Universal Basic Income in a Blockchain-Based Community Currency

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ABSTRACT

Recent advancements of blockchain technologies ensure security and trustability of Community Currency Systems (CCSs), enabling their increasingly widespread adoption. These systems aim at empowering the local economies by virtue of a medium of exchange whose governance and circulation are local. Smart contracts enable the enforcement of token economy policies, which facilitate the experimentation of radically new economic models. Recent studies investigated blockchain-based CCSs. Still, to the best of our knowledge, this is the first study analyzing a CCS providing a token-based Universal Basic Income (UBI). We evaluate the Circles UBI decentralised application utility in delivering an unconditional income to its users, focusing on its main pilot project running in Berlin. We analyse the structural changes in the network, especially in relation to a subsidy program, involving local businesses. We also identify prominent users based on centrality measures, and investigate how the UBI was effectively spent. We adopt a method agnostic to the economic context to identify optimal aggregation windows for the temporal network of CCS transactions based on the Causal Fidelity (CF) index. This aims to provide static representations as accurate as possible in terms of sequential order of edges, which aspect was not considered in previous research on CCSs. Our findings suggest that the pilot project sustained the expansion of the economic network and the system facilitated trade in urban communities in Berlin. Future research is needed to identify methods to ensure sustainability of self-organised CCSs adopting a UBI issuance scheme and to further decentralise their governance.

GoodIT '23, September 06–08, 2023, Lisbon, Portugal

ACM ISBN 979-8-4007-0116-0/23/09.
https://doi.org/10.1145/3582515.3609538

CCS CONCEPTS

• **Networks** → **Peer-to-peer networks**; **Network economics**; • **Applied computing** → *Economics*; *Digital cash.*

KEYWORDS

blockchain, community currency, temporal network, transaction network , universal basic income, token economy

ACM Reference Format:
Sowelu Avanzo, Teodoro Criscione, Julio Linares, and Claudio Schifanella. 2023. Universal Basic Income in a Blockchain-Based Community Currency. In *ACM International Conference on Information Technology for Social Good (GoodIT '23), September 06–08, 2023, Lisbon, Portugal.* ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/3582515.3609538

1 INTRODUCTION

Since the introduction of Bitcoin [24], blockchain technologies underwent notable development. Ethereum and Solidity support the distributed execution of Turing-complete *smart contracts* [7] [1]. This largely increased the applicability of blockchain and originated a new class of software systems, defined as Decentralised Applications (DApps) [2] [34]. Recent studies have discussed the socially and environmentally beneficial use cases of DApps [1] and their applications focused on the empowerment of local economies [6]. Blockchain-based Community Currency Systems (CCSs) pursue this goal by enabling the circulation of a tokenized medium of exchange based on community agreement and voluntary acceptance. CCSs are typically implemented by a local institution or a grassroots initiative as tools for community empowerment or social and humanitarian intervention [8]. Even though the history of community currencies is not recent [19], in the last decade new technologies like DApps allowed to implement CCSs with increased security, trustability and transparency compared to traditional systems. This

[1]Smart contracts are programs executed on a blockchain whenever their encoded conditions are triggered. Their correct and transparent execution is ensured by blockchain properties.
[2]A DApp is an application running on a blockchain-based network, adopting smart contracts as an architectural component for the decentralized execution of part of its functionalities.

catalysed widespread adoption and provided highly granular data on the local economy [22]. For this reason, network analysis methods are suitable to study and evaluate CCSs. A classification of economic models adopted in these systems was recently proposed [8] distinguishing between *credit clearing systems*, *reserve-backed* CCSs and *basic income* currency systems. While the former two have been extensively discussed, fewer studies covered the third category.

In this paper, we analyse the transaction network of the Circles UBI system (Universal Basic Income) [30], which aims at providing a token-based unconditional income to its users. The Basic Income Earth Network (BIEN) [3] defines UBI as a periodic cash payment delivered to all individuals unconditionally on a regular basis [29].

Circles UBI is among the few projects leveraging blockchain-based tokenization to achieve this goal. In this system, policies regulating the issuance and interoperability of different tokens are established and enforced through smart contracts [30], which is not the case in other projects sharing the same objective. The token economy model adopted is based on the circulation of multiple types of token, defined as *personal currencies*. These tokens implement and adapt the ERC20 interface [25]. Every user is assigned automatically their own *personal currency* upon registration on the Circles DApp [4]. An equal amount of each users' *personal currency* is issued and distributed periodically to every wallet on the DApp. Each user can, therefore, spend their *personal currencies* as a claim to the goods and services supplied by other users in the network. On the front-end, each unit of *personal currency* is exchanged as one Circles unit with the same exchange rate.

If their owners directly *trust* one another or are connected by a *trust* path [30], their *personal currencies* are fungible[5] by design. Users can *trust* another account via a dedicated functionality of the DApp, and the *hub* smart contract [6] stores information about *trust* connections and token ownership and ensures fungibility among the currencies. The *trust* relation network is designed as an economic Web of Trust (WoT). The WoT protocol, mainly used in cryptographic communication systems for identity verification [31], was rarely applied to economic networks. In the Circles UBI system, its implementation aims at ensuring economic security and scalability in a self-organized and decentralized fashion, preventing untrusted users to exchange with the rest of the system. The system relies on the Gnosis blockchain for the smart contract implementation [7].

In order to investigate the CCS utility in distributing the unconditional income, we focused our analysis on the first pilot project launched in Berlin by Circles Coop [8] . Since July 2021, Circles Coop is running a subsidy program for a group of local businesses which allows them to convert their Circles tokens into national currency (Euro) [8]. At the time of writing, the subsidized businesses, which regularly cash out their Circles tokens to Euro, are 18. This program aims at solving structural *deadlocks* [9] in the economic network and incentives local businesses to accept Circles tokens as medium of payment for their goods and services. As suggested by Criscione et al. in [8], *deadlocks* and *gridlocks* are typical of a phase in which the economic network is too small to effectively match demand and supply. This is often the case in the initial phase of CCSs' adoption. In these circumstances, convertibility to national currency is intended to increase acceptance of the tokens as medium of exchange and enablethe expansion of the network. Our work will, therefore, also provide insights concerning the long-term sustainability of this class of CCSs.

