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VALUE OF DECENTRALIZED CONSENSUS SYSTEMS – EVALUATION FRAMEWORK

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Research

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Abstract

The emergence of decentralized virtual currency systems based on cryptographic operations has been accompanied by efforts to utilize the technology as infrastructure for further applications besides cryptocurrencies such as Bitcoin. So-called Decentralized Consensus Systems (DCSs) could reshape financial and other information-based industries, where the invention, registration and transfer of assets constitutes the core of business activities. The starting point for this paper is the observation that innovative applications beyond payments already attract the attention of scholars and practitioners, whose works so far are mainly focused on explanatory issues. What is missing are approaches to evaluate the value of DCSs, taking into account the diversity of applications ranging from currencies to the decentralization of business operations. To fill this gap, this paper firstly discusses the potentials and introduces a contextualization of DCSs operating as digital infrastructures. Furthermore, the notion of economic value is examined. This forms the foundation for the subsequent development of an evaluation framework regarding the value of DCSs in order to provide a basis for the assessment of business models. The framework is then exemplarily applied to the Bitcoin system, which is evaluated according to various indicators such as venture capital investments, research or demand.

Keywords: Decentralized Consensus Systems, Cryptocurrencies, Bitcoin, Value, Digital Business Models.

1 Digital Transformation Everywhere?

The development and diffusion of digital technologies transforms the processes of entire industries and provides the foundation for completely new business models based on digitization (Brynjolfsson and McAfee, 2014). In the electricity industry, for instance, the ongoing deployment of advanced metering infrastructures enables demand response applications to intelligently control consumers' electricity demand (Borenstein et al., 2002). Digital ecosystems emerge around platforms such as Facebook, Google, Amazon or Alibaba as catalysts for business models in technology-enabled and interconnected environments (El Sawy and Pereira, 2013). Simultaneously, the omnipresence of mobile devices like smartphones, tablets or smartwatches allows for ubiquitous access to services offered by means of digital ecosystems. The corresponding network economy is characterized by distributed service environments exhibiting network effects, where data collection, processing and analysis constitutes a core component of business activities (Shapiro and Varian, 1999). This reflects the transformation of sociotechnical systems beyond supporting administrative purposes and running individual software in well-bounded organizational contexts (Tilson et al., 2010). Nowadays, the high degree of interconnectedness of societies through networking technologies enables socially embedded systems affecting our everyday lives.

A growing importance of digitalization can also be observed for the financial sector. This is particularly well illustrated by the increasing utilization of electronic payment systems (EPS) in the course of a steadily growing number of online transactions (Capgemini and Royal Bank of Scotland, 2014). The latest trend in the field are mobile payment solutions, ApplePay probably being the most prominent representative. They can be used in a variety of payment scenarios: Besides purchases of digital content like music or applications, payments for physical goods and services at vending or ticketing machines and manned point-of-sale terminals are also supported (Dahlberg et al., 2008). In this way, mobile payments establish a link between mobile devices and EPSs. Prevalent EPSs are nevertheless solely aggregating existing payment mechanisms and, therefore, mediating conventional financial infrastructures (Abrazhevich, 2001). This means that although access channels to payment services are increasingly based on digital technologies, the underlying technical infrastructure is characterized by proprietary, complex solutions. For instance, credit card payments rely on interbank clearing and settlement of transactions through financial networks involving various intermediaries.

This practice radically changed when a whitepaper introduced Bitcoin as the world's first practicable decentralized payment system in 2008 (Nakamoto, 2008). An until this time unique combination of technical design features based on cryptographic operations allows for the transfer of funds without relying on any financial intermediaries. Instead a decentralized peer-to-peer network acts as a trusted third party, where everybody is free to participate. From a monetary perspective, Bitcoin implements its own unit of account, bitcoin, which circulates independently of any central issued fiat currency like Euro or US-Dollar (Yermack, 2013). For that reason, the Bitcoin system is often referred to as "virtual currency" or "cryptocurrency". The technology as such rapidly becomes more relevant due to the technical infrastructure backing Bitcoin. It relies on cryptography to verify the actual state of the system by consensus amongst participants of the peer-to-peer network and includes this state in a shared public ledger called blockchain. In the Bitcoin system, an ongoing consensus is established regarding which transactions are valid and hence included in the blockchain (Glaser and Bezzenberg, 2015).

Originating from Bitcoin, the technology forms the infrastructure for a diverse range of systems and applications. Recently, the notion of "Decentralized Consensus System (DCS)" emerged as general terms for such systems. As digital technologies already have transformed various industries, DCSs could reshape the financial and other information-based industries far beyond payment systems (Tilson et al., 2010). Among the first alternative uses was a decentralized Domain Name System called Namecoin. Soon the idea arose to use the technology as infrastructure for the invention, registration and transfer of all kinds of digital assets (Franco, 2014; Vigna and Casey, 2015). This is summarized by the term smart property, which denotes the control of ownership of property via digital contracts (Szabo, 1997). Examples could be of intangible nature such as shares, bonds or emission rights, but also of physical nature like cars or houses (Al Kawasmi et al., 2015; EBA, 2015).

While the technology sounds promising, evidence from reality seems quite puzzling. After peaking at over 1.000 US$ at the end of 2013, the price of a bitcoin at exchanges fell steadily and fluctuated between 200 and 300 US$ over the course of the first nine months in 2015 (Coindesk, 2015a). Additionally, the public attention for Bitcoin noticeably diminished in terms of hits on Wikipedia (stats.grok.se, 2015) as well as search queries on Google (Google Trends, 2015). The same can be stated for tweets on the social media platform Twitter (Garcia and Schweitzer, 2015). By contrast, the venture capital investments in Bitcoin-related start-ups are constantly increasing (Coindesk, 2015b), which also holds true for the number of transactions (Blockchain.info, 2015). This contrary indications regarding the popularity and acceptance of Bitcoin as the longest running and most popular DCS lead to the research question: What economic value can be provided by DCSs? Previous contributions addressing the value dimension of DCSs propose a taxonomy concerning the concept of DCSs (Glaser and Bezzenberg, 2015) and examine digital business models for Bitcoin companies (Kazan et al., 2015).

