Blockchain Complementors' Platform Choice Model

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***Abstract*— In the distributed ledger platform (DLP) industry, blockchain platform managers of DLPs (hubs) are trying to attract companies (spokes) to innovate in their platform ecosystem. This study takes the perspective of a spoke and aims to understand the decision criteria of spokes when choosing DLP to participate and exert efforts to. Only architecture and governance related criteria, which reflect the differences among the prevailing DLPs, are explored in this research. A multiple-case study design was chosen, in which 15 interviews with 12 spokes companies and one hub were conducted for this qualitative research. The empirical results revealed that spokes are motivated to join and contribute to a DLP ecosystem caused by (1) the pluggable consensus algorithm of a DLP, (2) the security level of a DLP, (3) the low entry barrier with regard to the programming languages of the smart contract in that DLP, and (4) the degree of which a DLP governance model is community-managed. Furthermore, this research introduced an ontology that classifies spokes according to whether the spokes mainly build their products in a permissioned or permissionless DLP. The findings showed that a permissionless DLP-oriented spoke's platform choice is positively influenced by (5) the native currency of a DLP, whereas a permissioned DLP-oriented spoke's platform decision is negatively influenced by (5). The spoke typology also moderates the strength of motives (1) and (2). This leads to the conclusion that these two types of spokes behave very differently when deciding which DLP to join.**

***Index Terms*—Blockchain, Distributed Ledger Platform, Innovation, Motivation, Platform Ecosystem, Permissioned Blockchain, Permisionless Blockchain.**

I. Introduction

SINCE the rise of Bitcoin in 2008, blockchain or distributed ledger technology is known as a disruptive technology that threatens the business model of any intermediary in the financial markets. Originated as the innovation behind the cryptocurrency Bitcoin (Nakamoto, 2008), the blockchain serves as a public distributed ledger or an immutable database to record bitcoin transactions and track all the bitcoin ownerships (Back et al., 2014). The distributed ledger is public as it is shared among all the network participants and anyone can take part in the system with no permission needed (Mainelli & von Gunten, 2014). Furthermore, the blockchain does not require any trusted central party to validate transactions, yet it prevents the double spending problem that prior digital currencies could only solve in a centralized network (Back et al., 2014). In short, the blockchain is a secure peer-to-peer public distributed ledger that uses cryptography to eliminate the middleman, to validate transactions, and to oversee behavior (Mainelli & von Gunten, 2014). Moreover, it is necessary to distinguish a blockchain from a distributed ledger. Blockchain, in fact, is just one implementation of distributed ledgers, and not all distributed ledgers have to use blocks or chains of transactions. However, in this study, the terms of blockchain and distributed ledger will be used interchangeably.

The design of Bitcoin blockchain initiated the creation of many other distributed ledgers that utilize the blockchain's main architecture with some modifications for particular usages. One of the emerging implementations of blockchain is using it as an application platform, to name Ethereum platform, Hyperledger Fabric, or R3 Corda distributed ledger as some striking examples. A platform, in this sense, is defined as a product or software that serves as a foundation upon which application developers, hardware producers or service companies can develop complementary hardware, applications or services (Gawer & Cusumano, 2014). As the pioneer, Ethereum decentralized application platform intends to host applications ranging from financial applications (financial contracts, derivatives, full securities life circle, etc.) to semi-financial applications (self-enforcing bug bounties) to non-financial applications (the DAO or decentralized autonomous organization) (Buterin, 2013). In comparison to Bitcoin, the advancement of Ethereum is that there is another logic tier, namely the smart contract, added to the distributed ledger. This smart contract layer and the initial blockchain architecture together form the next generation of blockchain (Gray, 2016).

This new type of decentralized application platform, enabled by smart contracts, could potentially disrupt the traditional business models of banks, insurers, and other financial intermediaries. Nevertheless, the current technology stacks of the existing distributed ledgers are far less efficient than the contemporary financial services platforms (Evans, 2014). Distributed ledger platform (DLP) managers, thus, have to deal with a major innovation challenge. By innovation, I refer to the "digital product innovation" definition: "Significantly new (from the perspective of a particular community or market) products or services that are either embodied in information and communication technologies or enabled by them" (Lyytinen, Yoo, & Boland Jr. 2016, p.49).

