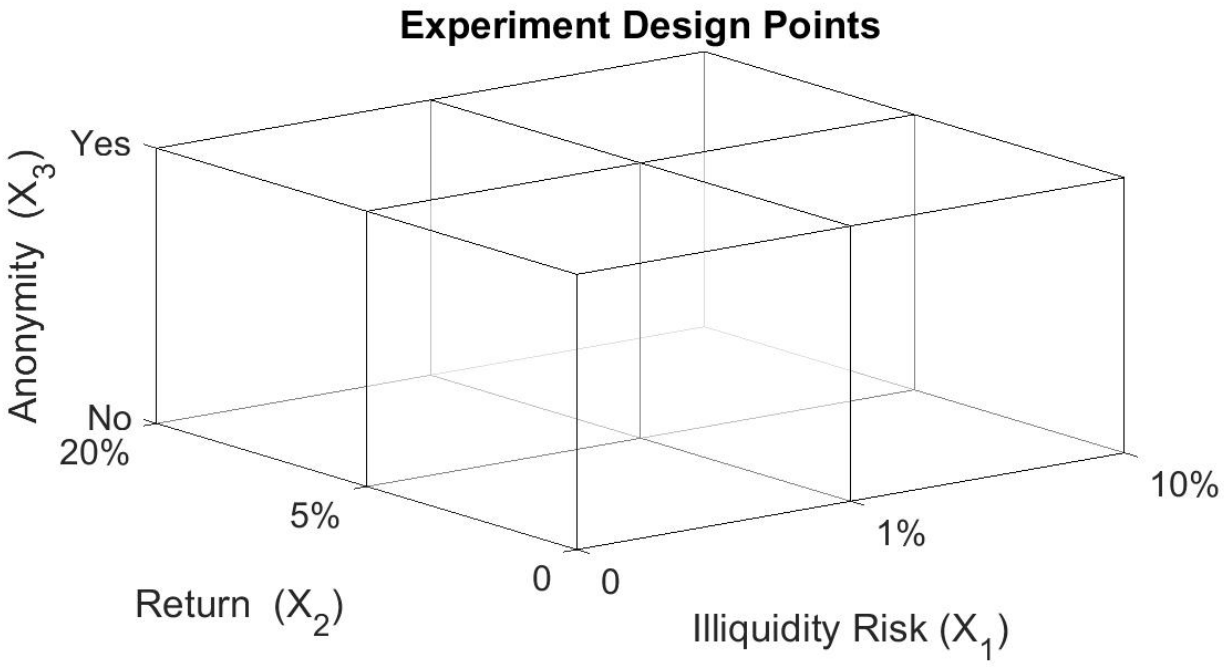

Figure 2: Full factorial design points used in this work. Two factors (illiquidity risk and return) have two levels, one factor (anonymity) has one level.

We proceeded to treat the data as per the recommended methodology in the literature of design of experiments for non-normal responses (see (Lewis, Montgomery, & Myers, 1999)(Lewis, Montgomery, & Myers, 2001) and Montgomery (2017)). In particular, we fitted to the data a Poisson regression model of the form:

$$E[Y] = \exp\big(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{1,2} X_1 X_2 + \beta_{2,3} X_2 X_3 + \beta_{1,3} X_1 X_3 + \beta_{1,2,3} X_1 X_2 X_3\big) \quad (0.0)$$

This model belongs to the well-known class of generalized linear model. After fitting (1.0), we have firstly tested its overall model fit using the likelihood ratio test. Then, we studied and interpreted the significance of the coefficients of the main effects $\beta_1, \beta_2, \beta_3$ and the interaction effects $\beta_{1,2}, \beta_{2,3}, \beta_{1,3}, \beta_{1,2,3}$.

To confirm the results obtained with the generalized linear model coefficients, we also computed alternative measures of statistical dependence between the output response (the value assigned by the subjects) and the three attributes. The rationale is that if all the available indices lead to the same indication concerning the attribute importance, then our inference concerning the relevance of the attribute is robust.

To do so, we use importance indicators introduced in the literature under the name of global importance measures, which are recognized to be among the most robust ways to infer parametric importance and to measure statistical dependence between a variable of interest and other variables on which the variable of interest depends in a statistical fashion.