Contribution: This work presents an evaluation framework for the value of DCSs. In particular, the concepts of value proposition and perceived value are included to determine the value created and captured by the ecosystem and the end-users of a specific DCS. The ecosystem consists of organizations offering complementary applications and services for a DCS. End-users utilize a DCS to track ownership and transfer of property, which may be supported by complementary applications and/or services.

The framework is exemplarily applied to evaluate Bitcoin according to several indicators. The framework provides an initial step for the assessment of concrete business models.

The remainder is structured as follows: In section 2, we give a brief outline regarding the potentials of DCSs, which is followed by their contextualization as digital infrastructures. In section 3, after an introduction of the concept of value, we present our framework to evaluate the value of DCSs. In section 4, we exemplarily apply the framework to evaluate the value of Bitcoin according to various indicators. We finish this paper with our conclusion and outlook in section 5.

2 Decentralized Consensus Systems as Digital Infrastructures

Decentralized consensus mechanisms have long been studied and applied in the area of distributed computing, to ensure that all parties eventually agree on the same state of a system (Chen et al., 1992). The general concept recently received attention thanks to Bitcoin and the underlying blockchain technology allows for the inclusion of a large number of varying assets ranging from financial instruments to physical objects. Consequently, this section gives a short overview regarding the potentials of DCSs, which is followed by a contextualization in order to facilitate the analysis.

2.1 Potentials of Decentralized Consensus Systems

The narrowest application of DCSs are cryptocurrencies. A common feature of Bitcoin and all other cryptocurrencies is their native asset (e.g. bitcoin, litecoin, dogecoin), which serves as a unit of account and is independent of any government-issued currency (following the common notion in the literature, a capital initial letter always refers the system, whereas a lower capital letter refers to the asset). This opens up opportunities for cryptocurrencies to act as a substitute for conventional currency at least in some contexts, depending on how well they fulfill the classical functions of money: unit of account, store of value and medium of exchange (Mankiw, 2016). If this holds true, it would “enable transactions across national borders and currency denominations without the interference of sovereign entities and central banks” (Lo and Wang, 2014, p. 2). By maintaining a fixed exchange rate parity or directly supporting conventional currencies, DCSs may represent a challenge for centralized consumer and interbank payment infrastructures. Particularly, they offer resilient networks (Zohar, 2015), some of them privacy (Miers et al., 2013) and theoretically reduced costs and entry barriers compared to conventional payment processes (EBA, 2015).

By supporting heterogeneous types of assets, DCSs set up the infrastructure for a wider range of applications (Glaser and Bezzenberg, 2015). Financial institutions are interested in DCSs for issuing financial assets because of issues of consumer and regulator trust. NASDAQ, for instance, is running a pilot project in its private equity market (Hope and Casey, 2015). More generally, DCSs could provide decentralized infrastructures for any application relying on intermediaries to track the ownership and enable the transfer of property (Fairfield, 2014). Within certain companies in the high-tech industry, DCSs are envisaged as a “framework facilitating transaction processing and coordination among interacting devices” (IBM, 2015, p. 11). They potentially constitute the digital infrastructure to connect billions of physical objects in the “Internet of Things (IoT)” (Hutchison et al., 2008). In this IoT, users bind with devices such as washers, cars or thermostats using secure identification and authentication. The devices intelligently interact and communicate with each other by exchanging data and information (Uckelmann et al., 2011). Thus, opportunities for completely new business models arise. As already acknowledged by IBM (2015), DCSs allow for a distributed, scalable and trustless form of coordination between intelligent devices. Contrarily, currently employed IoT solutions are based on centralized clouds and server farms, which are characterized by high costs for infrastructure, maintenance and service. Some even propose that DCSs may ultimately lead to organizations operating completely without human intervention (Franco, 2014).

Regardless of the existing advantages, DCSs also face some open issues worth mentioning. Decentralized systems will always be more expensive to operate than centralized systems. Especially the frequently implemented Proof-of-Work principle, where network participants contribute computing power to protect the integrity of the system, is being questioned concerning its sustainability in terms of operating costs and ecological footprint (Becker et al., 2013). Proof-of-Work was already proposed in 1997 as denial-of-service countermeasure against the systematic abuse of applications such as e-mail (Back, 2002). This approach to prevent attacks on a given system is grounded on an economic rationale. It assumes that if a sufficiently high level of costs in terms of computing power is required to perform a successful attack, it induces rational individuals to behave honest. This may be a level of costs higher than the expected gains from an attack, or that the intended use of the system is the most profitable alternative. Meanwhile there are several different approaches to so-called consensus mechanisms addressing those drawbacks. One attempt to deal with the issue is by extending the consensus mechanism with useful purposes, like incorporating obligations to store data files (Filecoin, 2014). Other approaches substitute computing power by other resources such as the stake in the system in terms of owned tokens (Bonneau et al., 2015). Nevertheless, the development of cost-efficient, scalable and secure DCSs remains a challenge.

2.2 Contextualization: DCS, Business Environment and User Side

Figure 1 presents the contextualization of a DCS by illustrating interactions with its ecosystem and end-users. Hence, it is distinguished between the layer of the DCS, the ecosystem and the end-users.