Or "The carrying out of new combinations of digital and physical components to produce novel products" (Yoo, Henfridsson, & Lyytinen 2010, p.725)

To put the innovation challenge differently, DLP managers have to answer the following question: how to stimulate innovation in their platform ecosystems? By ecosystem, I mean the collection of platform and applications and hardware that are specific to that platform itself. A crucial part of the answer to the question above is to firstly address the platform openness. In other words, should DLP managers (hubs) open their platforms in order to attract external companies (spokes or complementors) to participate and contribute to their DLPs? Giving guidance on this dilemma, Boudreau (2010) studied the discrete decision of whether an open or closed platform would lead to a higher rate of innovation. Unsurprisingly, his findings showed a significant positive relationship between opening the complement and the innovation rate. As noted by Gawer and Cusumano (2014), this result could be explained by a lower entry barrier and higher demand for the platform due to positive network effects. Later, Boudreau's discovery was emphasized again by Schweik and English (2012), who stressed that the openness of a platform is a key component that leads to innovation. A crucial reason for this is that innovation in a digital ecosystem is no longer generated by a single company but rather by both, platform providers, and external developers who together create co-innovation (Arndt & Dibbern, 2006).

The current trend of making blockchain platforms open-source also supports the view of scholars in this field. For instance, R3 has recently made an enormous move by turning its core platform Corda[1] into an open-source project. Shortly afterward, chain.com also announced to put their blockchain platform into the open-source world. Up-to-date, most of the biggest DLPs are operating under an open-source license. Bitcoin, Ethereum, Hyperledger, and Corda are living proof of this phenomenon.

While the leading players seem to agree on developing DLPs in an open innovation model (H. Chesbrough, Vanhaverbeke, & West, 2006; H. W. Chesbrough, 2003), there are still existing issues in how to pursue the innovation task for DLP managers. One possibility can be to adopt the spokes' perspective with the aim to explore what motives they have to join and contribute to a particular DLP. This is, in fact, not a new way to understand the decision criteria of complementors in choosing an ecosystem. Previous research in the field of smartphone ecosystems has already addressed this question multiple times (Koch & Kerschbaum, 2014; Puvvala, Dutta, Roy, & Seetharaman, 2016). Likewise, other studies in the area of open source software projects also tried to answer this question mostly by categorizing developers' motives into intrinsic and extrinsic motivations (Hars & Ou, 2002; Hertel, Niedner, & Herrmann, 2003; Hilkert, Benlian, & Hess, 2010; K. Lakhani & Wolf, 2003). However, as blockchain is a recently developed research domain, the architecture designs, as well as the governance models of currently popular blockchain platforms, differ greatly. As an illustration, Bitcoin and Ethereum blockchain do have native tokens tied to them, whereas the blockchains in Hyperledger project do not have this feature (Nguyen, 2016). Another factor is the governance model of each platform. Although operating under open source license, many blockchains vary in the extent to which its governance model is community-centralized. The heterogeneity in the technology and governance aspects of the prevailingly leading DLPs inspires me to raise this research question:

Research question: Which factors influence the choice of companies to join a blockchain platform ecosystem, and lead them to exert efforts in that respective ecosystem?

In order to address this question, I only explore mainly the technological aspects and one governance-related factor, which are the choices that are manageable by the platform governors. Other determinants such as the network size of the platform (Koch & Kerschbaum, 2014; Kude, Dibbern, & Heinzl, 2012), the community support, the toolkit quality, the third party software development kit quality (Koch & Kerschbaum, 2014; Puvvala et al., 2016), and the level of openness (Puvvala et al., 2016) are not covered in this research. Additionally, I use the recent framework of Glaser (2016) in dividing blockchain system into two layers: the fabric layer and the application layer. Based on that framework I classify spokes into two different categories: one layer and two layers based products. The former refers to spokes that offer products containing only the application layer while leveraging the fabric layer of the hub. The latter refers to spokes that offer products with both the application layer and the fabric layer. Subsequently, I test if these two groups of spokes show any variation in the motives to join a DLP.

This study utilizes the exploratory multiple-case study methodology to address the research question. It is exploratory in the sense that I used a set of technological and governance-related determinates derived from the current heterogeneous characteristics of the popular DLPs to create a framework to guide the process of data gathering and data analysis. As suggested by Eisenhardt (1989), I used a partially a priori specification of constructs in order to facilitate the collection and data analysis for this exploratory theory-building research. Aligned with this approach, a qualitative method was implemented. The use of multiple-case instead of a single case study helps to develop more robust theories and also has the potential to discover more reliable factors (Yin, 2009). Thereupon, this process is leading to the development of testable hypotheses. I collected data through interviews with key members of a limited number of spoke companies and one hub company. The chosen spokes are participating in one or more of the most popular hubs in the blockchain industry.

