

Prosocial Exchange Systems: Nonreciprocal giving, lending, and skill-sharing

ABSTRACT

Prosocial exchange systems support cooperation and exchange in support of more sustainable forms of consumption. While often assumed that exchanges within such systems are reciprocal, it remains unproven as to what extent reciprocity occurs. This study uses data from a live service – Streetbank.com - to present an analysis of direct and indirect reciprocal relationships (for interactions of giving, lending, and skillsharing) over 4 and half years. The dataset contains behavioural data relating to 5053 acts of offline non-monetary exchange. The analysis categorised different forms of exchange that took place – giving, lending, and skill sharing. These exchanges were then analysed for direct (one-to-one) and indirect reciprocity (chains of three or more users). The results show that instances of reciprocity are rare, and when present often span more than one type of exchange. The conclusion is that reciprocity cannot be assumed to be the norm in prosocial exchange systems. Practically, design and deployment should not be predicated on reciprocity. Furthermore, any means to encourage reciprocity should make patterns of exchange visible, and do so across hybrid forms of exchange.

KEYWORDS

Giving, Sharing, Reciprocity, Collaborative Consumption, Sharing Economy, Network Analysis

1 Introduction

There have been many attempts to categorize organizations and technology-based services that facilitate sharing or forms of consumption that privilege access over ownership (e.g. Botsman and Rogers 2010; Breitsohl et al. 2015; Bucher et al. 2016; Hellwig et al. 2015; Lamberton and Rose 2012; Scaraboto 2015; Schor and Fitzmaurice 2015; Watkins et al. 2016). The widespread use of the ‘sharing economy’ label in conceptual and empirical research often conflates two distinct types of organization (Harvey et al, 2018). The first category of service encourages collaborative forms of consumption that are monetized. These organizations and supporting technologies encourage people to consume products and services through selling, or paying for, access rights rather than outright ownership, but the organizations and indeed the people using their services are nonetheless financially motivated (see for example monetised ‘ridesharing’ applications - Glöss *et al.*, 2016). The second category are organizations with supporting technologies that exhibit prosocial forms of interaction design. These *prosocial exchange systems* enable people to circulate goods without the need for financial remuneration (Harvey, et al, 2014a; Harvey et al., 2014b). They are best conceptualized as a computer-mediated means for people to share, exchange or give away objects. Sometimes the motivational differences between these behavioural categories is unclear, or more than one behaviour is supported by the technology, and thus the behaviour exhibited by users appears as a ‘hybrid’ form of prosocial interaction (Arsel and Dobscha, 2011). If there is any sharing in the sharing economy these hybrid examples provide the best illustration but, in contrast to monetised alternatives, the social configurations they create remain under-researched.

Bucher et al, (2016) and Zhang et al (2018) both demonstrate the importance of social motivations for people who use sharing economy and collaborative consumption technologies.

A central theme is the idea of *reciprocity* and the perception of continued social exchange between users. Despite the importance often ascribed to reciprocity, empirical evidence is difficult to obtain where data is collected through interviews or surveys based on intention and attitudes of individuals, rather than observations of actual group behaviour over time. These methods cannot accurately study the flow of interactions across a whole population and thus are likely to misrepresent the actual likelihood of reciprocity occurring. Population datasets of non-monetary interactions are notoriously difficult to obtain for longitudinal study due to the lack of currency, quantification, record or receipt normally involved. However, this evidence is important given that some researchers have questioned the appropriateness of the reciprocity concept for explaining non-monetary exchange generally (Pryor and Graburn, 1980; Ingold, 1986; Hann 2006; Graeber 2014; Widlok, 2017). These doubts have been demonstrated qualitatively in studies of sharing technology (Hellwig *et al.*, 2014, Harvey *et al.*, 2014a; Aptekar, 2016), but quantitative network data examined across time is lacking. This is problematic because surveys provide a singular temporal insight in which respondents are asked to recall their specific behaviour across years of interactions with people (often strangers), which even if remembered and reported accurately, and despite known inconsistencies between consumer attitudes and actual behaviour (Moraes *et al.*, 2012), can only give insight into the immediate people with whom they met rather than the broader network topology across which reciprocity might have emerged.

The following paper presents a network analysis of a prosocial exchange system at scale and over time, to determine whether reciprocal relations emerge between people. The database is derived from logged interactions over the lifetime of a prosocial exchange system – Streetbank - that facilitates the giving and lending of goods and free provision of services. Through the application of a social network analysis approach (Kadushin, 2012), different types of

exchange are examined: giving, lending, and skill sharing. These behaviours are then analysed for patterns of reciprocity to empirically test whether this behaviour is or is not present in such a system. The data demonstrate that, for this case at least, direct (person to person) reciprocation plays a negligible part in the ongoing sustainability of the system, and that the overwhelming majority of interactions are one-sided. In the rare cases where reciprocity is present it is emergent from the interaction of the system as whole i.e. not just through one mode of exchange, such as giving. The results have theoretical implications for understanding the nature of sharing, but the lack of reciprocity found also has clear implications for how prosocial exchanges systems are designed and positioned.

The rest of the paper proceeds as follows. Section 2 discusses the historical background of prosocial exchange systems and recent empirical work which has attempted to understand why people use them. Section 3 presents Streetbank as a case study for studying non-monetary exchange relations. Section 4 outlines the research design of the study which is composed of an exploratory network analysis. Section 5 presents results, and section 6 discusses theoretical and practical implications. To the best of our knowledge, the study provides the first clear quantitative demonstration that prosocial exchange is not driven by either direct or indirect reciprocity.

2 Background

Researchers from a range of disciplinary backgrounds have developed different approaches to studying non-monetary exchange, but there is nonetheless one common recurring concept in explanation that is relied upon: *reciprocity*. It has been used to explain the psychological perspective of ‘tit-for-tat’ exchanges between individuals (Axelrod, 1984), the evolutionary benefit of altruism between strangers (Trivers, 1971), and has even been posited as an all-

encompassing feature of culture (Thurnwald, 1916; Levi-Strauss, 1963). Mauss (1925/1967) described gift economies that demonstrate a ‘polite fiction’, in which gifts are given freely and expressed as such, despite an expectation – indeed, a moral obligation – to return the favour. If much of the research already conducted into consumer gift giving is to be believed i.e. giving done within market economies (particularly following Sherry, 1983), this would also be the case for new prosocial exchange systems. As Giesler (2006, p. 284) notes, this tradition of research views *‘gift giving as a continuous cycle of reciprocities and theorizes the gift exchange process as a dialectical chain of gift and token gift transactions between two gifting partners.’* Most of the work that specifically analyses the reciprocity of computer-mediated relations between people has been restricted to interactions that occur solely online on websites. This research typically attempts to model social relations as ‘trust’ i.e. the way in which design may enable unfamiliar people to interact and share information without meeting in person and spending time together (e.g. Constant et al., 1996; Wasko and Faraj, 2005; Kankanhalli et al., 2005; Chiu et al., 2006). Although much of the work points out that people enact autotelic behavior, or in other words, an act for the sake of acting rather than for a subsequent instrumental purpose (Bucher et al, 2016; Zhang et al., 2018), the conclusion is normally one of *‘generalised reciprocity’*, contrasted with *balanced* or *negative* reciprocity (expectation of repayment in a future exchange or expectation of immediate repayment, see Sahlins, 1979). This form of studying trust has subsequently been extended into research of sharing systems where offline meetings occur. An example of this can be seen in a study of social relations on Couchsurfing (Lauterbach et al., 2009), where an emphasis is again given to generalised reciprocity when explaining the way people act.