The global sensitivity measures we compute are first order variance-based sensitivity measures, a sensitivity measure based on the distance between densities and two sensitivity measures based on the distance between cumulative distribution functions. Formally, let $(\mathsf{X}, \mathsf{B}(\mathsf{X}), P_{\mathbf{X}})$ denote the probability space associated with the vector of random variables $\mathbf{X} = \{X_1, X_2, ..., X_n\}$, with $\mathbf{X} \in \mathsf{X}$, $\mathsf{X} \subseteq R^n$. Then, one considers that the random variable of interest, Y, depends on $\mathbf{X}$ as $Y = g(\mathbf{X}) + \grave{o}(\mathbf{X})$, where $g : \mathsf{X} \mapsto R$ and $\grave{o}(\mathbf{X})$ is a stochastic error term with zero mean. Then, a first measure of statistical dependence between Y and any of the random variables X_i is given by the contribution of X_i to the variance of Y measures as

$$\eta_i = \frac{\mathsf{V}\left\{\mathsf{E}\left[Y \mid X_i\right]\right\}}{\mathsf{V}\left[Y\right]}$$

The quantity η_i is the variance-based importance of variable X_i (Saltelli & Tarantola, 2002) and coincides with Pearson's correlation ratio. This global importance measure is widely used in the literature; however, it does not satisfy Renyi's postulate D concerning measures of statistical dependence (Renyi, 1959). We then accompany this sensitivity measure by the calculation of additional sensitivity measures that satisfy such postulate. In particular, we consider the sensitivity measure

$$\delta_i = \frac{1}{2}\mathsf{E}_{X_i}\left[\int_{\mathsf{Y}} \left| f_{Y|X_i}(y \mid X_i) - f_Y(y) \right| \mathrm{d}y\right],$$

where $f_Y(y)$ and $f_{Y|X_i}(y \mid X_i)$ are, respectively, the marginal density of Y and the conditional density of Y given X_i, and the expectation is taken with respect to the marginal distribution of

X_i. Thus, δ_i measures statistical dependence as the distance between densities and it can be shown that its value is null if and only if Y is independent of X_i. To further corroborate the findings, we also estimate two global sensitivity measures that consider the distance between cumulative distribution functions:

$$\beta_i^{KS} = \mathsf{E}_{X_i}\left[\sup_y \left| F_{Y|X_i}(y \mid X_i) - F_Y(y) \right|\right],$$

and

$$\beta_i^{Ku} = \mathsf{E}_{X_i}\left[\sup_y \{F_{Y|X_i}(y \mid X_i) - F_Y(y)\} + \sup_y \{F_Y(y) - F_{Y|X_i}(y \mid X_i)\}\right],$$

where $F_Y(y)$ and $F_{Y|X_i}(y \mid X_i)$ are, respectively, the marginal cumulative distribution function of Y and the conditional cumulative distribution function of Y given X_i. The quantities β_i^{KS} and β_i^{Ku} measure the distance between $F_Y(y)$ and $F_{Y|X_i}(y \mid X_i)$ through the Kolmogorov-Smirnov and the Kuiper metrics, respectively. A thorough account on the theoretical aspects of these sensitivity measures can be found in (Borgonovo, Tarantola, Plischke, & Morris, 2014); details on their estimation can be found in (Plischke, Borgonovo, & Smith, 2013). To our purposes, it suffices to say that the highest the values of these quantities (η_i, δ_i, β_i^{KS}, β_i^{Ku}), the stronger the statistical dependence of Y on X_i.

3.5 Internal Validity

The PRINCE method (Johnson et al., 2017) eliminates the strategic responding. The subjects know that they are going to get an amount which depends on what they state and the number in the sealed envelope. The number that they state determines whether they are going to receive the number in the envelope or the Option to play for real.

In Part I, for each subject we repeated the third iteration (close to the indifference value) for 7 randomly selected choice questions. The consistency rate (rate of identical answer between the repeated and the original choice), are 85.7% for Part I, while 75% for Part III. Hence, the results in Part III are in agreement with the ones found in the literature (Stott, 2006), while the results in Part I are even higher.

There were no violation of monotonicity at an aggregate level. Indeed, in Part I, for a fixed level of IP, the mean values of z_i increased in the ER, and vice versa (for a fixed level of ER, they were decreasing in IP). These results hold in case of anonymity and in case of no anonymity.

3.6 Data Analysis

For 18 of the 98 subjects, the experiment ended prematurely. Indeed, to prevent considering data of subjects not understanding the task or not being serious about it, the experiment ended prematurely (see Appendix B for detailed explanation) for subjects who repeatedly preferred dominated choices. This left us with 80 subjects.