This research paper is structured as followed: the next section presents a literature review, which provides the underlying basis for the theoretical foundation section. Later on, I introduce the research design and the findings of this paper. Then, the theoretical contribution and the management implications are presented. Finally, limitations of this study and future research suggestions are discussed.

[1] Corda is a blockchain platform that can do the recording and manage financial agreement (Brown, 2016). The platform is managed by R3, a start-up that leads a consortium of around 50 financial institutions mostly including banks and some insurers.

II. Related work

In recent years, there have been many studies focusing on different battlegrounds in various industries, ranging from mobile operating systems (iOS, Android, Windows), internet browsers (Firefox, Google Chrome, Safari), social networks (Facebook, Twitter), to video gaming (Wii, Xbox, PlayStation) (Gawer & Cusumano, 2012, 2014). And still, the DLP industry has not gained much attraction so far. While DLP is, indeed, a new research avenue, scholars primarily have done numerous studies focusing on mono-disciplinary perspectives, e.g. consensus mechanism (Luu, Teutsch, Kulkarni, & Saxena, 2015; Vukoli, 2015), economics (Evans, 2014; Weber, 2015), personal data platform (Zyskind, Nathan, & Pentland, 2015), regulation (Dion, 2013; KIVIAT, 2015; Plassaras, 2013), etc., which are only single aspects of blockchain technology. Treating the distributed ledger as a technology platform ecosystem, however, has only been tackled by a few researchers in the information system literature (Buterin, 2013; Cachin, 2016; Glaser, 2016).

In the platform ecosystem literature, the theme of discovering spokes' motivations in contributing to different open source projects or mobile operating systems also has a heavy weight. Most of the studies follow the old-established theory of categorizing motivations of software developers into two groups: extrinsic motivation and intrinsic motivation (Hertel et al., 2003; K. R. Lakhani & Hippel, 2003; K. Lakhani & Wolf, 2003; Roberts, Hann, & Slaughter, 2006; Stewart & Gosain, 2006). One the one hand, extrinsic motivation consists of direct and indirect motives. The former is referred to as financial rewards and the potential for meeting a user need. The latter includes learning by doing, skill development (in open source software projects), and career and peer signaling (K. Lakhani & Wolf, 2003; Roberts et al., 2006). On the other hand, intrinsic motivation is related to joy, enjoyment, the stimulation connected with intellectual challenge, and the satisfaction of completing a task at hand (Amabile, Conti, Coon, Lazenby, & Herron, 1996; Csikszentmihalyi, 1990; Ryan & Deci, 2000). Despite that, the results from previous studies show inconsistencies regarding the question of whether intrinsic or extrinsic motivation has higher weight when it comes to the developers' decision to participate and exert efforts in a platform ecosystem. Some scholars showed that intrinsic motives outweigh extrinsic ones (Hertel et al., 2003; K. Lakhani & Wolf, 2003)**,** whereas others found that extrinsic motives are more important (Hars & Ou, 2002; Hilkert et al., 2010).

In these motivation studies in the field of software platform ecosystem, scholars have been paying more attention to the internal and external motivation dimension. There has been little research that actually explores the motives of spokes (as a company, not as an individual developer) in deciding which platform to choose among a pre-selected set of popular platform ecosystems. Even as for the decision criteria, there have not been many studies about "platform war" in other industries but in the mobile industry. By way of example, Koch and Kerschbaum (2014) have conducted a quantitative survey with individual developers to understand their decision criteria in choosing between iOS or Android. They revealed that network size, openness, entry barriers, and toolkit quality (SDK quality and quality of support and documentation for app development) are the most important factors in the decision-making process of complementors. In a similar study two years later, Puvvala et al. (2016) claimed that openness is no longer a determinant of platform choice. In fact, he used openness as a moderator variable instead of an independent variable to test the developer's choice to join a mobile platform ecosystem. As a result of this new approach, development costs (infrastructure costs, licenses fees) and supports (3rd party SDKs, community support) turn out to be more important than expected returns (monetary, non-monetary returns) and ease of coding (handset fragmentation, availability of prototype, development environment with native apps and toolkits, restriction on coding).