Economic relations, in which a transfer of property takes place, are unlikely to be of a similar nature to other human relations such as friendship or trust because of two constraining factors for the emergence of network relationships: (1) *excludability* - transfers are restricted by personal property; and (2) *subtractability* - goods cannot be used infinitely without degrading (See Ostrom, 2003). Goods come in a variety of forms and qualitative studies of prosocial exchange system users suggest a similarly broad range of motivations for donors and recipients alike (Guillard and Del Bucchia, 2012; Albinsson and Perera 2012, Hellwig *et al.*, 2014, Harvey *et al.*, 2014a; Aptekar, 2016). Motivation may vary, for instance, as people may use the system because of self-interest, decluttering, a desire to help others, environmental concerns, or ‘greenwashing’ (Arsel and Dobscha, 2011; Aptekar, 2016). However, generalised reciprocity is nonetheless routinely described as the concomitant psychological driver which can explain how these systems are reproduced (e.g. Nelson and Rademacher, 2009; Willer *et al.*, 2012; Lampinen *et al.*, 2013; Klug, 2017).

Rather than a simple form of *direct reciprocity* (a sequence of bi-directional transfers between two nodes, delimited by time), the generalised reciprocity concept suggests more complex or emergent forms of reciprocity. Generalised reciprocity is deployed in two clear ways: (1) to explain presumed behavioural chains of people returning favours in a circle of normative commitment or interdependence (Geisler, 2006; Yuan *et al.*, 2018), henceforth we refer to this behaviour as *indirect reciprocity* i.e. a circular and sequential transfer between three or more nodes, delimited by time; or (2) as a form where reciprocity occurs attitudinally as a widespread folk belief. However, though previous researchers who posit generalised reciprocity as a causal determinant of prosocial exchange have examined attitudinal perspectives on reciprocity through interviews, surveys or participatory methods (e.g. Nelson and Rademacher, 2009; Willer *et al.*, 2012; Lampinen *et al.*, 2013; Klug, 2017), a lack of publicly available network

data has, to the best of our knowledge, thus far eluded researchers of prosocial exchange systems and prevented a broader examination of indirect reciprocity.

One further dimension to reciprocity is the nature of exchange that might be supported. Belk (2010) and Harvey et al (2014a) highlight that many prosocial exchange systems do not support only one type of exchange but may support both giving and lending, or may involve sharing around either tangible physical goods and objects, or around the sharing of services. Services that support more than one kind of sharing, or encourage exchanges with characteristics of multiple prototypical forms, can be considered 'hybrid'. Hybrid exchange adds another dimension to the study of reciprocation in that reciprocity may take place over different forms e.g. giving, lending, or sharing. For example, people in car sharing schemes may be unable to directly reciprocate by offering a car journey, because they cannot drive, but may instead offer forms of reciprocation or gifts in kind (Lovejoy and Handy, 2011).

The belief that reciprocity occurs only directly between people, or occurs at all, may result in a false conceptualisation of users and consequently management of these systems may therefore be based on a false premise i.e. behavioural reciprocity is assumed and this affects structures and designs of exchange systems even though it might not actually occur. It also encourages a motivational or attitudinal approach to research without attending to the social antecedents and context of behaviour. This echoes an issue previously identified in the related field of charity donation, where Hibbert and Horne (1996, p.9) noted "*donor behaviour research has concentrated heavily on motivation but has paid scant attention to the actual giving situations.*" By neglecting the situational determinants of behaviour, motivational research fails to account for potential attitude-behaviour gaps that may exist.

We suggest that an alternative approach is to first observe the actual interactions of users at scale and then use abductive reasoning to account for the observation using inference to the best explanation. Abduction has historically been resisted within the HCI literature, but data-driven approaches can help answer questions beyond the scope of hypothetico-deductive approaches, particularly where observed behavioural data gives unprecedented insight into how people act in natural settings (Hofacker et al., 2016). However, many of the organizations that facilitate non-monetary exchange over the Internet are of a not-for-profit status, so unlike their commercial counterparts, they are not as reliant upon exploiting user data for financial gain. They are created to encourage altruistic user interactions, so can be reluctant to release data publicly that could jeopardise their effectiveness. As well as practical considerations of releasing data, these organizations typically adhere to a legal and moral duty of care not to reveal the data ‘footprint’ of their users inadvertently (e.g. Streetbank, 2019a), which is challenging given new informational and physical privacy threats that arise from sharing property (Lutz *et al.*, 2017). These challenges have made it difficult for researchers to gain access to historical datasets which could be used for analysis and public dissemination. Nevertheless, through collaboration with a prosocial exchange system called Streetbank based in London, England, we have been granted access to an unprecedented historical dataset. In the following section we provide an overview of Streetbank and their user demographics.

3 Data source: Streetbank

Streetbank is a London-based charity established in 2009 by Sam Stephens. Streetbank hosts an online service called streetbank.com. It was created with the intention to improve social relations in local neighbourhoods by encouraging altruistic acts of non-monetary exchange. Anybody can sign up and make requests or offer help to local people. Users can offer their belongings to others who can choose to lend the items for a short period of time, or if they

prefer users can give away their belongings entirely. The service also provides a means to match users for ‘skill-sharing’ e.g. language lessons, music tuition, help with technology etc. By offering multiple forms of sharing, Streetbank is typical of a hybrid exchange system (Harvey, 2014a). The service has proven to be successful with over 38,000 users signed up in a variety of countries including the UK, USA, and Australia, and continues to operate. Streetbank has been cited in numerous articles on the sharing economy, particularly as a positive example of sharing (when contrasted with pseudo-sharing i.e. commodity exchanges branded as ‘sharing’ – See Belk, 2014), and as a case study on the transformative potential of sharing to reframe political economy (Bradley and Hedren, 2014; Kennedy, 2016; Martin, 2016; Hult and Bradley, 2017; Rufas and Hine, 2018; Dellaert, 2019). However, it has nonetheless not received much empirical scrutiny despite calls for analysis of the new social configurations of people using prosocial exchange systems (e.g. Snow *et al.*, 2017). An example of local items (either for borrowing or available for free) and skillshare opportunities visible to users in a UK city is presented in Figure 1.