1.1 Main contributions and research questions

A major contribution concerns the evaluation of the Circles UBI utility in distributing the tokenized UBI. Our work will provide insights on the *subsidy program* impact on token circulation and system behavior. We will characterize the prominent users of Circles UBI, and assess how the UBI issued was spent. This work will guide future implementations of CCSs using a UBI issuance scheme [8]. These objectives will be achieved by responding to the following research questions:

- **RQ1:** *How did the subsidy program affect the economic network structure in the context of the Circles UBI pilot?*
- **RQ2:** *Who are the most prominent users of the Circles UBI system?*
- **RQ3:** *How is the tokenized basic income spent by Circles users in the Berlin pilot?*

A further contribution of this article consists in applying the approach proposed by Lentz et al. [18] in the context of CCSs for the selection of aggregation time-windows that best represent the network temporal dynamics. This approach is based on unfolding the accessibility graph of the temporal network in order to compute the ratio between causal paths and the total number of paths among nodes, defined as causal fidelity (CF) [18]. This method for selecting aggregation time-lengths is *agnostic* to economic context data. For this reason, it is more applicable when less data are available on the economic network. This aspect is deemed especially beneficial in the initial phase of a CCS. In fact, at an early stage economic relations have to consolidate and are potentially volatile.

The subsequent section will discuss related works. Section 3 will provide a description of the dataset and methodology adopted, Section 4 will discuss the results of the analyses. Finally, Section 5 and 6 will draw conclusions and outline directions for further research.

2 RELATED WORKS

Recent studies discussed blockchain-based systems enabling issuance and circulation of tokens for social economy stakeholders [6]. For instance, the CommonsHood DApp [32] aims to facilitate tokenization of assets and rights in local communities [32]. Via this DApp, users with no knowledge of programming can mint

[3] https://basicincome.org/
[4] https://circles.garden/
[5] According to Shorish et al. [28], given a map between items and attributes, two items are perfectly fungible with each other if they are fungible (or interchangeable) and therefore indistinguishable in all considered contexts.
[6] https://github.com/CirclesUBI/circles-contracts/blob/master/contracts/Hub.sol
[7] https://www.gnosis.io/
[8] https://circles.coop/

[9] A *gridlock* is a situation in which the payment system can work only if the transactions are carried out simultaneously. A *deadlock* is a situation in which the payment system can work only by adding more liquidity in it. A *functional deadlock solution* is a strategy that does not require any intervention in the structure of the economic network, while a *structural deadlock solution* does.

and exchange different kinds of tokens. Users creating a new token instance in CommonsHood can explicitly define its terms and conditions in human-readable documents named *manifestos* [4]. CommonsHood, conversely from Circles, is not focused on a UBI model, as its design is agnostic to the economic system where it is adopted. For this reason, interoperability among different token instances is not enforced by smart contracts and tokens are not periodically distributed to community members. The Trustlines DApp[10] is based on a WoT protocol[31] similarly to Circles. This ensures the fungibility of token instances adopted by individual users. Nonetheless, its economic model is more oriented to mutual credit than to UBI. Some examples of CCSs oriented to UBI include Real Economy Currency (REC) in Barcelona [20] , or Mumbuca [11] in Brazil [27]. However, the Circles UBI system [30] differs from the other two projects in terms of both token economy and software architecture. In fact, neither REC [26] nor Mumbuca [13] adopt blockchain and smart contracts to automate UBI distribution. Due to these reasons, we decided to focus our analysis on the Circles UBI system.

Several studies have adopted network-based methods to analyse emerging dynamics in CCSs. For instance, the network analysis of Local Exchange Trading Systems (LETS) characterizes the prominent users in the network based on different centrality measures and rich-club phenomenon [12]. Another recent work on the Sardex monetary network[16] shows the importance of cycle density as a measure quantifying the systemic and individual performance. Study[9] analyses as a graph the relations among economic sectors of which the Sardex network consists. Those CCSs are not based on blockchain technology and the currency is issued as a mutual credit system. Recent works analyse the structure and dynamics of Sarafu network, a blockchain-based CCS[21, 22]. Sarafu is among the most advanced digital CCSs, as it has reached a considerable scale (around 40,000 users in 2021) [22]. All approaches to analyse CCSs adopted in the studies mentioned are based on a static network representation. As pointed out in [18], representing systems evolving in time through static networks might not provide an accurate representation of the underlying dynamics. In static representations, the number of connections and paths among nodes are significantly overestimated, since several of the paths detected are not causal paths, that is, they do not follow a causal order. This is a relevant issue in describing currency flows in a CCS, which received little attention in literature.

Only one recent study analyses the temporal dynamics concerning cooperative behavior in the Sarafu Network [3]. In particular, this focuses on network aggregations whose length is based on to the pandemic spread and restrictions imposed by authorities. However, we are not aware of empirical studies taking explicitly into account causal fidelity in selecting the aggregation time-window in the context of CCSs and payment systems.

3 DATASET

3.1 Background

Payment systems can be modeled as temporal networks. A *temporal network* is a tuple $N = (V, E, T, \phi, \omega)$, where: V is the set of nodes, E is the set of edges, $T = [0, T_{\max}]$ is the time interval, with $T_{\max}$ being the maximum time, and $\phi : E \times T \rightarrow \{0, 1\}$ is the edge-presence function, indicating whether an edge exists at a certain time. This returns 1 if the edge $e \in E$ and $\phi(e, t) = 0$ otherwise. $\omega : E \times T \rightarrow \mathbb{R}$ is the edge-weight function, assigning a weight to an edge at a certain time. One way to capture longer term dynamics, it is to aggregate temporal networks into snapshots, represented by weighted directed graphs. In a graph $G = (V, E, W)$ edge $e \in E$ represents the currency flow in the period considered from node v to x $\forall v, x \in V$. W is the weight representing the sum of currency flowing from one node to the other in the period considered.

The **accessibility graph** of any given graph has edges between all nodes connected by a path within the network. The accessibility graph of a temporal network [18] displays the causal paths among nodes, in which the temporal order of edges is taken into account. The process of unfolding it based on the evolution of the temporal network reveals important properties concerning the distribution of shortest temporal path duration. In particular, its density is the density of causal paths among nodes. Causal Fidelity is defined as the density of the temporal accessibility graph divided by the static representation one. As the latter contains also non-causal paths, the index ranges between 0 and 1. This is a measure of the accuracy of a static representation in describing temporal dynamics, which we use to detect optimal aggregation windows. The adoption of this technique is twofold. First, it detects structural changes in the observed period. Second, we can use those structurally different periods to optimally aggregate the temporal network and proceed with static network analysis.