The current discussion in blockchain research around permissioned and permissionless blockchain fueled another perspective in this paper. **"**A public blockchain is a blockchain that anyone in the world can read, anyone in the world can send transactions to and expect to see them included if they are valid, and anyone in the world can participate in the consensus process – the process for determining what blocks get added to the chain and what the current state is" (Buterin 2015, p. 1) In contrast to that, a permissioned blockchain can be a consortium blockchain or a fully private blockchain. In this type of DLPs, the consensus process is controlled by one or a number of pre-selected participants, and the right to read the DLP could be public or restricted to certain nodes (Buterin, 2015). When a company decides to write applications on top of a public, meaning a permissionless, blockchain, they only create applications on the application layer while using the fabric layer from the public DLP as the base layer (Glaser, 2016). On the contrary, a company, that offers products using a permissioned blockchain, actually has to write and manage both the application layer and the fabric layer in their product. Taken this difference into account, there could be a potential variance in the way these two types, the public blockchain-oriented spokes, and the private blockchain-oriented ones, evaluate different DLPs.

In summary, scholars have been paying much less attention to the blockchain platform field compared to other industry platform ecosystems. In studying the motivation of software developers, researchers mostly look at the internal and external dimension, whereas there have not been so many studies exploring the actual decision criteria in regard to the choice between popular platform ecosystems. Even in the papers that address the decision criteria of spokes, there has been little importance placed on the technology-related factors that influence the motivation of software developers. Moreover, the dissimilarity in architectural design between different DLPs platforms signals potential variance in the spokes' motivations, depending on the technical characteristics of the DLP itself. Against this backdrop, my paper aims to (1) explore the technology and governance determinants that influence the choice of spokes to join and contribute to a DLP ecosystem, (2) examine how the combination of the technology and governance factors, together with the public or private blockchain-oriented determinant help to explain the motives of spokes in choosing various DLPs.

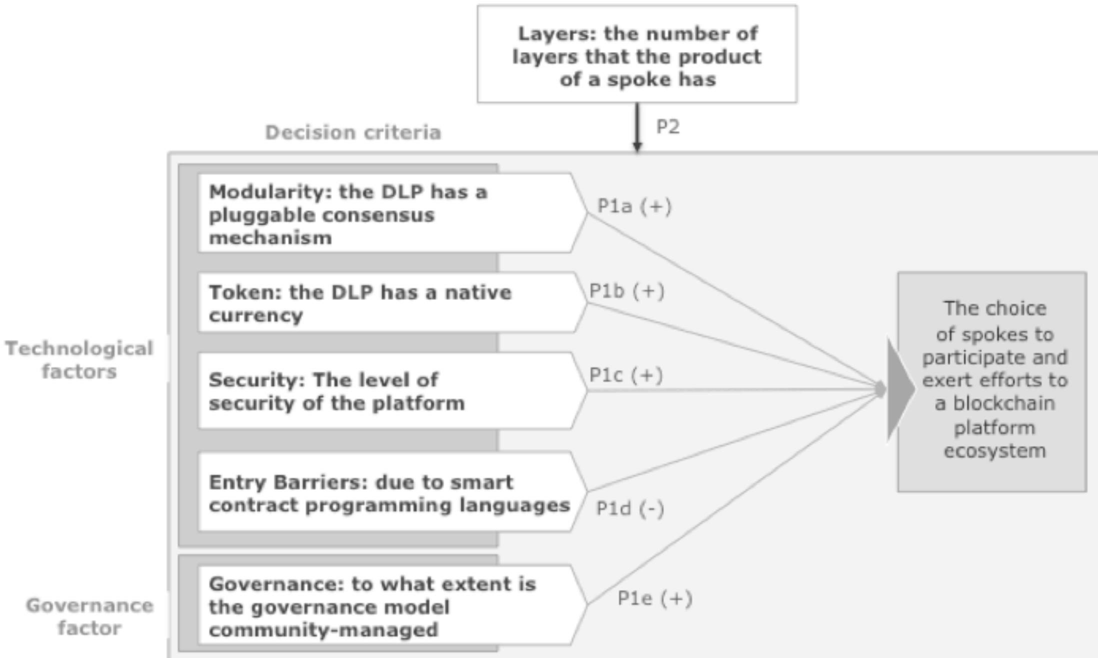

Fig. 1. Spokes' motives to join and exert efforts in a DLP ecosystem

III. Theoretical Foundation

This section introduces a theoretical framework, which describes the decision criteria of spokes in joining a DLP ecosystem based on the literature review in the last part. This framework only considers the technological and governance aspects, which are derived from the heterogeneous characteristics of some prevailing DLPs. An overview of the framework is shown in Figure 1.