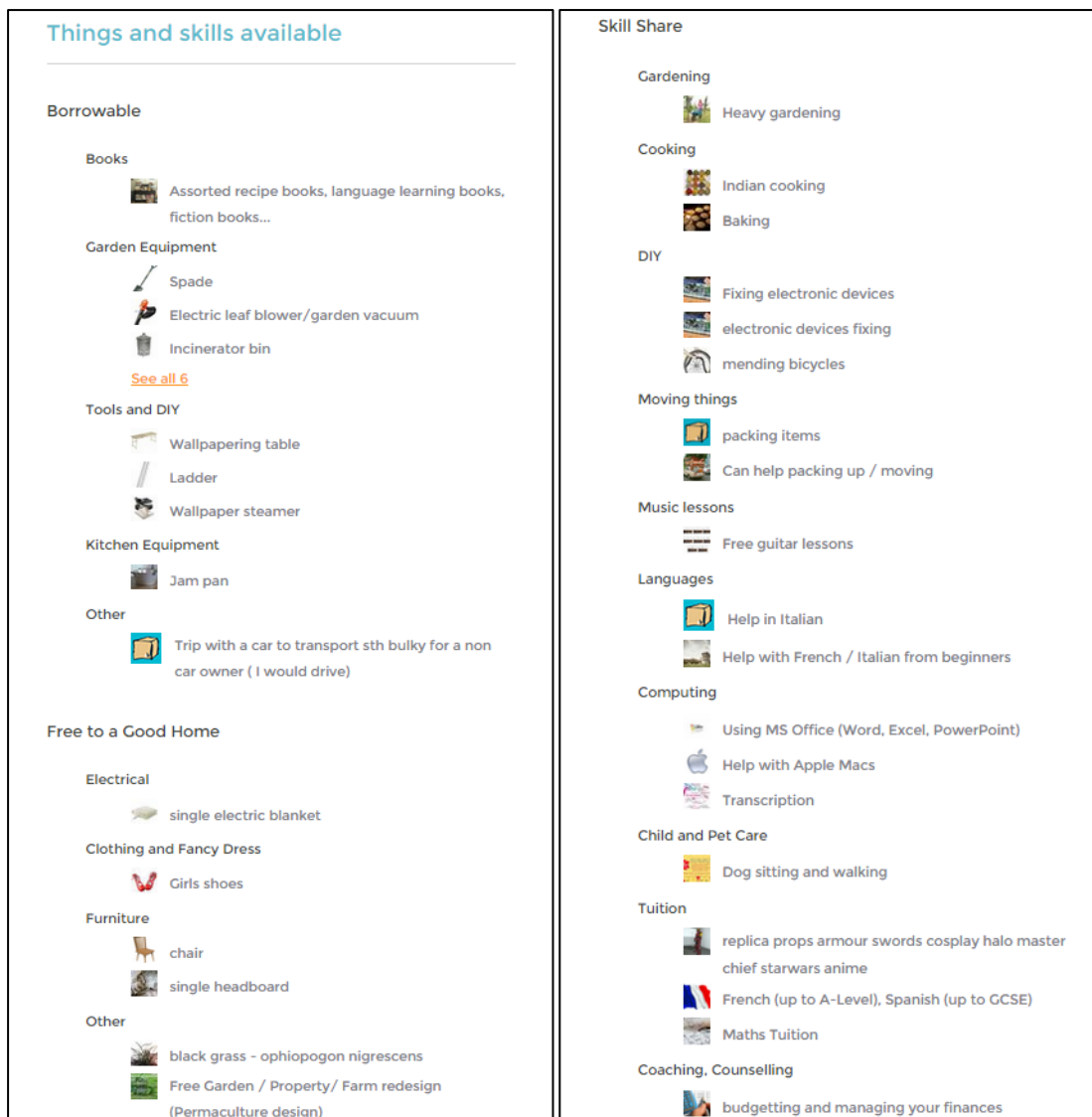


Figure 1: A localised example of the items and skills available on Streetbank

Streetbank records information about users as a means of supporting initial interpersonal dialogue online, with the hope that this dialogue will result in an offline interaction and potentially long-term relationship. The nature of the interaction depends on the type of relationship that both participants desire, as it is possible to borrow items or give them away entirely. The user interface will typically present available items within the immediate local area (with the aim of creating a ‘bank’ of items at street level, hence the website name), but

there is also the option to broaden searches for items outside the local vicinity as shown in the figure 2.

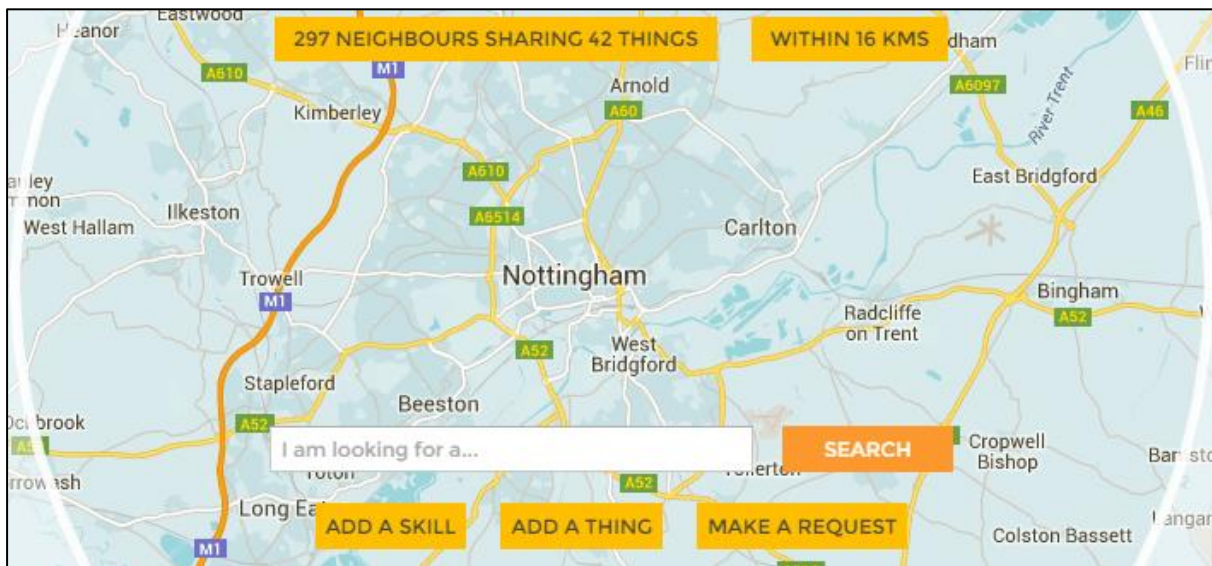


Figure 2: Streetbank user interface - search functionality

The design therefore facilitates interactions between people who a) do not necessarily know each other, and b) do not necessarily live close to each other. Once a request is made online the message is made available to the respondent through the website messaging system and is also relayed via email. If both parties agree upon the terms of the offline interaction a meeting is then arranged. Anecdotal evidence from discussion with Streetbank staff suggests that offline meetings generally occur at the place the item or person with the skill is located, although this is not a formalised rule. Intermediary persons and intermediary locations such as public locations and workplaces may also be involved in the interaction. Once an offline interaction has taken place, feedback happens informally between users, rather than a public rating, as is seen on some other prosocial exchange systems (e.g. Harvey *et al.*, 2014a). At the time of data collection, unlike websites such as Couchsurfing, there is currently no reputation mechanism on Streetbank which can serve as a means of analysing failures to meet offline (although this functionality is planned).

The dataset presented in the following sections is based on the online messages (specifically formal ‘accept’ and ‘reject’ messages) rather than physically observing offline meetings because of the scale of the analysis necessary. As the messages are explicitly categorised (request / accept / reject) this provides an opportune data source to examine the broad patterns of social interaction that take place, and to demonstrate whether patterns of reciprocation occur naturally.

4 Research Approach

The design of the study focuses on topological network measures of a longitudinal dataset to examine the following three research questions:

RQ1: How do different forms of hybridised exchange take place within the data? Here we are interested in understanding how Streetbank facilitates hybridised forms of prosocial exchange, including giving, lending, and skillsharing (as called for by Harvey et al., 2018).