3.2 Data preparation

In order to prepare the dataset for the analysis, we filtered out all system transactions. These include in particular all periodic basic income disbursements since the deployment of the Circles DApp. From the worldwide Circles UBI transaction network, we isolated the **Largest Weakly Connected Component** (LWCC). This includes all the subsidised businesses in Berlin and their direct and indirect connections, being their supply chain, clients and all other users who traded Circles. We decided to analyze this sub-network, as it is connected to the Berlin pilot, being currently the only one that reached a considerable stage of development, even though other pilots have been launched in other countries. This sub-network consists of 5,151 nodes and 31,035 edges, representing users and transactions respectively. In order to gain a deeper understanding of the *subsidy program*, we further isolated two sub-networks of the LWCC:

- The **Subsidized Business** (SB) network, providing information on the business-to-business dynamics. This consists of the businesses involved in the *subsidy program* (18 nodes), that performed 714 transactions in the observation period.
- The network of **Trade Partners** (TP) of subsidized businesses. This sub-network, counting 675 users and 5,993 transactions, includes the businesses taking part in the subsidy program, as well as their clients and suppliers.

The blockchain transactions analysed took place from October 16 2020 to March 21 2023. Furthermore, in order to analyse the use of UBI, we assigned each subsidized business to one of the 7 sectors

[10] https://trustlines.network/
[11] https://www.marica.rj.gov.br/programa/moeda-social-mumbuca/

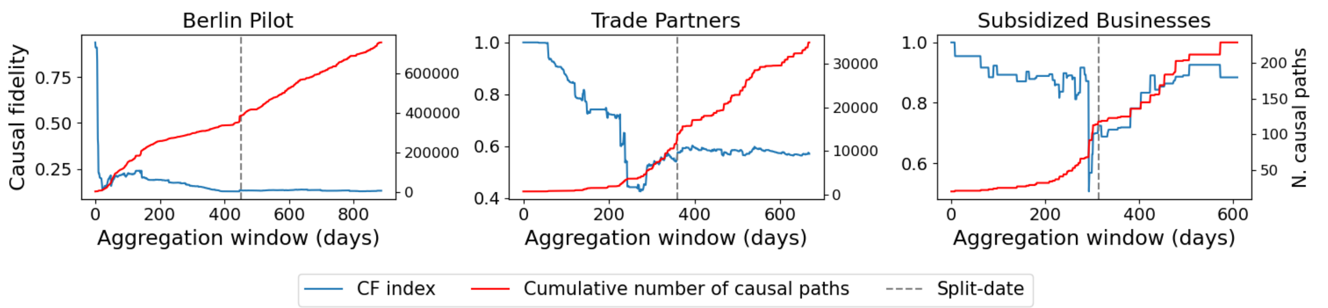

Figure 1: Causal Fidelity per aggregation time-window. The first image from the left (Fig.1.1) refers to the LWCC network involving the whole Berlin pilot, the second (Fig.1.2), to the TP network, the third (Fig.1.3), to the SB one. The grey lines are associated with the time-lengths selected per each temporal network. Red lines show the number of causal paths associated to each time-length.

indicating the core activity performed - i.e., *Food and Beverage*, *Art*, *Care/Health*, *Consulting*, *Bikes*, *Books* and *Cash out*. The largest category includes 8 small businesses whose core activity relates to *Food and Beverage* production and distribution. These are cafés and breweries in Berlin and organic food delivery startups. Two local artists (*Art*) participate in the *subsidy program*, accepting Circles in exchange for handicraft products. The *Care/Health* category includes 2 businesses focused on holistic and alternative health treatment. Two startups offer business and marketing consulting to other SBs (*Consulting*). Other organizations part of the Circles *subsidy program* include one shop having as its core businesses bike repair, bike rental and sharing (*Bikes*), one business running a co-working space in Berlin (*Co-working*) and a bookshop (*Books*). The Circles Coop supports the system financially by enabling subsidized businesses to convert Circles to to Euro (*Cash-out*).

3.3 Methodology

In order to respond to the research questions, we analysed the temporal structure of the three sub-networks. This guided the selection of time-lengths for their aggregation into graphs that provide a representation as accurate as possible of causal paths. To do so, we analysed the unfolding of the accessibility graph over time, whereby we computed the causal fidelity (CF) measure per each possible aggregation window (Figure 1), based on the method proposed in[18]. The process was repeated for each network (SB, TP and LWCC).

As explained in [18], high initial values of CF are a trivial effect, as short-time lengths aggregate only few of the causal paths in the network. This is clearly shown by the red lines in Figure 1 charts, representing the number of causal paths corresponding to a given aggregation windows. These are especially low before the troughs of CF, and steeply increase afterwards. All aggregation windows shorter than those associated with the minimum CF value were discarded. We computed a pivot value per each network, corresponding to the mean of CF after the troughs. Per each network, we selected the time length associated with the closest CF to the pivot value that also enabled static representations of the temporal network based on two balanced snapshots. Each snapshot is a temporally aggregated, directed, and weighted graph.

In the LWCC network, the CF pivot value computed was 0.13325. Hence, the shortest time-length providing a CF value that is close enough to the pivot was 451 days, with a CF of 0.1338. In the TP network, values of CF between 360 and 365 are especially close to the pivot (0.57503). Hence, by selecting 360 days as an aggregation time-length, we were able to divide the network in two balanced snapshots. In the SB network, the average of values of CF after the trough is 0.83311. We chose the time-length corresponding to the first plateau, reached at 313 days. This enabled us to divide the network into two balanced snapshots with a resulting CF of 0.7239.

Firstly, we derived statistics on the topology each of the six resulting graphs to investigate the evolution of the three networks in time. Subsequently, we computed the volume of transactions per month per each category of users (*subsidized businesses*, *trade partners* or simple *users*), as well as the user activity per month (Figure 2). This gave us insights on the influence of the *subsidy program* on the economic network dynamics (RQ1). Secondly, we analysed the centrality measure distributions and their correlations. This provided both information on the structural changes and enabled us to identify the prominent users in the network (RQ2). The centrality measures adopted were weighted and unweighted in- and out-degrees, PageRank and Betweenness centrality [8]. We analysed the heterogeneity parameter (HP) of these distributions, defined as $\kappa = \frac{\langle k^2 \rangle}{\langle k \rangle^2}$, where $\langle k \rangle$ is the average and $\langle k^2 \rangle$ is the average of the squared values in the distribution. This presents values significantly higher than 1 if the distribution is highly heterogeneous. Thirdly, we identified the backbone of the network based on core decomposition [5], and characterized users taking part in it. Finally, we responded to RQ3 by analysing the volume spent in the overall time-span and its distribution across spending categories, described in Section 2.2. We, then, quantified the amount of cash-out by the subsidized businesses, compared to spending in Circles tokens.