A. Technological Factors

This subsection will introduce the first four technological factors in my framework: modularity, security, entry barriers, and native token. With each determinant, a hypothesis is proposed.

Modularity refers to the ability to which changes in a subsystem do not make any ripple effect on other components in the same ecosystem (Tiwana 2014). Even though a modular product architecture enables components of the platform and applications to be developed independently, they can work together through interfaces in an ecosystem (Sanchez & Mahoney, 1996). The opposite of a modular architecture is an integral one, where interfaces between components are not standardized and interactions between modules are complex and overlapping (Yoo et al., 2010). Hence, changes in one module will have consequences on the whole ecosystem. The decision which architecture to pursue might contain a trade-off. On the one hand, modularity empowers platform providers to massively distribute innovation among millions of application developers (Tiwana, 2014). An integral architecture, on the other hand, provides high performance and quality, which are essential for goods such as sports cars or high-end electronics (Yoo et al., 2010). Platform managers should increase the level of modularity (1) when a platform's market is heterogeneous, (2) when there is a high level of uncertainties regarding technological trajectories, or (3) when external innovators have diverse skills and knowledge of end-users that platform providers do not have in-house (Tiwana 2014). Applying this suggestion to the DLP area and taking into account that the current technology stacks of the existing distributed ledgers are far less efficient than the contemporary financial services platforms, DLP hubs should consider designing their architecture with a high level of modularity (Evans, 2014). Anyhow, greater modularity also reduces the performance, which is currently a big issue of blockchain technology (Yoo et al., 2010). Ethiraj and Levinthal (2004) showed that modularity is, indeed, beneficial for innovation but too much modularity is not preferable. More concretely, they stated that an intermediate level of modularity supplies the highest level of innovation. Tiwana (2014) further amplified the finding by confirming that the ideal amount of modularity is "just enough" modularity. Applying that logic, DLP architects should at least aim for the most necessary features to be modular, given the current challenge in scalability of the technology. Aligned with the academic literature, Hyperledger Fabric platform plans to have a pluggable consensus mechanism, which is the architecture part that can potentially be innovated to increase the performance and scalability of a DLP. Precisely, a spoke can choose one in several available consensus mechanisms to deploy in its private blockchain. Notably, one cannot exchange the consensus algorithm when their permissioned DLP is already up and running. While Hyperledger Fabric is the pioneer to implement this architecture design, most of other prevailing DLPs, nonetheless, do not have this feature included in their current roadmaps. This raises the question, whether the spokes will also notice that and be motivated to participate in such a modular platform. I, therefore, formulate the following hypothesis: *Proposition 1a: Companies (spokes) are motivated to join and contribute to a DLP ecosystem caused by the pluggable consensus mechanism in the architecture* *design of that DLP.*

Nakamoto (2008) called the Bitcoin platform an electronic cash system, which has bitcoin as its native cryptocurrency. Almost all applications built on top of Bitcoin blockchain platform leverage the use of bitcoin. After the creation of Bitcoin, other distributed ledgers developed their ecosystems around one or multiple digital tokens. Ripple, for example, has XRP as their native cryptocurrency. Ethereum platform, besides having its native digital token Ether, also allows other applications to mint new tokens, which have their values tied to the value of Ether (e.g. DAO, REP). While some popular public DLPs are designed with a native currency, many other renowned blockchain platforms, such as Hyperledger Fabric or Sawtooth Lake, do not have any native currency in their architectures. The native cryptocurrency is developed as an incentive mechanism for miners[2] in a blockchain network. Moreover, it also helps small spokes to raise fund in their bootstrapping phase. Recently successful cryptocurrency-crowdfunding from the DAO[3] with more than $150 million (at the time of the crowdfunding), and Augur[4] with $5.2 million (at the time of the crowdfunding) inspire me to formulate the following hypothesis: *Proposition 1b: Companies (spokes) are motivated to join and contribute to a DLP ecosystem caused by the existence of a native cryptocurrency tied to that DLP.*

One essential innovative feature of blockchain is immutability. All the data written on a blockchain will persist as long as the blockchain does (Mainelli & von Gunten, 2014). There have been many spokes who built up their application leveraging this immutability by recording the full history of high-value objects such as paintings, diamonds, and real estates on blockchain. It is important to be aware that the security of a public blockchain network running Proof of Work (PoW) as a consensus mechanism is currently quite expensive because it is provided by the hashing power from thousands of miners running their computers to secure the blockchain networks (Nakamoto, 2008). With the effort to make consensus cheaper, other novel consensus mechanisms are being developed and heavily invested in by different blockchain platforms, such as Proof of Stake based Casper from Ethereum (Buterin, 2016). Yet, up-to-date none of them has successfully replaced PoW as the most established consensus mechanism. Taking this current challenge into account, most spokes have to rely on the hubs to render the fabric-level security because it is too expensive for them to do it on their own. I, therefore, formulate the following hypothesis: *Proposition 1c: Companies (spokes) are motivated to join and contribute to a DLP ecosystem caused by the security level of that DLP.*