RQ2: Does direct and indirect reciprocation occur in the network? This question is a direct response to work which suggests generalised reciprocity is the psychological mechanism through which prosocial exchange systems are reproduced (Nelson and Rademacher, 2009; Willer et al., 2012; Lampinen et al, 2013; Klug, 2017).

RQ3: To what extent do donors and recipients form interdependent subgraphs within the broader Streetbank network? Beyond reciprocal relations, what other topological network features have emerged, and what do they reveal about the formation of new social configurations (which as suggested by Snow et al, 2017, remains unclear from existing empirical research.)

The overall aim of the research is to provide the first comprehensive study of user behaviour in a prosocial exchange system using quantitative network methods. We now briefly outline the methods used to answer each of the research questions in turn.

RQ1 – Analysing forms of hybrid exchange

The core research method is exploratory network analysis (Kadushin, 2012). Network analysis software was used for both statistical analysis and visualisation purposes. The open source software named ‘Gephi’ was used for visualisation of the Streetbank network graph (See Bastian et al, 2009). UCINET and Pajek were used for network analysis and topological measures (See Borgatti *et al.*, 2002; Borgatti *et al.*, 2013; De Nooy et al, 2018).

In addition to descriptive data analyses (e.g. how many exchanges take place, and of what type), a simple measure of who is both a donor and a recipient would indicate a user who at least performs both roles. However, such a user may not donate and receive from a single other user (i.e. the reciprocation is not direct). To address this issue, social network analyses are introduced in RQ2.

We are also interested to understand how geography influences the exchanges that take place, and compare across forms of exchange. Postcodes of senders and recipients were included in the dataset. These were combined with a separate dataset of UK latitude and longitude for each postcode. The data provide an insight into the distances Streetbank users travel to complete their exchange. The Haversine formula is used to calculate distance between two points on a sphere given their longitudes/latitudes and is regularly used in research examining the influence of social networks on offline travel behaviour (Rossi and Musolesi, 2014; Baucom et al., 2013). The data can subsequently be used to estimate the distance likely travelled for each offline

interaction before estimating the network average and variance. These estimates are of interest because distance variance may provide further insight into how important travel considerations are to users and how location-specific information should be presented to encourage user participation.

RQ2 – Calculating Direct and Indirect Reciprocity

Direct reciprocity is measured by counting bi-directional edges between nodes as a proportion of all edges within the network. We define indirect reciprocity as an arrangement in which exchanges follow a circuitous pattern between three or more people, within a directed (time-bound) sequence. Direct reciprocity measures are widely available in network analysis software but indirect measures of reciprocity are not widely used. Indeed, to our knowledge there are no existing empirical studies of indirect reciprocity in prosocial exchange systems such as Streetbank. It was therefore necessary to write a bespoke algorithm to count the number of direct cycle subgraphs within the Streetbank network. Python was used to identify the presence of indirect reciprocity by counting the number of directed cycle subgraphs within the dataset, from three people upwards. The total directed cycles at each depth is then aggregated and the number of edges that fall on a cycle are then calculated as a proportion of all edges within the network. An example of a directed cycle with a depth of four is shown below between nodes 2-3-5-4.

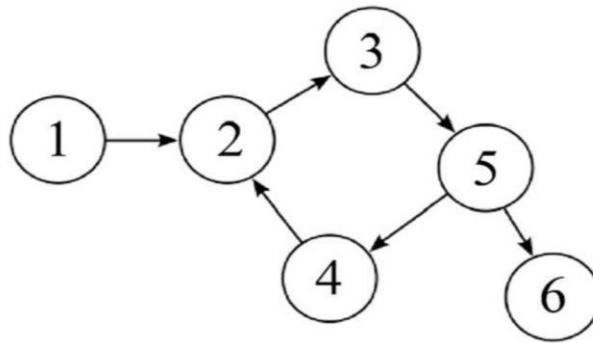


Figure 3: Example of indirect reciprocity through a four-person directed cycle

Temporal sequence is also important throughout the directed cycles because this would provide evidence that people were actually responding to the idea of giving something in order to get something back in future from other people in the network.

RQ3 – Network topology and user interdependence

We introduce a range of topological measures to demonstrate the configurations of exchange relations formed by Streetbank users. In and out degree distributions give a sense of the typical profile of a user (how much an individual gives and receives), but we are also interested in the broader structures that have formed throughout the network. Transitivity is a specific term used in network analysis, where a set of relations are said to be transitive when ‘A is related to B and B is related to C then there would be a relationship from A to C’ (Borgatti Everett and Johnson, 2013, p.155). For directed graphs, transitivity helps to illustrate the emergence of chains of dyads, but they are not necessarily reciprocal. Indeed, it may even be expected if the people who take part in Streetbank adopt a ‘pay it forward’ mentality (Yuan et al., 2018). In the context of the social networks being examined in this study a partially transitive relation is a situation in which a person both donates and receives an object within the context of the social network, but the original donor and the final recipient do not have a direct relation. A network with complete transitivity would demonstrate a high degree of inter-relatedness and

potentially dependence between the participants. However, for most social networks there are ‘structural holes’ between nodes (Burt, 2004). In this study, we perform measures of transitivity known as a triad census (Batagelj and Mrvar, 2001), but we also identify the presence of cliques to illustrate the broader structures that could indicate ‘community’. A clique is a maximally complete subgraph in which all participants are connected to each other.

4.1 Data Collection

The source dataset was collected by mining Streetbank’s web administration interface. A script was written to scrape data from the website and the resultant data was transferred into a Microsoft Excel spreadsheet. Personal data (names, email addresses etc.) were not collected. The data set was cleansed so as not to store or inadvertently reveal the details of any single user of the service. The focus was solely on interactions between users. For example, there was no data recorded about the content of messages, only what type of category the interactions were i.e. request, accept, or reject. All the messages collected are time stamped and have associated postcode data for sender and recipient.

4.2 Ethics

The dataset contains only adults (aged 18 years and over) as per the terms of Streetbank’s terms and conditions. Specific personal information relating to individual users was not stored or analysed. All social network data included for consideration within the study were anonymised at point of collection and only aggregate statistics were included for analysis.

5 Results and Discussion

A broad overview of the dataset revealed 38,199 users. In total the dataset covers 4 years 6 months and 15 days (1660 days). The most active member communities are in the UK – but increasingly the service is becoming popular in Australia and America. Many of the users are active online but have not used the service to meet offline. The number of messages in the dataset are categorised as follows: 10250 Request Messages; 5053 Accept Messages; and 1097 Reject Messages. The 5053 Accept messages were taken forward for further analysis as these represent formal consensus agreed between donor and recipient to actually meet in person offline.