3.7 Results

The first question that our experiment aimed to answer was whether there is a third attribute of a medium of exchange (MoE). The issue was specifically posed in one of the elicitations (elicitation 18): the subjects were asked to communicate their preferences for allocating the available budget between an anonymous (ANM) medium of exchange with zero illiquidity probability (IP) and zero return (ER) versus a non-anonymous medium of exchange with zero illiquidity probability and zero return. Thus, the two media of exchange differ only in the third attribute (anonymity).

The majority of subjects, 60 over 80, allocated the entire budget to the anonymous medium of exchange. Therefore, anonymity *per se* does matter and, where possible, subjects consider it as a valuable attribute. In particular, let us analyze the answers in which fixed the levels of IP (X_1) and ER (X_2), the MoE varied from non-anonymous to anonymous. Analyzing these elicitations amounts to answering the question: for a given level of return and illiquidity risk, how much does a subject value anonymity? Technically, these elicitations are equivalent to a one-factor-at-a-time approach (Daniel, 1973), and the methodology therein introduced has been used to analyze the data. Table 3 reports the results.

Table 3: Analysis of points.

Illiquidity Probability (X_1)	Return (X_2)	Anonymity Shift(X_3)	Average Change in Value
0%	0%	No ->Yes	+2.94
1%	0%	No ->Yes	+0.94
10%	0%	No ->Yes	+0.5
0%	5%	No ->Yes	+1.06
1%	5%	No ->Yes	+2.00
10%	5%	No ->Yes	-0.38
0%	20%	No ->Yes	+2.25
1%	20%	No ->Yes	+2.00
10%	20%	No ->Yes	+1.625

Table 3 shows that the presence of anonymity causes an average increase of 1.44%. Also, the increase is registered at all the illiquidity-return combinations, but for one, characterized by an illiquidity probability of 10% and a return of 5%; however, in this case the value is close to zero (0.375%).

The highest value to anonymity is assigned for the MoE which has no illiquidity probability and no return (first asset in Table 3). Note that this point in the design concerns the same assets as in question 18, where we saw that anonymity *per se* matters. In all other combinations, anonymity still matters, although the assigned value is smaller in magnitude.

Then, anonymity matters and it is assigned a positive value by subjects, on average. However, this result then opens the question of how relevant is anonymity with respect to the other two attributes. To answer this question we analyzed the complete elicitations 1-18 using the methods described in the statistical analysis section concerning the full factorial design.

The analysis reveals that the generalized linear model is strongly statistically significant as a whole. Precisely, we tested the overall model fit using the likelihood ratio test. The likelihood ratio test statistic is X^2 =2544.8 with a p-value <2.2e-16. Therefore, we have strong evidence in favor

of rejecting the hypothesis H_0: $\beta_1 = \cdots = \beta_{1,2,3} = 0$. Moreover, we can plot the Pearson residuals as graphical model check (Figure 3).