The entry barriers for companies entering a mobile operating system might include several factors: monetary entrance fee, licensing cost, availability of software development kits, development tools, and programming languages used for development (Koch & Kerschbaum, 2014). Similar to the mobile operating system ecosystem, these factors can also be applied to a DLP ecosystem. However, the programming language of the smart contract is picked because of the current variation in prevailing DLP ecosystems. While certain DLPs offer some matured languages with hundreds of freely available libraries for the smart contract, others introduce new domain-specific languages (DSLs) that require software developers to spend time and effort to learn and master these new DSLs. For startups and small companies, the learning effort could be reasonably offset by the potential benefits. Notwithstanding, for big corporations and consulting firms, the process of training their employees or even finding developers that are able to code these DSLs could be a potential barrier. I, therefore, formulate the following hypothesis: *Proposition 1d: Companies (spokes) are motivated to join and contribute to a DLP ecosystem caused by the low entry barrier with respect to the programming languages of the smart contract in that DLP.*

B. Governance factor

Alongside with the rapid expansion of the open source software (OSS) projects, we observe the growth in the diversity of sponsors and stakeholders of those projects. Consequently, new OSS governance models emerge which differ from the community-managed governance model. As introduced by O'Mahony (2007), a community-managed model consists of five elements: independence, pluralism, representation, decentralized decision-making, and autonomous participation. (a) Independence refers to the fact that the project does not solely rely on any single sponsor. (b) The term pluralism is associated with a governance model for development that contains different and sometimes opposing approaches, methodologies, theories or points of view. (c) Representation describes the ability to represent all participating members in decisions that affect the community. (d) Decentralized decision-making means that the decision-making is decentralized to some extent. (e) Autonomous participation implies the OSS project let its members participate freely.

It is the accepted wisdom in the distributed ledger world that decentralization is the manifesto for blockchain innovation (Buterin, 2017). Many developers believe that the governance model of open source blockchain projects should also be decentralized or managed by the community. For illustrating this aspect, one should look at three leading open source DLPs: Hyperledger Fabric, Ethereum, and Bitcoin, where the extent to which these platforms follow the community-managed governance model differs greatly. In Bitcoin ecosystem, the current development is centralized and mostly funded by Blockstream. After all, the decision-making process is very decentralized as there are different groups of miners, core developers, exchanges, and wallet providers leveraging their businesses on the 15-billion market capitalization coin (the bitcoin price reference is in January 2017). In contrast, Ethereum where the decision right and the core development is more` centralized in the Ethereum Foundation. Being governed by Linux Foundation, Hyperledger Project is considered the most community-managed governance model. Given this variance in the governance model, spokes' choice might, therefore, be

[2] The miners validate transaction on blockchain by providing enormous computational power and receive the native currency of that blockchain as a reward. They are called "miners", because they invest their mining power to create new bitcoin or Ether, just analogous to gold miners expending their resources to dig gold and add to the circulation (Nakamoto, 2008).

[3] https://en.wikipedia.org/wiki/The_DAO_(organization)

[4] https://en.wikipedia.org/wiki/Augur_(software)

influenced by this determinant. I, thus, formulate the following hypothesis: *Proposition 1e: Companies (spokes) are motivated to join and contribute to a DLP ecosystem caused by the extent to which a DLP governance model is community-managed.*