5.1 Users and types of exchange

Number of unique offline active users i.e. donated or received	3961
Number of unique donors	2483 (Blue)
Number of unique recipients	2268 (Orange)
Users that have BOTH given and donated using Streetbank	790 (Intersection)
Number of offline donor-recipient dyadic relationships formed (duplicate dyads removed)	4230

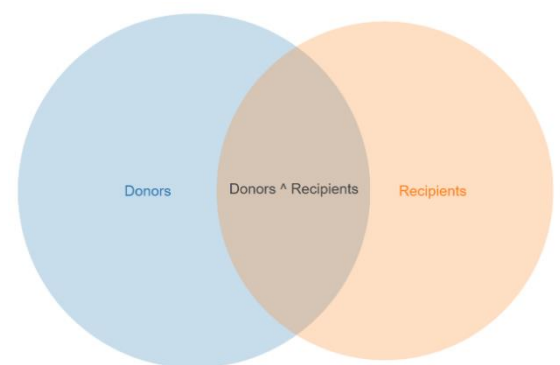


Table 1: Active ‘offline’ users - overall statistics & proportions

What is particularly novel about this dataset is that it does not arbitrarily sample from a bounded period of time, but covers the entire history of the website beginning with the first recorded interaction between users. This provides an opportunity to analyse the entire history of computer-mediated social interaction rather than an isolated segment of time. Despite this longitudinal view, only a fifth of users have successfully used Streetbank to both donate and receive from other members. This is the simplest measure of balance in the network. It suggests that there are qualitatively distinct roles in the network that further analysis might help

to reveal. Balance in aggregate behavioural statistics does not necessarily indicate reciprocity though i.e. those users that have participated in direct or indirect chains of action which could have as associated instrumental purpose. As users may engage in more than one transaction, accepted transactions were analysed to determine the number of unique users. 3961 unique users, were identified. 2843 users performed a donor role, and 2268 users performed a recipient role. Of these, 790 at some time performed both a donor *and* recipient role, representing 19.94% of the 3961 unique users, who had successfully exchanged, but only 3% of the full user base of Streetbank. Persuading users to move from online interaction to offline interaction undoubtedly represents the most significant design challenge for Streetbank, or indeed any prosocial exchange system.

Categorising the type of interaction relies on users identifying the type of relationship they are agreeing to when accepting (either skillshare, free item, or lending). For design purposes Streetbank do not validate this procedure i.e. some interactions are not categorised by users. The subset of accept messages that could be categorised, lead to the following characterisation of exchange types: Skillshare – 1036 accept messages; Free item – 1646 accept messages; Lend item – 881 accept messages. The results suggest that though free items (users giving items away) is the leading behaviour exhibited, Streetbank is nonetheless genuinely used for multiple types of exchange and genuinely exhibits hybridity (as described by Harvey et al. 2018).

	Free Items (n = 1401)	Lend Items (n = 772)	Skill Share (n = 845)	Combined – including no category dyads (n =4276)
Mean average (kilometers)	2.02	4.91	2.84	3.47
Standard Deviation	11.9731	29.00698	17.90109	21.40355

Table 2: Estimated distance travelled for offline interaction

The statistics for estimated distance travelled for offline meetups reveal broadly similar patterns regardless of category, with a mean average of 3.47 kilometres travelled for each interaction (SD = 21.40). Free items had a notably smaller mean average and standard deviation than for lending items (2.02 and SD 11.97 compared to 4.91 and SD 29.00). Items borrowed are often of a high value, hence why the service is useful to so many people, and may go some way to explaining the higher average distance. This is potentially an interesting area for further study, particularly so if the financial value of the items being given away or borrowed could also be accounted for. There were some instances of users travelling long distances to interact with each other (far beyond street level vicinity). This seems antithetical to the reason Streetbank came into existence, but it demonstrates the extraordinary nature of the service because such interactions between strangers would have been very difficult to organise at this scale prior to the existence of the Internet. A limitation to the distance estimation is that it relies specifically upon postcodes and not specific addresses, and that household meetings are assumed to be the common place of transfer / skillshare. This is assumed because of anecdotal evidence, but the insight should ideally be corroborated with further ethnographic observation.

5.2 Network Analysis of Direct and Indirect Reciprocity

The directed network graph below presents an overview of successful transactions between Streetbank users and was visualised using Gephi. The layout algorithm used was created by Fruchterman and Reingold (1991) and is used to visually delineate disparate interactions (distance between nodes is non-representative). Users are depicted as nodes (n = 3961) and transfers are depicted as edges (n = 5053). In total, this represents 4230 dyadic relationships.

The relations formed between users tends toward simplistic unidirectional structures. The centre of the graph reveals more complexity and clustering than the periphery. The larger central components are closely related to geography (and distance travelled), so many of the more densely connected hubs correspond to local 'communities', particularly around London (UK), which is where Streetbank originates. Overall, the network density, a measure of the interrelationship of members of the network, is equal to 0.064%. This indicates the network is highly fragmented.

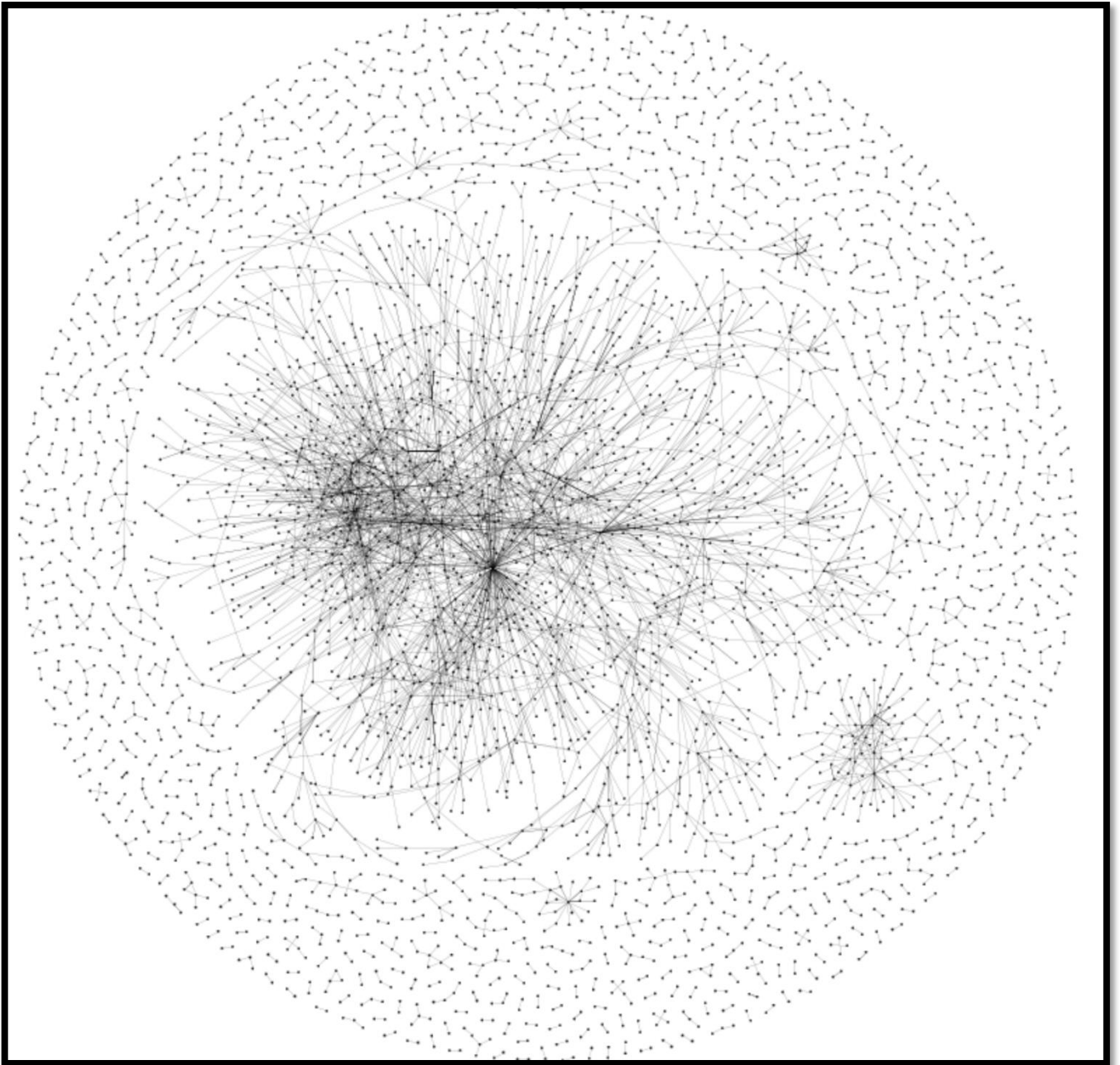


Figure 4: Directed network graph showing successful transactions between Streetbank users.