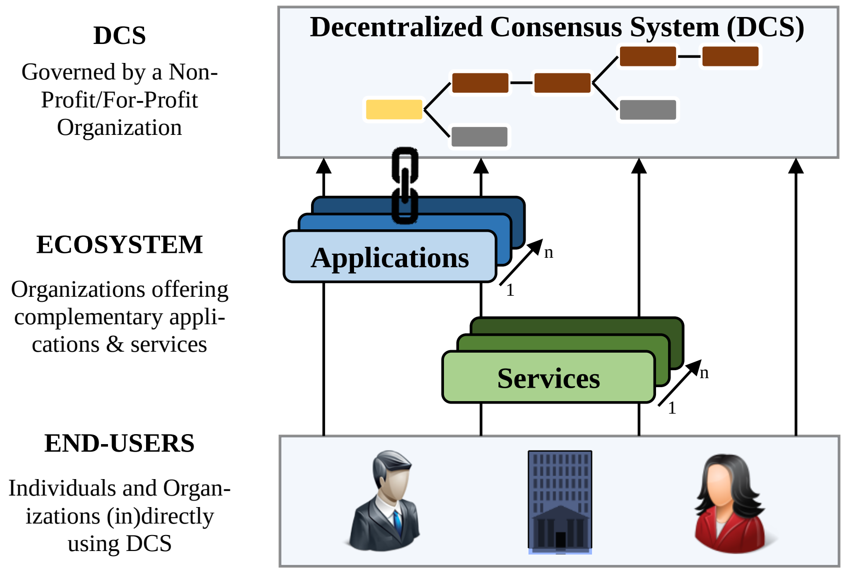

Figure 1. Contextualization of Decentralized Consensus Systems

One can differentiate between DCSs governed by non-profit and for-profit organizations (Chesbrough et al., 2006). Whilst non-profit organizations are predominantly foundations (e.g. Bitcoin Foundation, Ethereum Foundation), for-profit organizations are profit-seeking enterprises (e.g. Ripple Labs). From an organizational perspective the term DCS is used when referring to the system as a whole, whereas the technical backbone of a DCS is the underlying blockchain. Besides Bitcoin there are various other DCSs already running live or in test modes. Litecoin implements an independent blockchain technically nearly identical to Bitcoin, but differs in some design features such as the maximum number of coins and the implemented hash algorithm. Ripple Labs introduces the eponymous DCS Ripple as “the world’s first distributed exchange” and facilitates the decentralized transfer of any currency without restrictions (Gehring, 2014).

The evolving ecosystem around DCSs consists of organizations providing complementary applications or services for a DCS. In general, an economic ecosystem can be described as a business environment consisting of several entities and their corresponding relationships. It is characterized by competition and collaboration to pursue the overarching objective of generating added value (Henningsson and Hedman, 2014; Basole and Karla, 2011). Usually end-users are treated as an entity of the ecosystem, nevertheless we examine them independently owing to the complexity of DCSs. Although prevailing DCSs follow an open approach to encourage the participation of a community of developers providing applications and services, closed implementations without an ecosystem are also conceivable. For instance, nine of the largest investment banks, including GoldmanSachs and JPMorgan, recently announced a cooperation to develop common standards for DCSs to potentially reshape internal processes in the future (Stafford, 2015).

Applications are implemented on top of a given DCS to provide additional functionalities not initially available. They are related by a technical link to a specific blockchain. Zerocoin is an application based on Bitcoin, which adds anonymity as functionality, since users' privacy is originally only protected through pseudonyms. The technical link to Bitcoin is established by exchanging the native asset bitcoin for zerocoins, which are then stored in the Bitcoin blockchain (Miers et al., 2013). Ethereum encourages the development of applications for their DCS by providing a blockchain with a built-in Turing-complete programming language (Buterin, 2014). Contrary to applications, services do not require a technical link to a blockchain. Instead, their legitimacy is determined by a DCS. They render the use of already existing functionalities of a blockchain or application more convenient, but do not add any new functionalities. Consequently, the functionalities are in the center of the business models of service providers. BitPay offers payment processing as a service for enterprises who want to accept payments with bitcoin. Its business model consists of financial intermediation between these enterprises and their customers, by taking any volatility risk. Among the users of the service are major global players like Microsoft or PayPal (BitPay, 2015). Another service for DCSs are exchanges converting the respective exchange medium into fiat currencies (e.g. Bitstamp, Bitcoin.de or BTC China). Europe's largest bitcoin trading-platform Bitcoin.de cooperates with the FIDOR AG, which establishes a bridge to the financial industry and simplifies the clearing of transactions (Kannenberg, 2015).

End-users are entities that demand the functionalities offered by a DCS or a corresponding application. The end-user base consists of actual individuals as well as organizations like enterprises or governmental bodies. They get access to the DCS via different channels. Direct access describes the use of a DCS without any interposition of applications. Therefore, the available functionalities are restricted to those already implemented in the underlying blockchain. Indirect access describes the use of a DCS supported by applications. In this case, it is possible to use functionalities not initially implemented in the blockchain backing a DCS. In the case of Bitcoin, this means that the use of privacy-enhancing applications like Zerocoin is possible. Irrespective of any applications, users may refer to services enhancing the convenience of functionalities.

3 Evaluation Framework for Decentralized Consensus Systems

The preceding section characterized DCSs as digital infrastructures by presenting a layered contextualization and illustrating their potentials. However, current literature lacks approaches that explain where and how the value of a DCS arises. After discussing the concept of value, a framework for an analysis of the value of different DCSs is proposed.

3.1 The Concept of Value

The notion of value describes a complex and abstract concept, which causes confusion around economists about its meaning and how it can be operationalized (e.g. Farber et al., 2002; Payne and Holt, 2001). A variety of economic research is focused on how concepts like value, utility, quality and costs are related (e.g. Giddings, 1891; Grönroos, 2011). This results in a large number of differing definitions and uses of the value concept amongst academics (e.g. Salem Khalifa, 2004; Zott et al., 2011). For the development of the evaluation framework the notion of 'value proposition' is adopted. Value proposition can be interpreted from two different perspectives. It is either referred to as a decision variable to gain a competitive advantage from a business perspective or the value created from a customer perspective (Antonopoulou et al., 2014). Such a far-reaching definition is employed because it allows including the general value created and captured by the ecosystem and end-users. It is important to note that the concept of value proposition is not targeted at a specific entity, but instead captures the value provided for all entities on a certain layer.