4 RESULTS

4.1 Structural changes in the network

The different time-lengths in the three sub-networks are reflective of dynamics impacting the CCS at different moments in time. Table

1 summarizes the main characteristics of each graph. General statistics on the the six resulting graphs revealed how the networks evolved in different maturity stages of the Circles UBI system and how the *subsidy program* impacted it. The whole network of the Berlin pilot shrank over time, both in terms of users (from 3,977 to 1,991) and in terms of trade partnerships established (from 8,879 to 4,262). By contrast, the remaining two networks have grown over time, as visible from Table 1, both in terms of users and trade partnerships. This entails that even though the system was adopted by fewer users in the second period, those who were directly (SB) or indirectly (TP) involved in the *subsidy program* showed increased trade and usage. This phase transition is confirmed by the monthly transaction volume and monthly active user statistics in Figure 2. Figure 2.1 clearly displays increasing volume of transactions to users connected with the *subsidy program* after January 2022, and Figure 2.2 shows a stabilization of user activity in June 2022. Moreover, from June 2022 onward, the vast majority of active users is consistently associated with the *subsidy program.* Weighted in-degree and weighted out degree distributions provided information on how the *subsidy program* affected the network in terms of transaction flows. Average values of both measures sharply increased from the first to the second observation in all networks, consistently with the overall trade volume increase. Mean values and heterogeneity parameter (HP) of unweighted in-degree and out-degree distributions in this context provide information on the amount of trade partnerships established by each node in the time-span and their distribution across the user base. Mean of both in-degrees and out-degrees increased significantly in the SB network, and only slightly in the TP one. This, conversely, decreased over time in the overall Berlin network (LWCC). This indicates that the subsidised businesses and their trade partners on average have increased the number of both forward linkages (connections with clients) and backward linkages (connections with suppliers), likely due to the impact of the *subsidy program.*

We observed that heterogeneity parameter (HP) is remarkably smaller in the out-degree distributions compared to the in-degree ones. The HP of in-degree distributions decreased in the TP network (from 41.2 to 37.4) and in the SB one (from 2.6 to 2.5), but it steeply increased in the overall Berlin pilot (from 7.1 to 22.4). Moreover, a slight reduction of out-degree heterogeneity occurred in all networks. This highlights three main aspects. Firstly, opportunities to spend Circles *personal currencies* were more equally distributed than opportunities to be paid in Circles tokens at all times. Therefore, few important nodes concentrated a larger part of incoming connections compared to outgoing ones. Secondly, the opportunities to spend Circles became more widespread over time as the *subsidy program* achieved wider outreach. Thirdly, the opportunities to receive tokens concentrated in the SBs and their TPs in the second observation, but they became more equally distributed within these sub-networks.

Table 1 shows that while the aggregated graphs corresponding to the two observations of the whole Berlin pilot network (LWCC) are weakly disconnected, the TP and SB ones are weakly connected, indicating higher connectivity in correspondence with the *subsidy program.*

4.2 Prominent Users of Circles UBI

The high heterogeneity of degree distributions discussed above reveals the presence of users acting as hubs in the network. In order to investigate what nodes occupy such prominent positions, we analysed also Page Rank and betweenness centrality. The former is a measure of the fraction of flows controlled by each user if the existing network dynamics would continue indefinitely [22]. The latter measures market power in the economic system [8], as a node with high betweenness centrality score can successfully perform brokerage in trade networks, and potentially increase their profit margin by mediating among diverse communities.

The PageRank distribution heterogeneity increased in the LWCC network and it decreased in the SB network. This suggests that subsidized businesses (SB) increased their control of CC flow compared to the rest of users in the second period. It also highlights that the SB network became more decentralized over time, as the number of businesses involved grew from 15 to 18. The betweenness centrality heterogeneity decreased in all networks, as a result of consolidated network connectivity in the second observation. In the LWCC network, mean PageRank of subsidized businesses increased remarkably (0.003 to 0.01) from the first to the second observation, suggesting that the percentage of flows controlled by those actors increased exponentially. Furthermore, the PageRank mean slightly increased also for trade partners of subsidized business (0.0004 to 0.0005) and other users (0.0002 to 0.0004), revealing that both categories increased participation in trade in the second period. Betweenness centrality shows a far weaker increase for subsidized businesses (0.006 to 0.007), indicating that the prominence of the businesses involved in the *subsidy program* is not specifically based on brokerage. Conversely, the mean betweenness centrality of users not directly and indirectly involved in the subsidy program shows a remarkable decrease, from 0.00023 to 0.00005, indicating that these became less important in the overall network, which is confirmed by the decrease in volumes traded to this category (Fig.2).

The evolution of correlations among different centrality measures indicates that structural changes also affected users' prominent roles in the Berlin pilot. In the first graph, the correlation between the different centrality measures is significantly weaker than in the second. In particular, the Pearson correlation of PageRank increased both with weighted in-degree (from 0.18 to 0.51) and weighted out-degree (0.31 to 0.78). Similarly, correlations of betweenness centrality with weighted out-degree (0.16 to 0.79) and with weighted out-degree (0.18 to 0.74). All correlations were statistically significant, as they showed p-values close to zero. This can be explained as a reorganization of the network from a multi-core network to a single-core structure made mostly of subsidised businesses and their trade partners. To better understand this phenomenon, we performed core decomposition on the network, and assigned a rank to Circles users based on their core number. As visible from Figure 3, the network transitioned from a multi-core to a single-core structure in which the subsidized businesses (in green) and their trade partners (in red) occupy prominent positions. This is also evident analysing the relative frequency distribution of users across the different cores in Figure 4. Subsidized businesses (in blue) tend to occupy denser cores compared to other users (in

Network	***Berlin Pilot***		***Trade Partners***		***Subsidized Businesses***	
Causal Fidelity	0.13		0.57		0.72	
Split-date	10/01/2022		02/06/2022		14/06/2022	
Time	First period	Second period	First period	Second period	First period	Second period
N. of Users	3,977	1,991	390	514	15	18
N. of Trade Partnerships	8,879	4,262	842	1,298	38	55
Volume of Transactions	652,988.5	1,647,143	260,491.1	890,483	84,778.8	285,506
N. of Transactions	19,066	11,969	2,343	3,650	329	385
N. of WCC	31	95	1	1	1	1
N. of SCC	2,935	1,528	338	462	6	6

Table 1: General statistics on the aggregated graphs: each graph results from the split between the period before and after the Split-date shown. The resulting causal fidelity provides information on the accuracy of the static representations. The number of trade connections result from the aggregation of the transactions in each period. The last rows indicate the number of weakly and strongly connected components respectively.