Users are depicted as nodes ($n = 3961$) and transfers are depicted as edges ($n = 5053$)

4230 dyadic relationships that formed were analysed temporally in terms of the different forms of exchange (giving, lending and skill sharing). Overall, fully symmetrical dyads (where reciprocity is present) are rare (less than 1% for each form of exchange), but even when the

forms of exchange are combined dyadic reciprocity remains at 1.24% i.e. only one in a hundred dyadic relations that form lead to direct reciprocity.

	Combined	Free items	Lend items	Skill share
Symmetrical Dyads	52	13	6	0
Asymmetrical Dyads	4178	1363	766	929
All Dyads	4230	1376	772	929
Dyad-based Reciprocity %	1.24%	0.95%	0.78%	0%

Table 3: Dyad Symmetry statistics

At a dyadic level, the presence of balance is a rare occurrence. Skill sharing provides the most dramatic illustration of the absence of balance at the individual level. Not a single dyad has demonstrated a skill-sharing reciprocal arrangement. This has important implications for the way that Streetbank and other prosocial exchange systems should characterise the service they are promoting. The sharing they describe is sharing in practice not just description. Streetbank users are acting in an autotelic manner not dependent on a bi-directional exchange, so to explain it in terms of direct reciprocity would be a mistake. As the membership sets for donors and recipients are so imbalanced, one possible reason is that these are ‘positional’ forms of prosocial interaction, or in other words, they occur between people who occupy distinct objective places within broader social structures (Elder-Vass, 2015).

Dyadic statistics offer a first insight into direct reciprocity, but dyadic interaction should also be considered against broader social structures that can reveal longer reciprocal chains between small groups or communities. The results for the indirect reciprocity analysis are shown in the two figures below. The results reveal that indirect reciprocity has occurred within the Streetbank network up to a depth of 7 people (time-ordered cycles) across the study period of 1660 days. However, these circuitous patterns are exceptionally rare. Indeed, when both direct and indirect reciprocal interactions are taken together (67 instances) they still only account for 1.58% of exchanges. Furthermore, many of the exchanges which are reciprocal take a long

time to emerge. As shown in figure 6, only 33 instances of reciprocity occur within 100 days. This raises the question how, long can a reciprocal act be delayed and still be described as a psychological driver of participation? We propose that many of the instances of reciprocity may in fact be due to chance rather than the formation of interpersonal indebtedness or obligation.

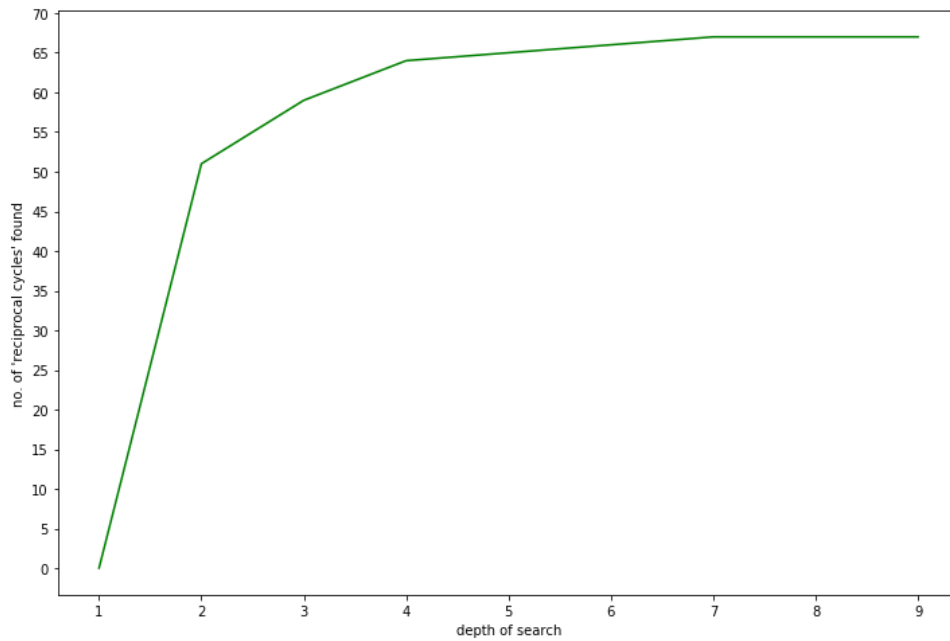


Figure 5: Indirect reciprocity statistics generated through time-ordered cycles

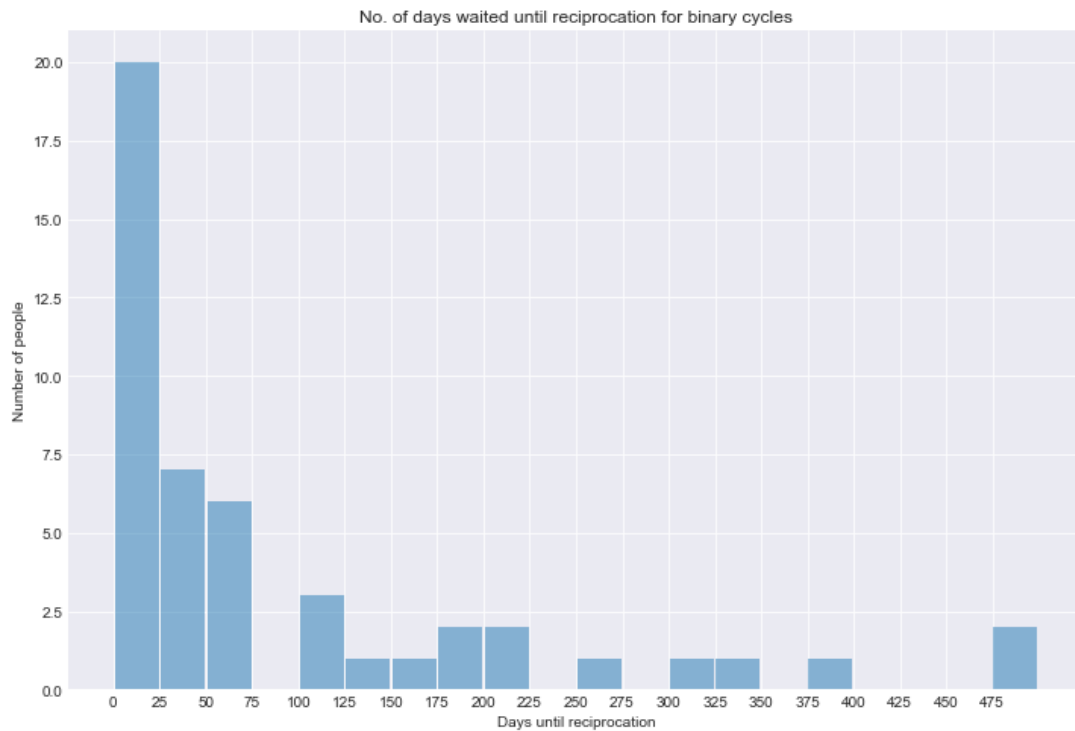


Figure 6: Delay period for reciprocity.