Additionally, the framework is enriched by a value concept taken from marketing, which is usually referenced as 'perceived value' and allows for the inclusion of value captured by single individuals (e.g. Afuah, 2002; Tellis and Gaeth, 1990). This understanding is particular suited to study the benefits of DCSs, because it implies an interaction between single end-users and applications and/or services (Payne and Holt, 2001). For instance, an exchange offering its service for a particular currency creates value for the users. However, the service only provides perceived value for users demanding this currency. To put it differently, it is the perceived value an application or service offers that attracts customers (Chang and Wildt, 1994; Wang et al., 2004). The current paper follows a uni-dimensional approach by using economic reasoning, operationalized as utility, to assess the benefits and costs associated with DCSs (Agarwal and Teas, 2004). It should be noted that the utility concept always refers to individuals. Therefore, it is provided for the stakeholders in case of an assessment of organizations. The utility concept is related to perceived value in economic terms as the "difference between the 'utility' provided by the attributes of a product and the 'disutility' represented by the price paid" (Sanchez-Fernandez and Iniesta-Bonillo, 2007, p. 429).

3.2 Framework: Value of Decentralized Consensus Systems

Although all DCSs share the same fundamentals, i.e. their technical backbone is a blockchain facilitating decentralization, there are also differences. Depending on their organizational structure and business model, some DCSs encourage third-parties to provide complementary applications and services via open interfaces, while also proprietary systems are conceivable. Additionally, DCSs also differ regarding to their provided functionalities. Thus, the potential value of every concrete DCS needs to be assessed independently. Table 1 illustrates the proposed framework to evaluate the value of DCSs.

A distinction is drawn between two layers where value is provided. The ecosystem (layer 1) consists of organizations providing complementary applications and services for a DCS. End-users (layer 2) are individuals and organizations that demand the functionalities offered by a DCS or corresponding applications and use services. Layer 1 and layer 2 are interconnected, because value is not only provided out of the use of the DCS, but also by applications and services. Thereby the emerging value is not only depending on the DCS infrastructure, but also on the whole spectrum of applications and services that support a successful use of the DCS (Vargo and Lusch, 2004). DCSs are platforms connecting application developers, service providers and end-users. The existence of network effects, where the value for one user depends on the number of other present users, is an important characteristic of such multi-sided platforms (e.g. Armstrong, 2006; Evans, 2013). This is represented through interactions between the ecosystem and the end-users.

Value proposition and perceived value are included as concepts to measure the emerging value. Despite their close connection, the concepts of value proposition and perceived value should not be equated. Although a DCS, service or application may create value within one or more of the layers, it does not necessarily provide the same value for every single entity (Winkler and Dosoudil, 2011). That is because customers perceive value differently depending on their needs (Hassan, 2012). Utility functions are stated to model the perceived value for the individual stakeholders in the ecosystem and the end-users leading to the utility functions u_i (for the ecosystem) and u_j (for the end-users). The sum of the utility of the respective entities on the respective layer is stated as U_E (for the ecosystem) and U_U (for the end-users). We assume that the overall utility U_O depends on the different layers' utility levels. Through this general representation, it is possible to use proper types of utility functions (e.g. Cobb-Douglas or quasi-linear) to model the preferences of different individuals.

<table>
<tr><th colspan="5">Infrastructure: Decentralized Consensus System
Governed by Non-Profit/For-Profit Organization</th></tr>
<tr><td></td><td colspan="2">Open Systems
▪ Open Strategy: Business models based on invention and coordination with community (Chesbrough and Appleyard, 2007)
▪ Publicly available source code
▪ Promote the development of applications</td><td colspan="2">Closed Systems
▪ Closed Strategy: Business models based on ownership and control (Chesbrough and Appleyard, 2007)
▪ Privately kept source code
▪ Prevent external applications</td></tr>
<tr><td></td><td>Layer</td><td>Value Proposition</td><td>Measurements</td><td>Perceived Value</td></tr>
<tr><td>Value Capture</td><td>1. ECOSYSTEM
Organizations offering complementary applications & services</td><td>▪ Higher return on business Activities (Chesbrough and Rosenbloom, 2002)
▪ Higher return on innovation activities & intellectual Property (West and Gallagher, 2006)</td><td>▪ Profit
▪ Market share (Antonopoulou, 2014)
▪ Decreasing costs for information and processing (Brynjolfsson and Hitt, 2000)</td><td>$U_E = \sum_{i=1}^{n} u_i$</td></tr>
<tr><td></td><td>INTERACTIONS
Between Ecosystem and End-Users</td><td>▪ Network effects (Armstrong, 2006; Evans, 2013)</td><td></td><td>$U_O(U_E, U_U)$</td></tr>
<tr><td>Value Creation & Value Capture</td><td>2. END-USERS
Individuals and Organizations (in)directly using DCS</td><td>▪ Support of transaction phases
▪ Reduction of information asymmetries (Sambamurthy et al., 2003)
▪ Organizational transformation and improvement (Sambamurthy et al., 2003; Mooney et al., 1996)</td><td>▪ Profit (Antonopoulou, 2014)
▪ Decreasing costs for information and processing (Brynjolfsson and Hitt, 2000)</td><td>$U_U = \sum_{j=1}^{m} u_j$</td></tr>
</table>