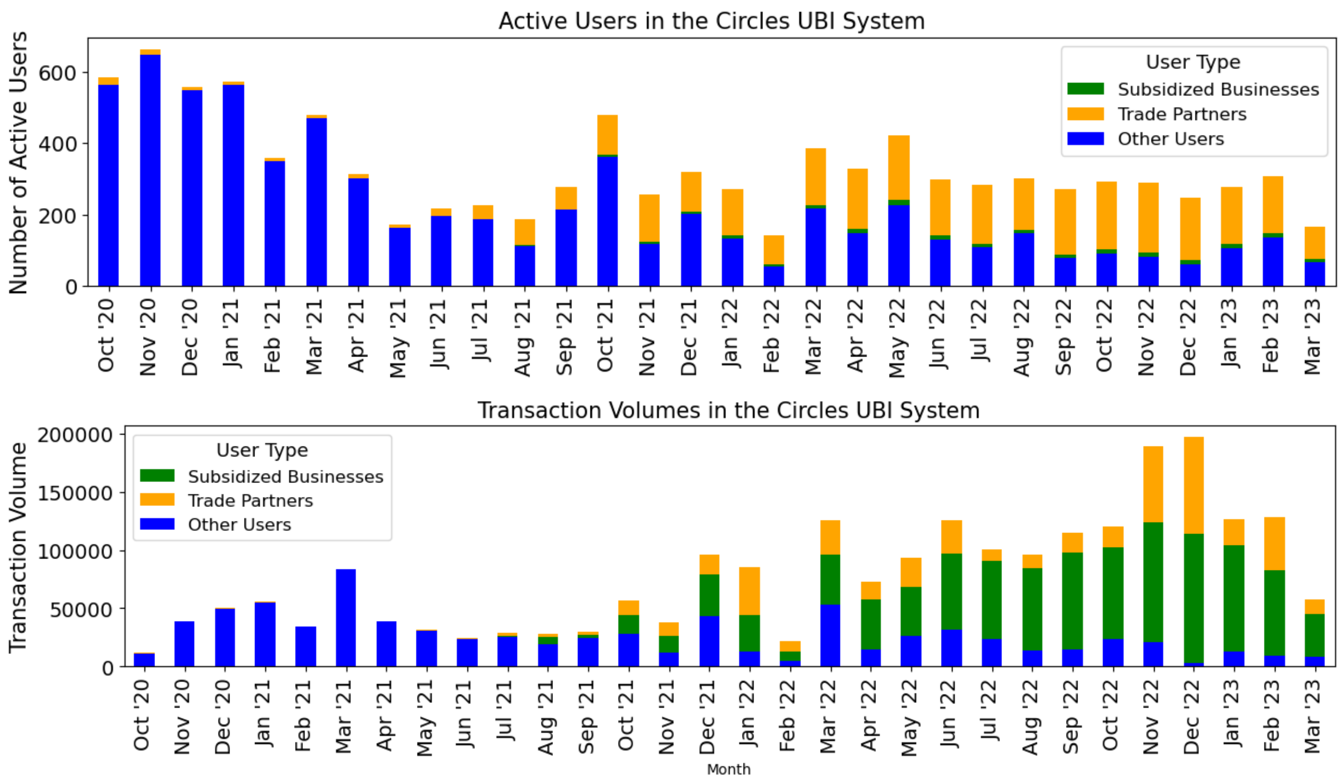

Figure 2: User activity (Fig.2.1 on the top) and monthly transaction volumes across receivers' types (Fig.2.2 at the bottom). An active user is defined as a person transacting at least once in a month.

green) in both snapshots. While users not connected to the subsidy program formed denser cores in the first snapshot (9-14), this is not the case in the second period, in which the densest cores (11 and 12) are mainly populated by the subsidized businesses and their trade partners (in orange). This highlights the stronger connection of the network backbone to the *subsidy program* in the second period. This is also confirmed by the significant reduction of trade partners of subsidized businesses belonging to less dense cores in the second observation. Furthermore, we observed a strong correlation, based on Kendall *tau* coefficient, between the core number and the size of the strongly connected component each node belongs to (0.65 - 0.59). This shows that nodes part of the backbone are likely also more involved in cyclical motifs.

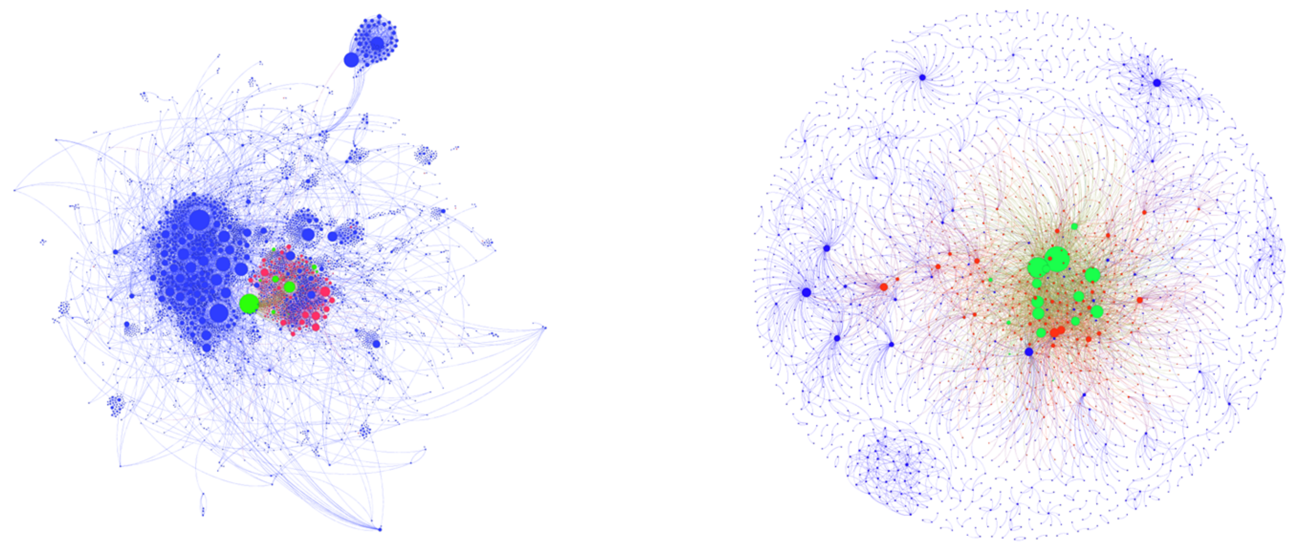

Figure 3: Circles UBI payment network in the Berlin pilot before January 2022 on the left (Fig.3.1) and after January 2022 on the right (Fig.3.2). The node sizes are assigned based on their degree centrality. Nodes in green are businesses part of the subsidy program, those in red are their trade partners. Nodes in blue are other users. Gephi was adopted to visualize the graphs.