These network measures reveal unequivocally that group-enabled indirect reciprocity is not a common feature of this prosocial exchange system, and thus provides empirical contradiction to previous work which argues such systems persist because of generalised reciprocity (Nelson and Rademacher, 2009; Willer *et al.*, 2012; Lampinen *et al.*, 2013; Klug, 2017).

5.3 Network Topology and User Interdependence

The Streetbank network is not premised on reciprocity, but this topological characteristic does not preclude the emergence of novel social configurations or even communities of users emerging. The distribution of in and out degree measures gives the clearest insight into the basic structure of the donor-recipient network. The figure below reveals that the cumulative percentage of users that have used the service as either donor or recipients follows a similar structure, with the vast majority of Streetbank members using the service ten times or less in both roles.

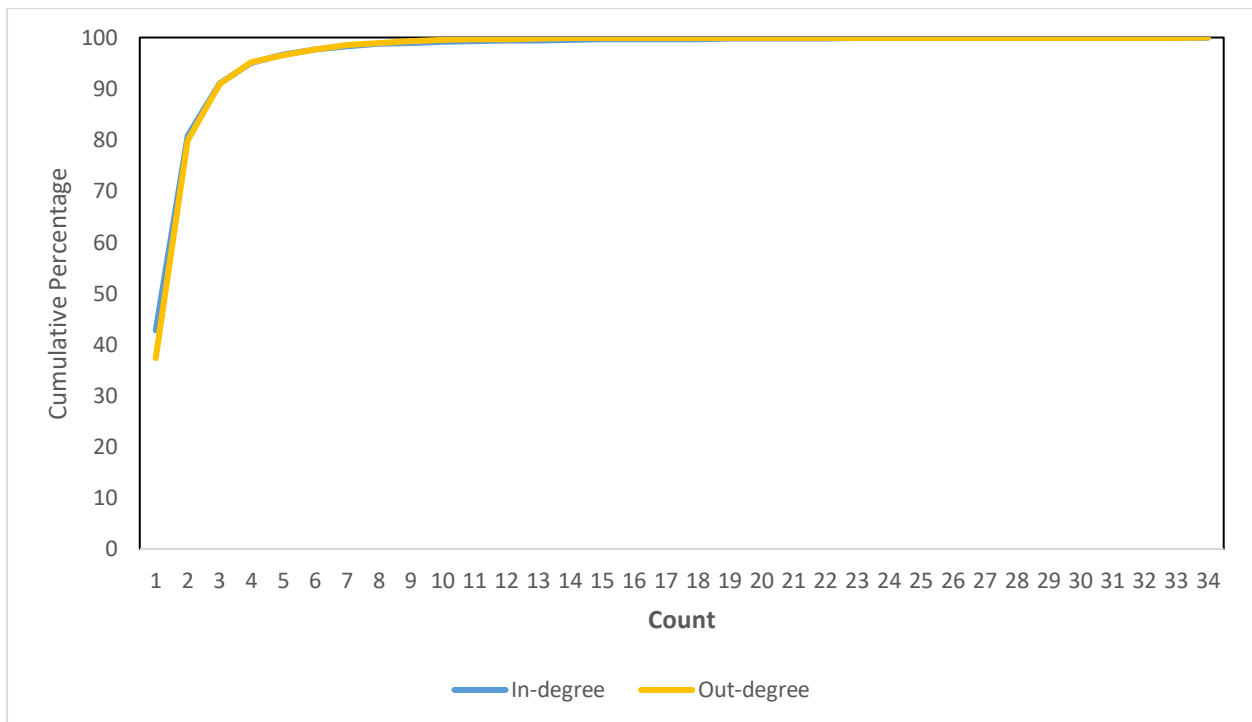


Figure 7: Cumulative Percentages for In-degree and Out-degree scores

The triad census reveals that the network is overwhelmingly intransitive, regardless of the category of interaction. The triplet measure provides a more practical basis to examine the structural relations that have emerged because of the choices made by Streetbank users.

	Combined	Free Items	Lend Items	Skill Share
% of Transitive Triads	0.021%	0.021%	0.012%	0.014%
Transitivity: % of ordered triples in which a->b and b-->c that are transitive	2.45%	2.37%	1.50%	1.41%
Transitivity: % of triangles with at least 2 legs that have 3 legs	0.50%	0.29%	0.29%	0.20%

Table 4: Triads and Transitivity analysis

The majority of non-vacuous triplet combinations were only evident when the categories were considered as one combined network. This suggests that user interdependence has not emerged based specifically on one category of the interaction. Indeed, it is only through multiple different forms of interaction at scale that the limited presence of interdependence and community structures have come to exist. 2.45% of ordered triples (where transactions occur in sequential order) in which a->b and b-->c are transitive. This demonstrates that it is much more common for Streetbank users to act in fragmented chains of dyads rather than channels for indirect reciprocity. This is illustrated further by the global measure of transitivity for triangles with at least 2 legs that have 3 legs (0.50%), relations between users tend towards extended links rather cohesive groups or loops. The network is highly fragmented, as shown visually in the network graph, which clearly illustrates the many disparate components at an offline level.

The Streetbank network is largely intransitive, unlike many other social networks. As suggested by Kadushin (2012, p.25) statistical tests ‘are very supportive of the proposition that interpersonal choices tend to be transitive’, but this study provides a counterexample. This is due to the nature of these relationships between people relying on intangible concepts such as friendship, support, alliance etc. These are all capable of being reproduced without necessarily subtracting from the quality of the relationship – one person may engage in relationships with several people without diminishing their own personal standing. However, when the concept

associated with a directional relationship is a transfer (i.e. transmission of a physical entity) that entity has the potential to be *excludable and subtractable* (Ostrom, 2003). This means that scarcity and personal agency are both constraining factors for the potential emergence of transitivity in the network. The consequence is that chains of actors are more common than circuitous donation patterns, which supports previous research (Snow et al, 2017) that further research into the socio-economic status of participants in sharing systems is required. However, if the notion of community is premised on interaction rather than directionality of transfer, we can symmetrise the graph (make it undirected) and look for evidence of nascent community structures created through cliques (instances where everybody in a group interacts with each other).

Clique Size	Combined	Free items	Lend items	Skill share
3 person	194	26	5	4
4 person	4	0	0	0
5 person	0	0	0	0

Table 5: Clique analysis

The network analysis revealed 194 3-person cliques, 4 4-person cliques, and 0 5-person cliques. This suggests that despite the design emphasis of Streetbank toward creating highly-interconnected local communities, there is a general proclivity of users toward disparate dyadic relations. The clique analysis also demonstrates that users are not acting as if each category of interaction (giving, lending or skill sharing) require different normative commitments i.e. as though a long-term relationship should be associated with specific patterns of interactions.