Table 1. Value Framework for Decentralized Consensus Systems

3.2.1 Business Strategies of Infrastructure Providers

Regardless of the organizational structure, i.e. a non-profit or for-profit organization governing a DCS, one can distinguish between open and closed systems. The former adopts an open approach to innovation, where the organization pursues a so-called open strategy. Building on works of Chesbrough (e.g. Chesbrough, 2003; Chesbrough et al., 2006), open strategy addresses the challenge of aligning organizations' business strategy with the benefits of openness "as means of expanding value creation" (Chesbrough and Appleyard, 2007, p. 58). This implies business models which are based on invention and coordination with a community. Thereby, organizations utilize knowledge from internal sources as well as outside sources (West and Gallagher, 2006). Open innovation is a common paradigm in the area of digital technologies, with open source software as its most popular example. The underlying open source code of Linux, for instance, is used by a large number of companies and volunteers contributing to the development of the operating system (Germonprez and Warner, 2013). The same holds true for most current DCSs, irrespective of whether they are governed by a non-profit organization (e.g. Ethereum Foundation, whose DCS Ethereum is open source) or for-profit organization (e.g. Ripple Labs., whose DCS Ripple is open source). This aims at promoting the development of corresponding applications on layer 1. But also closed systems are conceivable, where organizations governing a DCS pursue a closed strategy. The associated business models are characterized by ownership and control, where only knowledge from inside the organization is exploited (Chesbrough and Appleyard, 2007). In this case, the source code is kept private, which prevents the development of applications by external organizations on layer 1. This type of system seems more appealing for DCSs governed by for-profit organizations, because innovation from outside sources is the "most beneficial choice for non-profits" (Hull and Lio, 2006, p. 62). How value is concretely captured by organizations governing a DCS requires the examination of specific business models, which are outside of the scope of this paper. A differentiation between open and closed systems is nevertheless important to determine the value creation and capture on layer 1 and 2, since it determines the development of applications.

3.2.2 Ecosystem

The ecosystem consists of application and service providers, who capture value by extending the scope of a DCS or offering intermediary services. The former provide direct access to a DCS via executing complementary applications on top of the blockchain. Smart contracts, for instance, are able to automatically verify the interactions between parties and, thus, add additional functionality to the existing DCS (Peters et al., 2015). By offering additional functionalities, application providers generate profits, which increase proportionally to the amount of end-users that demand them. The latter support services by intermediation that renders the direct or indirect use of a DCS more convenient. Bitcoin payment processors, for example, provide ready-to-use online-shop solutions, which ease the access and implementation of the technology for the respective merchant (Chircu and Kauffman, 1999).

3.2.3 End-Users

End-users create value by the use of the DCS, applications and/or services provided by entities on the first layer. Through the facilitation of certain transaction phases and the reduction of information asymmetries, new or altered business models are adopted and an adjustment of behavioural patterns takes place. By disintermediation and irreversibility of transactions, DCSs are potentially able to decrease the costs during the respective phase of a transaction, given that sufficient amount of network participants is not faulty (Sun and Duan, 2014). Property-ownership recording systems for any kind of high-value property lead to a substantial reduction of costs by relying on general public consensus instead of a trusted third-party like notaries (Sun and Duan, 2014). In particular, they enable transaction contracts to be precisely defined and automatically executed (Omohundru, 2014). Following Brynjolfsson and Hitt (2000), organizational transformation and improvement are achieved by the usage of IT innovation, which enables complementary organizational investments as well as productivity increases. NASDAQ, which makes use of a DCS to create a new private market platform that connects private companies with investors, needs to exert complementary organizational investments in order to offer this service for their customers. However, this platform will potentially increase profits as a growing number of customers profit from the new technology (MIT Technology Review, 2015).

3.2.4 Interactions

A comprehensive approach to assess the value of a DCS requires an integrated view on both layers and the associated indirect network effects between them. Those effects are present if the value of a user in one group depends on how well users from another distinct group are attracted (Armstrong, 2006). Application and service providers benefit from a wider range of end-users through increased turnover and potentially higher market share. Vice versa, end-users benefit from a greater amount of application and service providers owing to a wider choice and the possibility to maximize their utility.

Determining the overall value of a DCS requires the distinction of two scenarios. The first scenario is described by a DCS which is an open system and allows for coordination with the community and a publicly available source code. The openness of the system enables agents on layer 1 to develop application on basis of the source code and to create value through complementary innovation (Gawer and Henderson, 2007). Examples for open systems are Bitcoin or Ripple, which release their source codes in order to benefit from the participation of the community. Consequently, the overall value depends on the value on both the first and second layer. The second scenario describes a DCS which is privately governed and prevents the development of complementary innovation through external applications. Accordingly, value is achieved through the services offered on the first layer as well as the usage of a DCS by entities on the second layer.

4 Evaluation of Bitcoin

Most attempts to evaluate the economics of DCSs in general, and Bitcoin in particular, are of pure descriptive nature. Franco (2014) provides a comprehensive overview of the technical and economical co-development of Bitcoin and other DCSs. The role of intermediaries (i.e. exchanges, payment processors) in the Bitcoin ecosystem, especially how intermediation leads to centralization tendencies in the decentralized envisaged Bitcoin system, raised much attention (e.g. Böhme et al., 2015; Gervais et al., 2014). There are also more concrete economic analyses addressing a specific scenario like for example the suitability of Bitcoin for money laundering (e.g. Brenig et al., 2015; Dostov and Shust, 2014) or the incentive-compatibility of Bitcoin mining (e.g. Eyal and Sirer, 2014). The European Banking Association published an opinion letter concerning the potential economic benefits and the causal drivers of risks regarding virtual currency schemes (EBA, 2014). This work was complemented by a report on the relevance of blockchains for organizations in transaction banking and payments (EBA, 2015). Kazan et al., (2015) propose a taxonomy of digital business models with focus on the value of Bitcoin for companies offering services. There is a body of literature concerned with the monetary aspects of the Bitcoin system, which refers to the question whether bitcoins are assets or currency units. The often cited work of Yermack (2013) draws the conclusion that Bitcoin fails to conform to the classical properties of a currency. This is mainly due to the excessive volatility, absent risk mitigation strategies, fixed monetary supply and security issues. These findings are supported by indications that Bitcoin is rather used as an asset than a currency (Glaser et al., 2014b).