C. Permissioned versus Permissionless

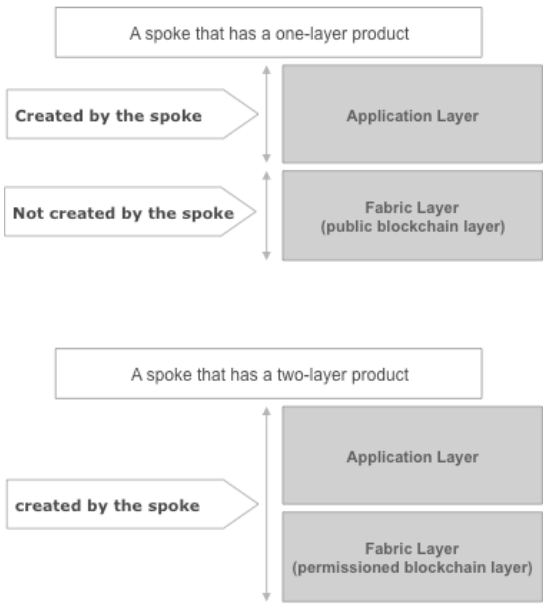

Fig. 2. A one-layer product and a two-layer product

Deriving from the current discussion around permissioned and permissionless blockchains, I define a new factor depending on whether a spoke writes applications on top of a public or private blockchain (Buterin, 2015). When a spoke offers a product based on a public blockchain, it creates an application and uses the fabric layer of the public blockchain (Glaser, 2016). The product, hence, has only one layer – the application layer. Contrasting, when a complementor offers a product using a private blockchain, the spoke creates and manages both the application layer and the fabric blockchain layer. The number of layers offered by the product, hence, is two. Figure 2 visualizes the typology.

The questioned raised here is whether a spoke that writes applications on top of a public DLP behaves differently from a spoke that offers products using a private blockchain when deciding which DLP to join. One would argue that the former would choose a permissionless DLP ecosystem, whereas the latter would prefer a permissioned one. Despite that, the current blockchain industry leaders behave quite differently. As most of the popular DLPs are open sourced, a spoke can use the source code of a public blockchain and make it private by adding a user management layer, which controls the nodes that can participate in the network. That means a private blockchain oriented spoke has the incentive to join a public blockchain ecosystem. Conversely, a public blockchain oriented spoke might not have the incentive to participate in a private DLP ecosystem. Although it is fairly correct to say this at the moment, it might change in the near future when a private DLP can be able to be interoperated with other public blockchains. For this reason, it is intriguing to explore whether there are interaction effects between the type of product offered by spokes and their technology and governance-related motives. This determinant might not influence the participation decision directly but rather be a moderator variable that could change the extent to which a particular technology or governance aspect causes the spokes' decision to join and exert efforts to a DLP. This leads to the following proposition: *Proposition 2: The number of layers, that the product of a spoke has, interacts with the extent to which particular technological characteristics and governance model of the hub motivate the spoke to join and contribute to a DLP ecosystem.*

IV. RESEARCH DESIGN

This section describes the overall strategy that was implemented to combine different components of the research in a structured way. The research design consists of three main subsections: methodology, data collection, and data analysis.

A. Methodology

In this study, I deployed a multi-case design, in which several instrumental cases from some popular distributed ledger ecosystems are employed. The reason for that is implementing a multiple case design instead of a single case can generate more general results (Benbasat, Goldstein, & Mead, 1987; Yin, 2009). Aligned with the exploratory nature of this research, I followed a qualitative approach, which allowed me to observe the participation decision of the spokes in a rich contextual manner. This is well-suited for discovering new theoretical relationships (Yin, 2009).

In order to refine the proposed theoretical framework, I ran several pilot cases in order to refine the framework and familiarize myself with the research topic (Yin, 2009). In detail, there were two spokes (spoke Pi1 and spoke Pi2) and one Hub (Hub 3) included in this round. Two face-to-face interviews with spoke Pi1, one video interview with spoke Pi2, and two interviews (one face-to-face and one video interview) with hub 3 were conducted. All the interviewees were in the manager positions of the blockchain-working group in their organizations to ensure that they fully understand the motives behind the decision-making process of their organization with respect to distributed ledger technology. Through the pilot cases, I detected several inadequate determinants in the initial framework and refined the data collection plan. The excluded factors are openness of the DLP, development support, market size, and reputation. When in fact, these are important factors too, they were not incorporated in this paper due to the scope of the research. The first criterion is that it must be a technical or governance factor, which is manageable by the DLP managers. The second criterion, which decided whether a factor is incorporated, is that there must be a variation in that factor between selected DLP ecosystems. Openness exemplifies the mentioned guideline. The level of platform openness is one important aspect in the area of mobile operating systems as it differs greatly in the "platform war" between the two giants in the field: iOS and Android. While iOS is considered to be less open and more vertical integrated than the rest, Android is known to be one of the most open mobile platforms. I decided not to include this factor in the framework because the level of