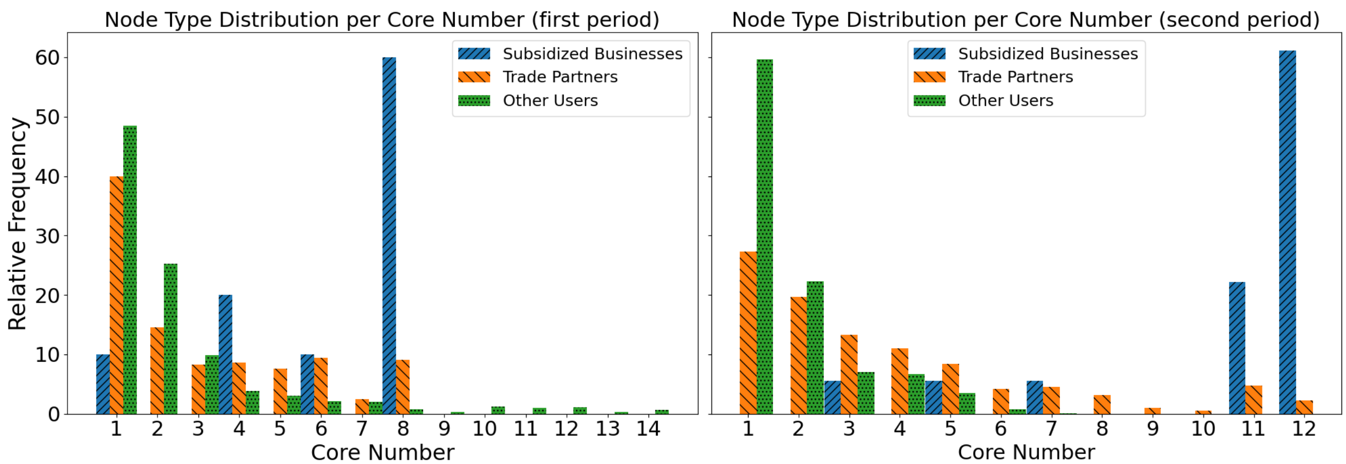

Figure 4: Relative frequency distributions of user types (subsidized businesses, trade partners and other users) across core number (on the x axis). Fig.4.1 on the left represents the Berlin pilot network before 10 January, Fig.4.2 on the right, after 10 January. The core number of a node is the largest value of k for which the node is a part of a k-core. A k-core is a sub-graph where every node is connected to at least k other nodes. So, a node with a higher core number is generally more centrally located within the network.

4.3 Spending across sectors

The overall volume spent to subsidized businesses adds up to 1,023,504 Circles tokens in the whole time-span. This corresponds to roughly 44% of the total volume of transactions, showing the importance of the *subsidy program* to facilitate the spending of users' *personal currencies*. Figure 5.1 reports spending volume across the different categories. Both the highest volume (389,101.29) and the highest number of transactions (3,183) involved the *Food and Beverage* sector. The Circles Coop received the second largest volume, by which the Circles tokens were cashed out, with fewer transactions (876). The third spending category per volume concerns Art, towards which 678 transactions were made counting a total spending of 111,029.55 Circles tokens. This shows that the system supported local artists, contributing to some extent to the development of the urban cultural scene. Other businesses involving significantly lower

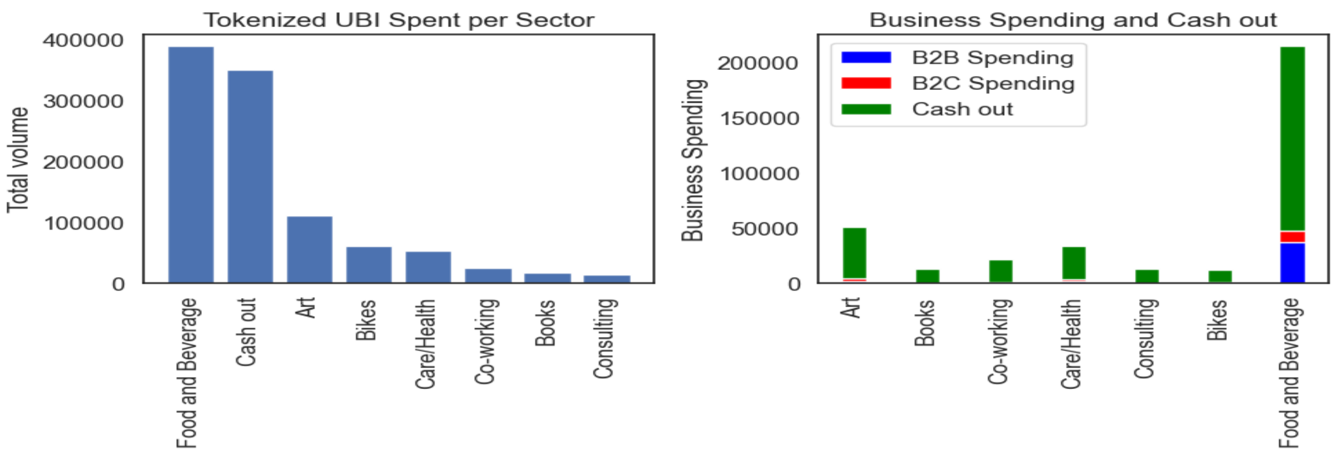

Figure 5: Spending volume transacted from all users in the Circles UBI pilot to subsidized businesses (Figure 5.1, on the left) and spending volume from the subsidized businesses to the rest of the network divided by target user type (Figure 5.2, on the right). Transactions are classified as business to business (B2B) if the recipient is another subsidized business, business to client (B2C) if the recipient is part of the extended network of trade partners.

incoming trade in Circles tokens include the bike rental shop (60,943 Circles tokens , 297 transactions), businesses related to *Care/Health* (54,549.59 tokens, 291 transactions), *Co-working* (25,666.44 tokens, 147 transactions), book sales (17,363.11, 108 transactions), and Consulting (15,280.09 tokens, 24 transactions). These include businesses that recently joined the subsidy program, businesses with a particularly small turnover, or products and services for which there is still lack of demand in the current scale of the economic network.

As visible from Figure 5.2, only a very small amount of funds spent at businesses participating in the subsidy program circulates locally. SBs belonging to only three sectors spend the tokens they receive to other Circles users, while the vast majority converts the Circles tokens to Euro. The only businesses re-injecting a considerable amount of tokens to the pilot economic network through Circles belong to the *Food and Beverage* sector, mostly directed to other subsidized businesses. This indicates that the network at this early stage has not yet reached a size enabling an efficient match of local supply of goods and services which is needed by all the subsidized businesses. However, multiple aspects need to be taken into account. Firstly, the heterogeneity and complexity of the different supply chains involved might affect this result. Due to this reason, some sectors (i.e. *Food and Beverage*) might be more keen on spending Circles locally, rather than cashing them out due to the reliance on a local supply chain. Moreover, it should be highlighted that the CCS is designed to circulate complementary to Euros, so its aim is not to substitute national currency. Finally, the incentive system in place, based on an increasing supply of currency might disincentive businesses from hoarding Circles.