The price formation is the object of investigation of several empirical studies (e.g. D'Artis et al., 2015; Bouoiyour and Selmi, 2014). The volatility of bitcoins in exchange for fiat currencies over the last few years and the unclear drivers of the price formation process of bitcoins render it a promising research objective (Dwyer, 2015). Most researchers look at the influences of supply and demand as well as micro- and macro-economic indicators (e.g. Kristoufek, 2015; Glaser et al., 2014a). Vockathaler (2015) illustrates the ambiguity of the results of previous works, showing that the significance of the variables differs considerably between various studies. Furthermore, it is shown that the price is driven by hitherto unknown sources.

Beside their descriptive nature, investigations of the economics of Bitcoin are primarily partial, meaning that they refer either to the first or second layer but do not include a broad perspective. A comprehensive evaluation of the value of Bitcoin as open system requires analysis of the value created and captured on both layers as well as the inclusion of interactions. However, an evaluation based purely on monetary measures is not feasible given a lack of appropriate data for both, the ecosystem and end-users of Bitcoin. For approximation, indicators are discussed according to the framework. The complete data collection is accessible at: http://files.telematik.uni-freiburg.de/ext/DataECIS2016.xlsx

4.1 Bitcoin-Related Research

Within the ecosystem of Bitcoin a further indicator for higher profits is academic and industrial research, which encourages innovation (Mansfield, 1991). In particular, knowledge and innovation have a substantial role in fostering business growth, technological performance and international competitiveness, leading to higher profits for companies in the ecosystem as well as general economic growth (Looy et al., 2015). We use five different databases as sources for the evaluation of Bitcoin-related research, which diverge with respect to their thematic orientation. While Science Direct, Springer and Web of Knowledge constitute sources for general academic literature, ACM as well as IEEE provide more specific data about publications in the research areas of computer science, business informatics and information technologies. Table 2 represents academic publications between January 2011 and October 2015, which contain the keyword “Bitcoin”. Between 2011 and 2014, academic publication increased exponentially, indicating a growing interest in the field of Bitcoin and associated applications. For 2015, the data cover only the time period between January and October. Nevertheless, the number of academic publications within this time period already exceeds the previous year's figure.

We analyze the existing academic literature as a proxy not only for academic but also industrial and institutional research activities. In particular, we assume that the increasing activity in Bitcoin-related academic research reflects a growing interest also in the industrial as well as institutional sector. This assumption can be confirmed when analyzing existing literature in all three sectors. Accordingly, academic research is accompanied by a plenty of industrial research (e.g. IBM, 2015) and institutional research (e.g. EBA 2014 and 2015). We excluded those data from our analysis due to the fact that industrial research is often held confidential and is not publicly available.

Database	Keyword	2011	2012	2013	2014	2015 [Jan.-Oct.]	Overall
ACM, IEEE, Science Direct, Springer, Web of Knowledge	“Bitcoin”	11	51	116	293	338	809

Table 2. Temporal Development of Academic Publications

4.2 Venture Capital Investments

Application and service providers in the ecosystem capture value through higher profits and lower costs, respectively. Increased profits are achieved by their function as intermediary in the transaction process as well as higher returns on R&D activities and innovation as the market share and overall demand for their products and services is rising (Howells, 2006). However, there is little debate over the fact that Bitcoin is still in its infancy and early market stage, which is comprised of innovators and early adopters. Consequently, Bitcoin’s ecosystem is characterised by plenty of private for profit start-ups, whereby cash-flows are typically negative and experience values are lacking (Damodaran 2012). Thus, profits cannot serve as direct measurement for the value of Bitcoin. According to Brynjolfsson and Hitt (2000), investments into IT serve as proxy for business profits by assuming linkages to productivity gains and organizational transformation. Given the uncertainties and risks related to the early market stage, IT investments are best described by looking at venture capital. It is typically employed in the context of high- risk, potentially high-reward projects (Gompers and Lerner, 2001).

For analysis, we extracted venture capital investments in Bitcoin start-ups between January 2013 and October 2015 from Coindesk (2015b). We extended the set by using data from VentureSource, Crunchbase and Coinfilter and checked for their validity. As illustrated in Figure 2, the amount of venture capital investments in US$ per year has increased between 2013 and 2015, whereas the total number of investments per year has decreased during the same period. Less diversification of investments in the ecosystem of Bitcoin can be ascribed to capital syndication. Consequently, the aggregation of venture capital investments explains higher total investment sums. From a risk-reduction perspective capital syndication means that investors try to reduce their risk resulting from adverse selection and information asymmetry by changing the mean by which investments are made and a greater range of analytical skills among investors (Lockett and Wright, 2001). Thereby, investors seem to identify the highest return on investment in the sector universal, capturing applications and services, which can be used for more than one purpose (e.g. full-service providers, wallet and exchange providers etc.). 21Inc., for instance, a start-up company in the ecosystem of Bitcoin, received one of the highest investment sums in 2015 (116 US$M.), based on their activities in developing an embeddable mining chip, which can be used in a wide range of applications (Casey, 2015). This argument is emphasized by the fact that in 2015, 92% of funding's were second or more rounds funding's (especially in the sectors universal, payment processor and mining), indicating either past return on venture capital or that investors expect future profits to arise (Mann and Sager, 2007).