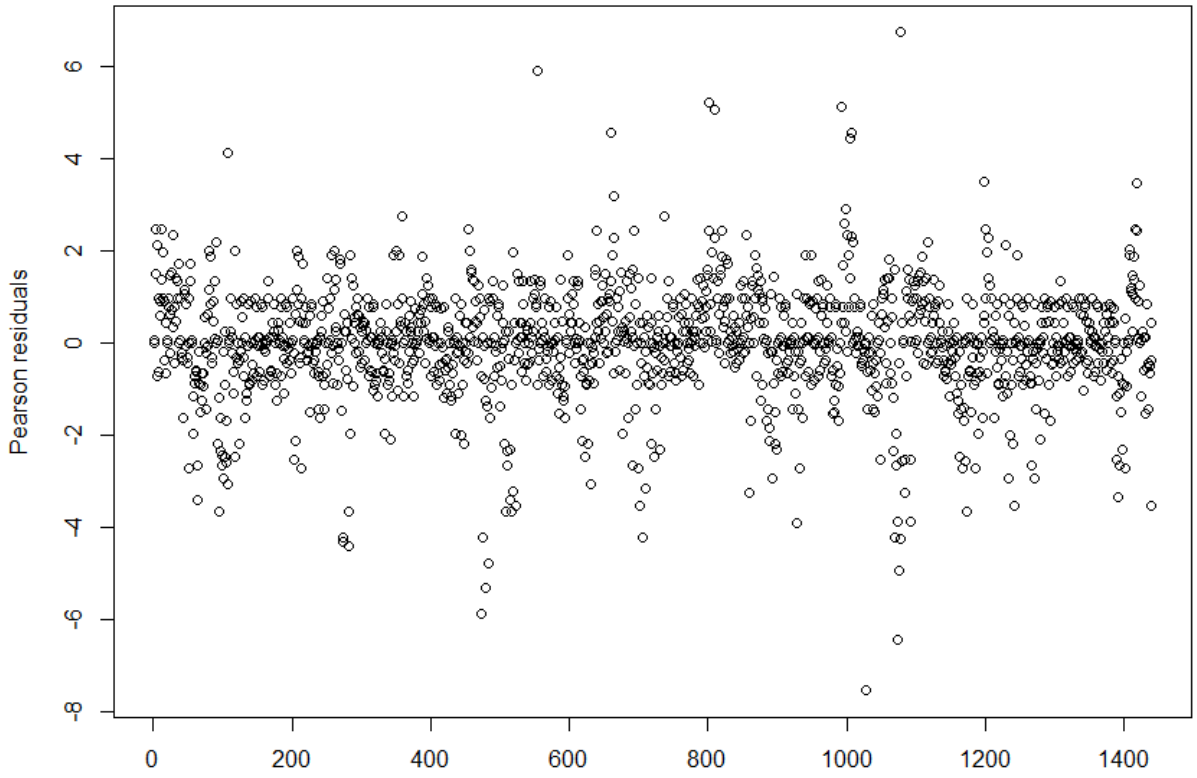

Figure 3: Diagnostic plot: Pearson residual against fitted values from model (1.0).

Figure 3 shows that Pearson residuals are centered around zero without a systematic pattern. This confirms the adequacy of the chosen model. We can then proceed with the analysis of the coefficients.

Table 4: Generalized linear regression results.

Coefficients	Estimate	Pvalue	Significance
(Intercept)	4.578822	<2e-16	****
X_1	-0.093505	<2e-16	****
X_2	0.124882	<2e-16	****

X_3	0.024475	0.0641	*
$X_1 \cdot X_2$	0.011400	0.0402	**
$X_1 \cdot X_3$	-0.011907	0.2638	
$X_2 \cdot X_3$	-0.004402	0.6520	
$X_1 \cdot X_2 \cdot X_3$	0.005302	0.4984	

Significance codes: '**** = very strong '***= strong; '**'=relevant; * = weak.

The results (see Table 4) signal the coefficients of the individual variables X_1, X_2 (illiquidity risk and expected return) and of the interaction term $X_1 \cdot X_2$ as strongly statistically significant; the coefficient of the third variable (anonymity) is indicated as weakly significant, and the remaining coefficients are deemed of very low statistical significance.

This result would indicate that the additive part of the model prevails over the part associated with interactions. To corroborate on this aspect, we looked at alternative model comparisons, still within an exponential model with Poisson regression. Although interaction effects were systematically of lower significance than individual effects, an additive would be less significant than the complete model, and thus a presence of interactions is warranted.

As for the coefficient values, these values would highlight that X_2 is more important than X_1, which in turn is more important than X_3. Thus, the results in Table 4 would suggest that participants have valued more strongly expected return and then the illiquidity risk, while anonymity seems to be less important.

To confirm this ranking, we calculated global importance measures from the data. Global importance measures are statistical indicators of the strength of the statistical dependence between the endogenous variable of interest (Y) and the covariates (X_1, X_2 and X_3) in our case [see (Borgonovo et al., 2014) among others.] We obtaining the results reported in Table 5.

Table 5: Statistical Dependence Measures Results.

Measure	X_1	X_2	X_3
β_i^{KS}	0.2314	0.3608	0.0945

δ_i	0.2314	0.4133	0.1169
β_i^{Ku}	0.2219	0.4027	0.0942
η_i	0.1661	0.4036	0.0015

Figure 4 reports a visualization of the results in Table 5.