6 Contributions

The most striking feature of the network is in the dearth of reciprocal relationships. Despite previous work suggesting generalised reciprocity is the psychological mechanism underpinning the reproduction of prosocial exchange systems (Nelson and Rademacher, 2009;

Willer *et al.*, 2012; Lampinen *et al.*, 2013; Klug, 2017), the Streetbank data reveals in this instance at least, choices made by individuals demonstrate no reliance on balance, direct or even indirect reciprocity. Qualitative research into prosocial exchange systems discussed previously pointed to this conclusion (Guillard and Del Bucchia, 2012; Albinsson and Perera 2012, Hellwig *et al.*, 2014, Harvey *et al.*, 2014a; Aptekar, 2016). However, this dataset provides the first large scale quantitative analysis of structural relations in a prosocial exchange system.

6.1 Relevance to theories of sharing and ‘hybrid’ forms of exchange

Streetbank, like other prosocial exchange systems, provides a means for people to act in an autotelic manner that aligns with their own personal projects. It doesn’t depend on balance between individuals, and many of the interactions do not take place in an immediate local setting. Further work should examine the way in which these acts are explained in relation to other forms of economic activity. If Streetbank, like other prosocial exchange systems, is not best described using prototypical categories (Belk, 2010) such as ‘gift’, ‘sharing’ or ‘exchange’ there should be an emphasis on creating broader ontological categories to describe economic interaction, without a reliance on culturally-specific naming conventions (See for example Harvey *et al.*, 2017). This is not a trivial issue. As already observed, the ‘sharing economy’ is a term used loosely to encompass a variety of exchange systems that are diverse, and this conflation potentially jeopardises the precision with which sharing systems can be understood in relation to concomitant psychological mechanisms.

6.2 Implications for HCI Design and Management

Beyond the detail reviewed above it is worth emphasising the salient findings and their implications for practice. Reciprocity has been a central feature of studies that aim to explain prosocial exchange behaviour. Studies repeatedly emphasise the notion of generalised

reciprocity when explaining the way people act (Nelson and Rademacher, 2009; Willer *et al.*, 2012; Lampinen *et al.*, 2013; Klug, 2017). The Streetbank findings suggest that reciprocity is largely absent. This is striking, but the analysis is based on behavioural data examined over four and a half years. Though Streetbank offers a particular service by combining three forms of interaction (giving, lending, and skill-sharing) it is nonetheless similar to many prosocial redistributive/sharing platforms which have emerged in the past decade (see for instance a comprehensive comparative review by Codagnone *et al.*, 2016). Streetbank's core functionality is similar to others that provide a platform for non-monetary models of exchange (e.g. Freecycle, Freegle, and many others). The findings are based on data-driven investigation and they suggest that a fundamental 'pillar' of sharing is not necessarily manifest in the world of online-initiated sharing (despite spawning offline interaction). Despite obvious similarities with other services these core findings require corroboration and further enquiry in order to generalise managerial importance.

There are also other important implications for managing comparative sharing formats aimed at fostering pro-social exchange. The findings can be used to inform the framing of marketing communications, perhaps to encourage certain preferred forms of behaviour. The 'myth' of reciprocity presents a fundamental challenge. There is a clear divide between 'takers' and 'givers', who are essentially discrete groupings, and a smaller third group who perform both roles. This study suggests that the core users should perhaps be regarded as providers and consumers. Streetbank simply provide an infrastructure for these constituencies to interact (like most sharing formats – monetized or not). What is striking is the limited control Streetbank have over the structure of networked relations between users which emerge through each type of interaction. The findings present a picture which might be at odds with the original managerial vision. Although the system is not monetized, this bifurcation means that there is a

clear supply and demand fissure; this makes the service more comparable to monetized platforms with their distinct and discrete constituencies of users and providers. In this sense, the ‘business model’ or core concept for the platform is refined and defined by the users – its true nature is a result of user autonomy (Friedman and Nissenbaum, 1996). The intention was to foster mutual exchange (Streetbank, 2019b), but the result seems to be an arena for discrete users who either primarily give or primarily take. Managerial misconceptions are not uncommon. Many businesses and not-for-profit services have failed because of a basic misunderstanding of the essential nature of what is going on ‘on the ground’ (Lovallo and Kahneman, 2003). This study demonstrates the value of a data-driven approach to understanding operational aspects of service (Kubina *et al.*, 2015). It provides a perspective which raises fundamental questions for managers and service providers of comparative platforms.

7 Limitations and Future Research Direction

The study reported in this article is limited in a number of ways: there is limited insight into the demographic information of the sample; the network analysis involves only one prosocial exchange system (users may be part of multiple networks); and because of the ‘hybridity’ exhibited in the design of the system there is a need to corroborate findings with new studies of prosocial exchange systems to scrutinise the external validity of the results. A further limitation is that there is no way of accounting for dyadic relationships that may have formed that are now maintained solely offline. This is an opportunity for Streetbank to assess whether ‘success’ of enabling donors and recipients to interact with each other repeatedly may in fact represent a threat to the existence of the overall system, as people might choose to circumvent the website when contacting each other. All of these limitations would benefit from further

scrutiny to account for how and why people use prosocial exchange systems and create novel social configurations over time.

It would be interesting to examine whether ‘success’ for this type of system is best conceived in terms of new friendship formation, or whether the service should aim to foster intermediate relations (somewhere between complete stranger and close friend), for the purpose of encouraging ongoing relations mediated through the website. If dyadic relations become very positive and ‘friendly’, then the prosocial exchange system may be circumvented. If ‘offline’ then it becomes personalised. If a relationship becomes highly personal, does this then lead to relationships being mediated through alternative means of communication, such as phone or text messages rather than the original service? If so, then the system might be undermined by its own success. This would suggest that a ‘throughput’ of users is required to ensure that those going offline are replaced by incomers who can ensure that the platform is sustained.

The research provides new insights but also raises many questions for further investigation and managerial decision making. For example, to what extent do reputation mechanisms that record the outcome of transactions influence the likelihood of indirect reciprocity within prosocial exchange systems? Do the recommendations of strangers improve the likelihood that long-term interpersonal relationships will form between other dyads? One aspect of the service not analysed in depth was the online messages sent prior to offline behaviour. The transitivity of all messages (requests and rejects as well as acceptance) is likely to be higher than offline actions. Understanding whether message response rates influence the likelihood that people subsequently respond positively would give further insight into the extent of ‘community’ that exists online. The extent to which interpersonal responses are necessary for the broader network would provide an important insight for managers hoping to create or improve prosocial

exchange systems, particularly in the absence of reputation systems. As reputation systems were not included in the design of Steetbank at the time of analysis it would also be interesting to compare the results with other services that have implemented such a system, or if Streetbank modify the design in future, a similar comparative study could reveal whether public measures of trust influence the reciprocal potential of prosocial action.

Another crucial issue is the lack of data on the value of these exchanges. From an economic point of view this form of activity presents a challenge. Goods and services are traded without money exchanges, so they are difficult to trace. However, there is significant economic activity evidenced in this study of a relatively small platform. Intuitively, such services have the potential to displace new purchases or purchases of used goods (for example on eBay). Aggregate statistics for this sector are simply not known with any accuracy, yet taken together they are of clear importance to local and national economies. Further research is vital if these services are to be properly understood, measured and managed for the benefit of everyone.

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