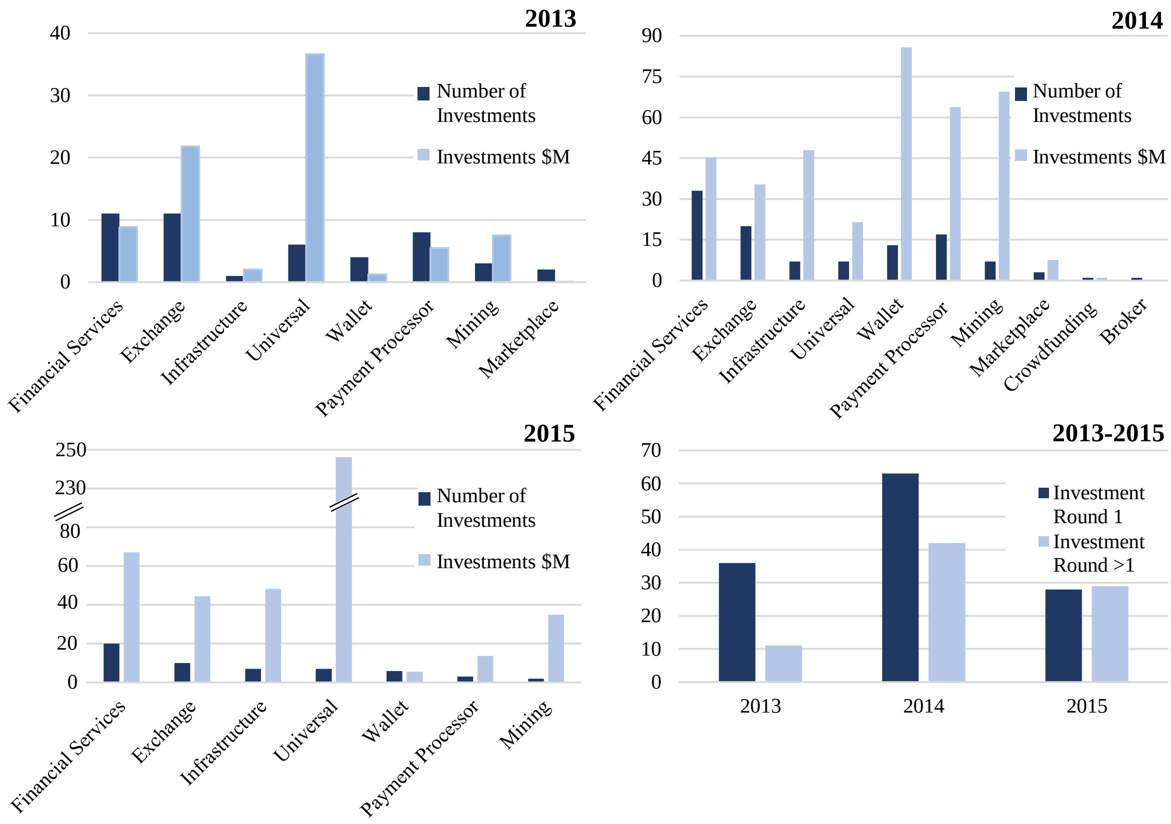

Figure 2. Temporal Development of Venture Capital Investments (Coindesk, 2015b)

4.3 Demand as Medium of Exchange

On layer 2, value is created by Bitcoin's ability to support different transaction phases and to reduce information asymmetries. Online retailers, for instance, derive advantages from reduced costs during the monitoring phase resulting from the irreversibility of payments and the associated impossibility of fraudulent chargebacks from end-users. More generally, individuals and organizations may benefit as end-users in a wide range of applications given Bitcoin's ability for disintermediation, due to the obsolescence of a trusted third-party within the transaction process. A complete set of data on cost reductions for information and processing of transactions, however, is not available. Nevertheless, given the cost reduction potential of Bitcoin, we expect increasing demand for Bitcoin assuming profit maximizing firms and individuals. We define demand for Bitcoin as the demand as medium of exchange (Buchholz et al., 2012). As an indicator for an increased demand a multi-dimensional proxy is used, comprising Bitcoin number of transactions, number of unique addresses and days destroyed. The latter is a measure of the level of activity and reflects the velocity of bitcoins within the system. It gives weight to a particular bitcoin depending on how long it has been in possession of an entity prior to its use in a transaction (a longer period of possession implies a greater weight).

The number of transactions has been increasing since the second half of 2012 (Blockchain.info, 2015). However, an increasing number of transactions alone is not a sufficient indicator for a growing demand of Bitcoin. Notably, raising transaction numbers may be caused by short-term purchases and sales effected by investors and for speculative purposes. For clarification Figure 3 shows the number of unique addresses and Bitcoin days destroyed during the same time period. Transactions are largely conducted using bitcoins with short periods of possession, which implies that they are rather expended on a regular basis than hoarded. Furthermore, the increasing number of unique addresses shows a tendency towards a growing number of end-users. In combination with the steadily growing number of transactions, an increasing number of addresses as well as volatile but relatively stable low level of days destroyed emphasize that the demand for Bitcoin as a medium of exchange increases.