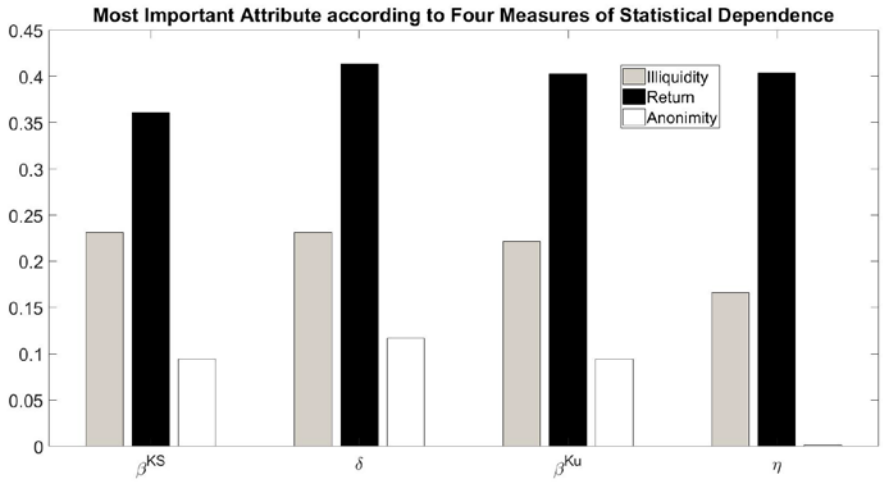

Figure 4: Measures of statistical dependence between the respondent answers and the attributes.

All dependence measures agree in ranking X_2, expected return, as most important attributes, followed by X_1, illiquidity risk, and X_3.

These results have been performed at an aggregate level of the respondent answers. They indicate that anonymity is regarded as less important with respect to illiquidity risk and expected return.

Given the relevance of the expected return property, we wondered what is the minimum level of return for which a subject is willing to allocate a significant portion of her/his portfolio to an anonymous MoE.

The risk return ratio curves measured experimentally are given in Figure 5.

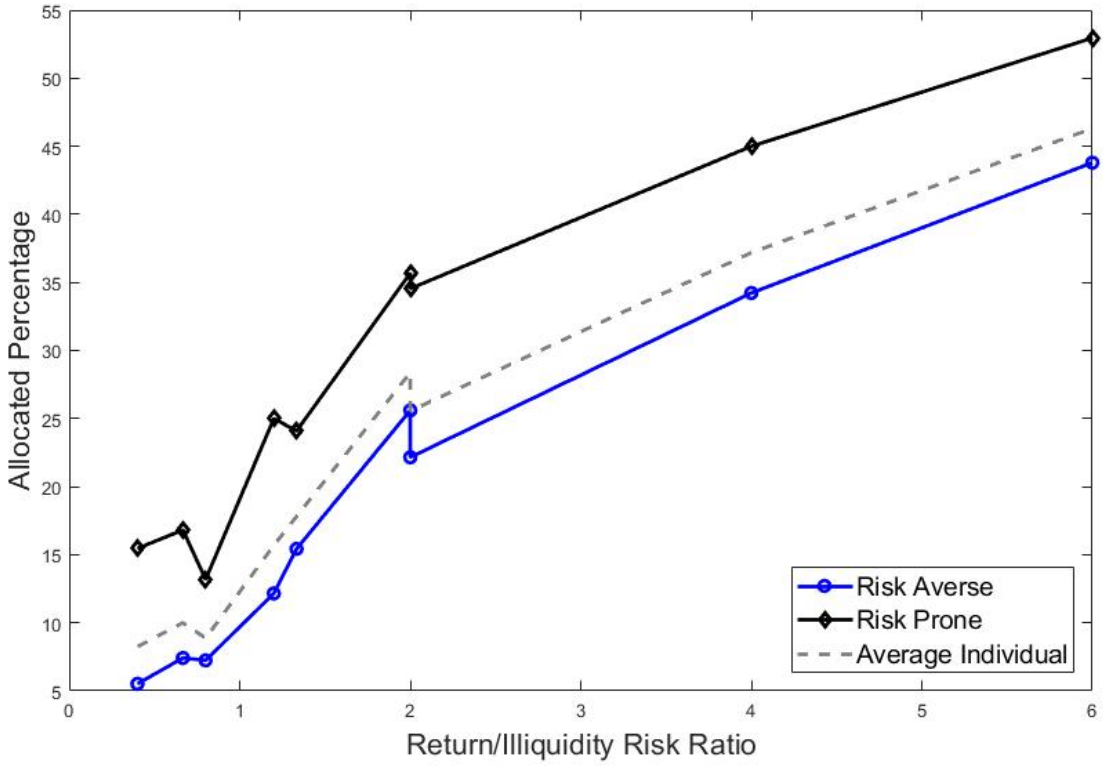

Figure 5: Return/Risk curves measured experimentally. On the horizontal axis we find the ratio between the return (in percentage) and the illiquidity probability.