5 DISCUSSION

In this research we adopted an approach to select the optimal time-window based on a pivot value of causal fidelity (CF). This approach enabled us to detect transition phases of the network, and aggregate the network into a sequence of meaningful static representations. As this approach is agnostic to the economic context, it seems adequate to guide the analyses of payment systems and CCSs when data are not sufficient to indicate precise time-lengths for meaningful aggregations. The Circles UBI system showed its utility in delivering a token-based unconditional income to a wide amount of users. The system displayed an notably high trade volume and user activity over the period considered. Our analyses suggest that users could spend their Circles in the TP network for purchasing everyday essentials, explicit goal of the CCS. The circulation of the Circles tokens was strongly affected by the *subsidy program* implemented by the Circles Coop, which allowed the convertibility of the Circles tokens to Euro. This strategy seems to have bootstrapped the system by establishing trustability, consolidating the economic network and ensuring the acceptance of the tokens by the businesses. This program affected both network structure and the role of prominent users in the network, as the participants involved in it. In the second period, subsidised businesses became part of the network backbone and increased their importance in the economic network. Network activity and token circulation concentrated in the sub-networks directly or indirectly connected to the *subsidy program*, especially in more recent observations. Large part of tokenized income has been cashed out, as per the *subsidy program* policies. This raises questions on how to incentive network members to actively supply goods and services independently from the monetary incentives provided via the *subsidy program* to ensure a long-term economic sustainability of the system. The system utility would, therefore, increase if solutions targeting these issues were designed and implemented.

Among the main limitations of this work, we recognize the impossibility to perform causal inference of the subsidy program impact. A causal inference study would require a randomised control trial which is not advisable for ethical reasons [15] and technical reasons. In fact, the isolation of control and treatment groups would not be effective in the case of a cash transfer program located in the same economic area. Moreover, a more complete identification procedure of prominent users would require a collection of both qualitative and quantitative data.

6 CONCLUSIONS

Approaches to tokenization aiming at facilitating self-organization of local communities have attracted increased interest by the scientific community[4, 22, 32]. Our work analysed the temporal evolution of the Circles UBI, as this is among the few examples of CCSs oriented to a UBI economic model and the only one based on blockchain [8]. We adopted an approach based on the causal fidelity (CF) index [18] to select an optimal aggregation window. This aims to provide a more accurate representation of causality in graph-based aggregations of temporal networks. By virtue of this approach, we analysed the structural changes occurring in the Circles UBI network and the prominent users of the system, based on diverse centrality measures. Furthermore, we analysed the overall spending in relation to the *subsidy program* implemented by the Circles Coop to bootstrap the system. Our analyses evidenced how the system succeeded in facilitating UBI distribution and local trade in the pilot taking place in Berlin. Further research is needed to cover long-term sustainability of UBI-based systems, governance-related aspects and incentives to economic participation in the system.

We identify three possible future directions for this research. Firstly, future research is needed to investigate ways to improve the utility of this class of software systems. This goal can be pursued by extending the system functionalities to further decentralize the governance of the system and reward user participation. In this context, smart contracts could be designed to automate the convertibility policies between national currency and the Circles UBI tokens. Decentralized Autonomous Organizations [14] could be developed to provide a decentralized and transparent governance layer for the CCS. DAOs could facilitate the implementation of community-driven solutions to structural deadlocks and gridlocks in the payment system. Secondly, more advanced network analytical tools can adopted to better describe the currency system. For instance, a precise estimation of the transfer velocity can provide a detailed outlook on the currency usage over time [23]. Moreover, further studies can be done on the balance of the payment system [10, 11] and how to improve it. Finally, structure and dynamics of the flow network could be carried out by studying the community structure [22] and network motifs [16, 17]. A third and final research strain is related to the discussion about the Central Bank Digital Currencies (CBCDs). In a recent survey, most of central banks in the world are already considering a digital currency [2]. However, the debate on the CBDC design and related risk is still ongoing [33]. The support of local and independent grassroots initiatives like Circles UBI could be considered an optimal bottom-up solution to the so-called *CBDC dilemma*.

ACKNOWLEDGMENTS

The Authors acknowledge the opportunity given by Freiburg Institute For Basic Income Studies (FRIBIS), the Circles Coop, and the Digital Territories and Communities research group (University of Torino) to start their research collaboration offering the material support necessary to achieve this result.

COMPETING INTERESTS

Julio Linares is founding member of Circle Coop e.G. in Berlin, Germany. Other authors have no competing interests to declare.

REFERENCES

[1] Richard Adams, Beth Kewell, and Glenn Parry. 2018. Blockchain for good? Digital ledger technology and sustainable development goals. In *Handbook of sustainability and social science research*. Springer, Cham, Switzerland, 127–140.

[2] Raphael Auer, Codruta Boar, Giulio Cornelli, Jon Frost, Henry Holden, and Andreas Wehrli. 2021. *CBDCs beyond borders: results from a survey of central banks*. Number 116 in BIS Papers. Bank for International Settlements, Centralbahnpl. 2, 4002 Basel, Switzerland. https://ideas.repec.org/b/bis/bisbps/116.html

[3] Cheick Tidiane Ba, Alessia Galdeman, Matteo Zignani, and Sabrina Gaito. 2022. Temporal analysis of cooperative behaviour in a blockchain for humanitarian aid during the COVID-19 pandemic. In *Conference on Information Technology for Social Good*. ACM, Limassol, Cyprus, 292–299. https://doi.org/10.1145/3524458.3547245

[4] Stefano Balbo, Guido Boella, Pierpaolo Busacchi, Alex Cordero, Luca De Carne, Diego Di Caro, Alberto Guffanti, Michele Mioli, Alessandro Sanino, and Claudio Schifanella. 2020. CommonsHood: A Blockchain-based wallet app for local communities. In *2020 IEEE International Conference on Decentralized Applications and Infrastructures (DAPPS)*. IEEE, IEEE, Oxford, UK, 139–144.

[5] V. Batagelj and M. Zaversnik. 2003. An O(m) Algorithm for Cores Decomposition of Networks. arXiv:cs/0310049 [cs.DS]

[6] Samuel Brülisauer. 2020. The digital social economy-managing and leveraging platforms and blockchain for a people-centred digital transformation. In *The digital social economy-managing and leveraging platforms and blockchain for a people-centred digital transformation: Brülisauer, Samuel*. CIRIEC International, Université de Liège, Liège (Belgium).