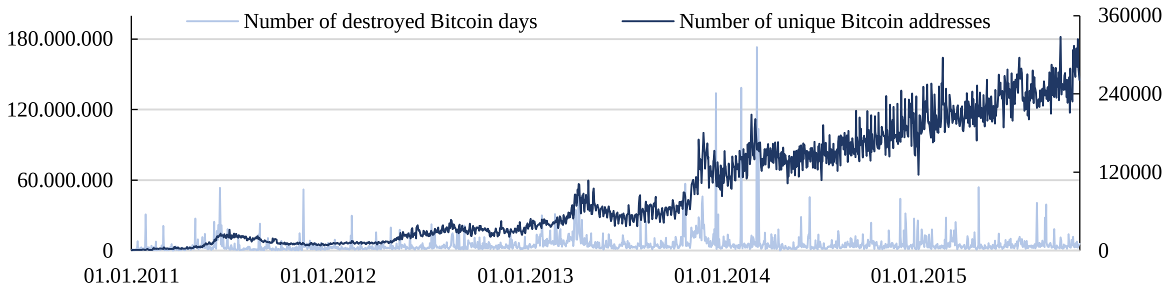

Figure 3. Destroyed Bitcoin Days and Unique Bitcoin Addresses (Blockchain.info, 2015)

4.4 Media Attention

On the contrary to the indicators named above, media intention constitutes a negative indicator. According to Garcia and Schweitzer (2015), media attention is interpreted as the degree of word-of-mouth communication and approximated by Bitcoin-related data on Google trends as well as the Twitter mood. We extended those data by looking at Wikipedia search queries, leading to the result of decreasing media attention for Bitcoin and consequently, declining public attention. This indicates a loss of relevance of Bitcoin as means of payment.

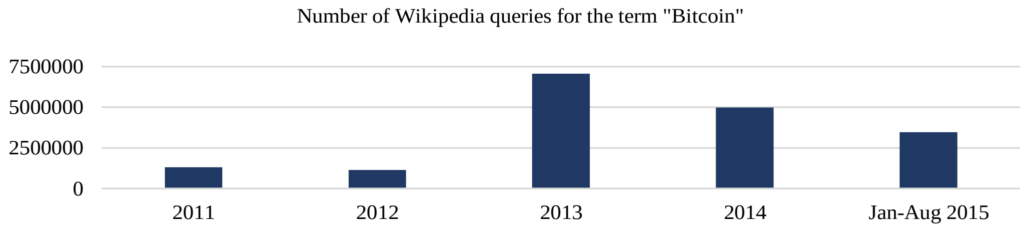

Figure 4. Wikipedia Queries for Bitcoin (Stats.grok.se, 2015)

4.5 Discussion of the Results

We summarize the analysis of the indicators concerning the value of Bitcoin in Table 3. Positive indicators suggest that Bitcoin provides value on the respective layer, whereas negative indicators point to the fact that entities in the ecosystem and end-users are not able to create and capture additional value by the use of the DCS. Referring to the ecosystem, venture capital syndication as well as the rising investment sum predicts future profits and indicates the value, which is captured by organizations offering complementary applications and services. Though it is possible to object that investments are made in a speculative bubble, we argue that capital syndication leads to a pareto-efficient portfolio selection (Brandner et al., 2002). Based on complementary management skills and more efficient decision-making mechanism (Brandner et al., 2002), we conclude that venture capital is invested in sustainable business models and the technology underlying Bitcoin. Moreover, Bitcoin-related research reflects the value of the DCS. Given the innovative potential of research, the findings are likely to be transformed into innovation, raising profits for application and service provider on the first layer. Demand for Bitcoin as medium of exchange illustrates the value created on the second layer. The growing use of bitcoins as an exchange medium indicates that individuals and companies identified potential for cost reductions through supported transactions and decreased information asymmetries. This conclusion is undermined by the decreasing development of the media attention, which can be interpreted as a loss of relevance for Bitcoin. Since crucial factors responsible for the price formation are still unclear, we assume a restricted explanatory power for the bitcoin price as indicator.

Infrastructure: Bitcoin		
Layer	**Positive Indicator**	**Negative Indicator**
1. ECOSYSTEM	▪ Venture Capital Investments ▪ Research	
2. END-USERS	▪ Bitcoin Demand	▪ Media Attention ▪ (Bitcoin Price)

Table 3. Evaluation Results

5 Conclusion & Outlook

In consideration of the growing propagation of DCSs, enabling various types of applications ranging from cryptocurrencies up to smart property, we assess the value they provide. This is exacerbated owing to short development cycles and a flexible environment, where novel systems, applications and services emerge regularly. Therefore, an approach is needed that is general enough to take these dynamics into account, but at the same time sufficiently specific to capture the particular technology-related features. This paper addresses this challenge by providing an evaluation framework for the value of DCSs. After setting the context, we introduced our understanding of the concept of economic value, which we subdivided into value proposition and perceived value. This was necessary due to the complexity and abstractness of the term value. The value concepts constituted the theoretical foundation for the construction of our evaluation framework. We identified the ecosystem (i.e. organizations offering complementary applications and services) and the end-users (i.e. individuals/organizations (in)directly using a DCS) as layers, where value is created and captured. As a first use case, we evaluated Bitcoin with several indicators and concluded that Bitcoin indeed creates value on the layers.

Our proposed evaluation framework constitutes a first step to assess the value of DCSs. Additional research needs to be conducted in light of the dynamics in this just emerging market. The presented evaluation focused on Bitcoin as the most prominent DCS, since there is the largest quantity of publicly available data. We are aware that, due to its focus on payments, Bitcoin is not necessarily representative for all kinds of DCSs. It nevertheless serves as a nice application example for the evaluation framework and allows for comparing the results with other DCSs. Consequently, we are going to identify additional indicators regarding Bitcoin and apply our framework to a selection of diverse DCSs. We intend to cooperate with organizations offering applications and services for a better understanding of their motives and business rationale. Additionally, we conduct empirical studies to get insights regarding users' motivation to utilize DCSs and applications and services supporting us in refining and extending our framework (i.e. specifying utility functions). Finally, we are going to assess concrete business models for organizations governing a DCS and application and service providers based on the framework. The framework is an integral component of our approach for the evaluation and design of DCSs. It complements our previous work, where we analyzed the incentives to misuse cryptocurrencies (as an application of DCSs) for money laundering for dishonest individuals (Brenig et al., 2015). This framework takes honest individuals into account, by addressing the stakeholders of organizations offering applications and services and end-users demanding the respective functionalities of DCSs.

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