The graph displays three curves. Each curve represents the percentage of the current budget that each subject would allocate to anonymous MoE with increasing "return\illiquidity probability" ratios. The black (–♦–), blue (– o –) and gray (- -) lines represent the allocations of a risk prone, risk averse and average individual, respectively. It is worth noting that the risk prone investors systematically allocate more to the anonymous MoE than risk averse individuals. In other words the risk prone individuals seems to give more value to the property of money as store of privacy. The more is true that risk propensity is associated with crime propensity the more will be true that individuals involved in illegal activities are likely to like anonymity.

For all types of individuals, the allocated percentage increases with the increase of the ratio between the return and the illiquidity probability. That is, the riskier the asset, the lower the percentage allocated to it, if such risk is not compensated by a corresponding increase in return. Thus, the analysis of the experimental results in Figure 5 suggests that risk attitudes influence the

amount allocated but not the trend. The trend is common to all individuals sees an increasing allocated percentage as the ratio illiquidity risk/return decreases. Such as observation further confirms the relevance of having a combination of properties in the same MoE.

However, note the diminishing marginal sensitivity (initial steep ascent and then more moderate growth) and the fact that one achieves a substantial (greater than 20%) allocation only for "return/illiquidity probability" ratios greater than 2. Consider now allocating more than half of the budget to the risky medium of exchange. The experimental results in Figure 5 suggest that the return must be at least 5 times greater than the illiquidity risk, and only risk averse individuals allocate more than half of their current liquidity. In other words the sacrifice ratio between the two properties of liquidity and return is relative high: to accept higher illiquidity risks the individuals call for a more than proportional increase in expected return.

These results could be interpreted as signaling that anonymous media of exchange are considered attractive if they promise gains substantially greater than the associated risk. This can explain the initial run to bitcoins, whose returns have been very high in the initial phase, overwhelming the associated illiquidity probability; they can also explain the appetite for the new emerging crypto currencies that can produce high returns in spite of an associated non-negligible illiquidity probability.

At the same time, this result seems to indicate an insight also for a cryptocurrency emitted by an entity whose illiquidity risk is small, such as a Central Bank. In that case, the illiquidity risk is null or negligible and therefore the "return/illiquidity risk" ratio is high as soon as the return is not negligible. That is, a cryptocurrency that ensures investor privacy (if not full anonymity) but is emitted by a reliable source with an associated sure and even small return, would find itself at the extreme left of the horizontal axis in Figure 2. Thus, there is substantial potential for the allocation in such medium of exchange.

4. Conclusion: Policy Implications

Summing up, the results of our experiments show that: 1) anonymity matters; 2) the cost opportunity is the more relevant property of money; 3) combining the three properties of money is likely to increase the appealing of a medium of exchange; 4) risk prone individuals like

anonymity; such a relation could be explain and confirm the association between anonymity and illegal activities; 5) given the level of anonymity, the sacrifice ratio between the two other properties of liquidity and return is relative high: to accept higher illiquidity risks the individuals call for a more than proportional increase in the expected returns.

These results allow us to discuss 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.

Given that the experiments show that anonymity matter, two considerations follow. On the one side cash can maintain its appealing. On the other side, the more other medium of exchange can credibility offer anonymity, but also the other two properties – low illiquidity risks and higher expected return – the more likely will be the crowding out of cash.

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.

All in all, for the banking currencies the challenge seem to be to remain a competitive medium of exchange without the anonymity property and with a low expected return. The future of the cryptocurrencies will depend on three different conditions, respectively linked to the capacity: to decrease the illiquidity risk; to strengthen the appeal in terms of expected return; to credibly guarantee the anonymity 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. In principle the illiquidity risk of a CBDC will be very low; at the same time it will be unlikely that its anonymity will be considered full as in the case of cash; the possibility to offer a yield could be a trigger to increase its appeal.

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Appendix A. Construction of the Envelopes and Playing for Real.

98 subjects participating at the experiment. An average payment of roughly 20 EUR per subject is reasonable to be expected. Since each of them had 10 EUR as flat fee, and 10 of them played for real one of the choice questions, we constructed 100 envelopes with an average amount of 100 EUR. Each choice question was present at least once among the 100 envelopes.