[7] Vitalik Buterin. 2014. Ethereum: A next-generation smart contract and decentralized application platform. https://github.com/ethereum/wiki/wiki/White-Paper Accessed: 2022-08-22.

[8] Teodoro Criscione, Eve Guterman, Sowuelu Avanzo, and Julio Linares. 2022. *Community currency systems: Basic income, credit clearing, and reserve-backed. Models and design principles*. Working Paper 04-2022. FRIBIS Discussion Paper Series. https://www.econstor.eu/handle/10419/263981 Available at https://www.econstor.eu/handle/10419/263981.

[9] Paolo Dini and Alexandros Kioupkiolis. 2019. The alter-politics of complementary currencies: The case of Sardex. *Cogent Social Sciences* 5, 1 (2019), 1646625.

[10] Tomaž Fleischman and Paolo Dini. 2021. Mathematical Foundations for Balancing the Payment System in the Trade Credit Market. *Journal of Risk and Financial Management* 14, 9 (2021). https://doi.org/10.3390/jrfm14090452

[11] Tomaž Fleischman, Paolo Dini, and Giuseppe Littera. 2020. Liquidity-Saving through Obligation-Clearing and Mutual Credit: An Effective Monetary Innovation for SMEs in Times of Crisis. *Journal of Risk and Financial Management* 13, 12 (2020). https://doi.org/10.3390/jrfm13120295

[12] Eva Fraňková, Jan Fousek, Lukáš Kala, and Jan Labohý. 2014. Transaction network analysis for studying Local Exchange Trading Systems (LETS): Research potentials and limitations. *Ecological Economics* 107 (2014), 266–275. https://doi.org/10.1016/j.ecolecon.2014.09.009

[13] Andrea Gama. 2023. Mumbuca - Open Source Community Currency. https://sw.jfiresearch.org/mumbuca/. Accessed on July 2023.

[14] Samer Hassan and Primavera De Filippi. 2021. *Decentralized Autonomous Organization*. Technical Report. Internet Policy Review. https://policyreview.info/glossary/DAO

[15] N Howard. 2022. Towards ethical good practice in cash transfer trials and their evaluation [version 2; peer review: 2 approved]. *Open Research Europe* 2, 12 (2022). https://doi.org/10.12688/openreseurope.14258.2

[16] George Iosifidis, Yanick Charette, Edoardo Airoldi, Giuseppe Littera, Leandros Tassiulas, and Nicholas Christakis. 2018. Cyclic motifs in the Sardex monetary network. *Nature Human Behaviour* 2 (11 2018). https://doi.org/10.1038/s41562-018-0450-0

[17] Chrysanthi Kosyfaki, Nikos Mamoulis, Evaggelia Pitoura, and Panayiotis Tsaparas. 2018. Flow Motifs in Interaction Networks. (2018). arXiv preprint arXiv:1810.08408.

[18] Hartmut H. K. Lentz, Thomas Selhorst, and Igor M. Sokolov. 2013. Unfolding Accessibility Provides a Macroscopic Approach to Temporal Networks. *Phys. Rev. Lett.* 110 (Mar 2013), 118701. Issue 11. https://doi.org/10.1103/PhysRevLett.110.118701

[19] Bernard Lietaer. 2013. *The future of money*. Random House, New York, NY, USA.

[20] Susana Martín Belmonte, Jordi Puig, Mercè Roca, and Marta Segura. 2021. Crisis Mitigation through Cash Assistance to Increase Local Consumption Levels—A Case Study of a Bimonetary System in Barcelona, Spain. *Journal of Risk and Financial Management* 14, 9 (2021), 430. https://doi.org/10.3390/jrfm14090430

[21] Carolina ES Mattsson, Teodoro Criscione, and William O Ruddick. 2022. Sarafu Community Inclusion Currency 2020–2021. *Scientific Data* 9, 1 (2022), 426.

[22] Carolina E S Mattsson, Teodoro Criscione, and Frank W Takes. 2023. Circulation of a digital community currency. *Scientific Reports* 13, 5864 (2023), e5864. https://doi.org/10.1038/s41598-023-33184-1

[23] Carolina E. S. Mattsson, Allison Luedtke, and Frank W. Takes. 2023. Inverse estimation of the transfer velocity of money. (2023). arXiv preprint arXiv:2209.01512.

[24] Satoshi Nakamoto. 2008. Bitcoin: A Peer-to-Peer Electronic Cash System. https://bitcoin.org/bitcoin.pdf Accessed: 2022-07-01.

[25] n.d. 2015. Ethereum Improvement Proposal 20: ERC-20 Token Standard. https://eips.ethereum.org/EIPS/eip-20. Accessed on September 2021.

[26] REC Barcelona 2023. *REC Barcelona - Tecnologia*. REC Barcelona. https://rec.barcelona/tecnologia/

[27] Danilo Pitarello Rodrigues and Denise Maria Neumann. 2021. Moeda social e desenvolvimento local em Maricá (RJ). http://bibliotecadigital.fgv.br:80/dspace/handle/10438/31485 Accepted: 2022-01-04T16:10:45Z.

[28] Jamsheed Shorish, Matt Stephenson, and Michael Zargham. 2021. *A PRACTICAL THEORY OF FUNGIBILITY*. WorkingPaper. Institute for Cryptoeconomics. Updated version.

[29] Malcolm Torry. 2019. *The Palgrave international handbook of basic income*. Palgrave Macmillan, London, UK.

[30] Circles Coop eG. n.d.. *Circles Whitepaper*. Circles Coop eG. Retrieved May 14, 2023 from https://github.com/CirclesUBI/whitepaper

[31] Alexander Ulrich, Ralph Holz, Peter Hauck, and Georg Carle. 2011. Investigating the OpenPGP Web of Trust. In *Computer Security – ESORICS 2011*, Vijay Atluri and Claudia Diaz (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 489–507.

[32] Cristina Viano, Sowelu Avanzo, Monica Cerutti, Alex Cordero, Claudio Schifanella, and Guido Boella. 2022. Blockchain tools for socio-economic interactions in local communities. *Policy and Society* 41, 3 (2022), 373–385. https://doi.org/10.1093/polsoc/puac007

[33] Carlos Viñuela, Juan Sapena, and Gonzalo Wandosell. 2020. The Future of Money and the Central Bank Digital Currency Dilemma. *Sustainability* 12, 22 (2020). https://doi.org/10.3390/su12229697

[34] Kaiwen Zhang and Hans-Arno Jacobsen. 2018. Towards Dependable, Scalable, and Pervasive Distributed Ledgers with Blockchains. In *2018 IEEE 38th International Conference on Distributed Computing Systems (ICDCS)*. IEEE, Vienna, Austria, 1337–1346.