For each subject and for each question, we stored the indifference value (IV).

In Part I, the choice questions were represented by the Option A as described in the text. Option B was a random number (RN) in the interval [EV(A)-0.1*EV(A), EV(A)+0.1*EV(A)]. If RN>=IV, then the subject –had he faced exactly that question with that RN- would have preferred the RN. That is what he gets. If RN<IV, then the subject would have preferred the Option A. That is what he gets. Getting the Option A, means playing Option A, with its risk component. In case subjects won an anonymous payment method, we provided them with cash, otherwise with a bank transfer.

In Part II, for an EV maximize the optimal cash a* to allocate in $(0\ ,0\ ,Yes\ )$ would be 100 (assuming positive assessment of anonymity). Hence, we constructed the Options in Part II as follows:

Option A:$((0^0\ ,0^0\ ,No^0\ );(0^{100},0^{100},Yes^{100}))$

Option B: :$((0^{10},0^{10},No^{10});(0^{90},0^{90},Yes^{90}))$

where a*=10 is our selected number in the envelope (RN). If If RN>=IV, then the subject would have preferred the Option A. That is what he gets. If RN<IV, then the subject would have preferred Option B. That is what he gets.

In Part III, for most of the choice questions an EV maximizer would have allocated most of the money under the payment method III (for the choice questions 19, 20, 21, 23, 24), and under the payment method II (for the choice questions for 22, 25, 26, 27). The selected number c* in the envelope was a RN in the interval [60-0.1*60; 60+.1*60] (or [10-0.1*10; 10+.1*10]), allocated under payment method III. Hence, we let the elicited subject specific a* under payment method I (which then was revealed to the subject at the end of the experiment), while the complement to 100 allocated under payment method II. The options in Part III were so structured:

OptionA:

$((0^{a*}, 0^{a*}, No^{a*}) ; (0^{100-a*-RN+10}, 0^{100-a*-RN+10}, Yes^{100-a*-RN+10}); (5\%^{RN-10}, 10\%^{RN-10}, Yes^{RN-10}))$

Option B:

$:((0^{a*}, 0^{a*}, No^{a*}); (0^{100-a*-RN}, 0^{100-a*-RN}, Yes^{100-a*-RN}); (5\%^{RN}, 10\%^{RN}, Yes^{RN}))$

where a* was elicited in Part II. If RN>=IV, then the subject would have preferred the Option A. That is what he gets. If RN<IV, then the subject would have preferred Option B. That is what he gets.

Appendix B. Bisection Procedure

Part I

We want to find the amount *z* that makes the subject indifferent between option A and option B.

We started with *z*= 100. There were two possible scenarios:

(i) If A was chosen we increased z by 20 until B was chosen. We then halved the step size and decreased z by €10. If A [B] was subsequently chosen we once again halved the step size and increased [decreased] z by €5, etc.

(ii) If B was chosen we decreased x by 20 until A was chosen. We then halved the step size and increased z by €10. If B [A] was subsequently chosen we once again halved the step size and decreased [increased] z by €5, etc

The elicitation ended when the difference between the lowest value of x for which B was chosen and the highest value of x for which A was chosen was less than or equal to €5. The midpoint was taken and stored.

In case a subject clicked 6 consecutive times on A (or B), the experiment ended prematurely for that subject. This has been performed to avoid severe and consecutive violations of stochastic dominance.

Part II

There were two possible scenarios:

i) If B was chosen we increased x by 10 until A was chosen. Then the experiment stopped and the midpoint between the highest value of x for which B was chosen and the highest value of x for which B was not chosen was stored.

ii) If A was chosen then the experiment stopped and the midpoint between 0 and 10 was stored.

Part III

The selected option became option A in the next question. Option B in the next question will be the option B in the previous with c which is either increased or decreased by 10.

There were three possible scenarios:

i) If B was chosen we increased c by 10 until A was chosen. Then the experiment stopped and the midpoint between the highest value of y for which B was chosen and the highest value of y for which B was not chosen was stored.

ii) If A was chosen then stop and store midpoint between 0 and 10.

iii) If B was chosen without any change, then the experiment stopped and the highest value for which B was chosen was taken.

If a*= 100 in elicitation 18, then in part III the second payment had by default an allocation of 0.

Appendix C

Available upon request to alessandra.cillo@unibocconi.it