TABLE I
SUMMARY OF CASE COMPANIES AND INTERVIEWS

Case	Core business	Position of the interviewee	Hub	Type	Number of Interview
Spoke A	Professional services	Head of blockchain	3	Main	1
Spoke B	Manage a marketplace on blockchain	Product Manager Blockchain developer	2	Main	1
Spoke C	Blockchain platforms for insurance markets	CEO - Founder	2	Main	1
Spoke D	Cryptocurrency issuance solutions	VP Product- Cofounder	1	Main	1
Spoke E	Professional services	Head of blockchain	2&3	Main	1
Spoke F	Financial instruments clearing services on blockchain	CEO - Cofounder	3	Main	1
Spoke G	Issuance and administration of financial instruments on DLP	CEO - Founder	2	Main	1
Spoke H	Security solutions on blockchain	CEO - Founder	1&2	Main	1
Spoke I	KYC solutions on blockchain	CEO – Cofounder	1&2	Main	1
Spoke K	Issuance and administration of financial instruments on DLP	CEO - Cofounder	2	Main	1
Spoke Pi1	Professional services	Head of blockchain Blockchain developer	2&3	Pilot	2
Spoke Pi2	Blockchain startup	CTO – Co-founder	2&3	Pilot	1
Hub 3		Executive Director Project Board Member	3	Pilot	2

openness among those three hubs only slightly differs with respect to the copyleft license. Apart from that slight difference, all three DLPs have the same level of openness according to the classification from Anvaari & Jansen (2010). More specifically, all three DLPs allow complementors to integrate, extend and also modify the kernel layer, the middleware layer, and the application layer. To sum up, openness as a determinant is qualified with the first criterion but not the second one.

After the pilot cases, the refined framework was then used to guide the coding and quantitative assessment of the collected data from the main cases. The coding step helps to ensure the reliability of the qualitative data by enabling me to do a quantitative analysis of the significance level of the technology and governance factors (P1, a-e) in the framework (Miles & Huberman, 1994). Besides, coding also allows me to further analyze the impact of each technology and governance determinant (P1, a-e) in combination with the type of products that the spoke offers (P2). The use of a mix of data analysis method helps to improve the confidence in the final findings (Yin, 2009).

In order to increase the reliability of this study, I created a case study database so that another investigator could repeat the whole procedures and assess the findings of this paper. The database consists of interview questions and guidelines, audio files from interviews, transcripts, coded data, and analyzed data.

B. *Data Collection*

The unit of analysis in this study is the actual decision of the spoke to join and exert efforts to the DLP ecosystem. As a result, all the spokes, which were selected, actually joined a DLP and contributed something to this DLP. There is no case where the spoke joined a DLP and then left without contributing anything to it. Furthermore, all cases were chosen from two types of spokes that are building applications on top of public or permissioned DLPs. The intention was to follow a literal replication logic, which leads to predicting similar results (Dube & Pare, 2003; Lee & Hall, 1989). All the spokes were chosen in a way that maximizes the variation in each independent variable and the moderator variable (Yin, 2009). A detailed view of the cases is presented in Table I.

Three DLPs were selected in this study. Hub 1 and hub 2 are public blockchains. Nevertheless, both can be manually forked and thereafter operate as a private blockchain. Hub 3 offers only permissioned DLP. All three hubs are concentrating on developing the fabric layer of the blockchain. There were 12 spokes in total, two spokes for the pilot cases and 11 spokes for the main cases. In the pilot cases, two spokes both participate in hub 2 and hub 3. For the main cases, two spokes participate only in hub 3, four spokes participate only in hub 2, one spoke participates only in hub 1, two spokes participate in both hub 1 and hub 2, and one spoke participates in both hub 2 and hub 3.

All complementors were selected in such a way that each one represents an independent legal entity except for spoke Pi1 in the pilot case. The selected spokes are located in North America, Europe, Australia, and the Middle East. I tried to generalize the finding of this paper by increasing the quantity of case and selected only one to two key members of each spoke. Most of the key interviewees are CEOs or heads of blockchain working groups in their companies. This is to ensure that the person has the suitable knowledge regarding the decision criteria in joining different DLPs.

Overall, there were totally 15 interviews taken with 12 spokes and 1 hub, five of the interviews were designed for the pilot cases. Even though my ambition was to have as many face-to-face interviews as I can, only three interviews (two with spoke Pi1 and one with the project principal of hub 3) were held face-to-face. This can be led back to the geographical and financial constraints, as the researcher lives in Germany and could not afford to go to other countries to make the interviews. Thus, among the 12 remaining interviews, eight of them were carried out via video call, the other four were done through regular voice call. Each interview lasted for one hour in average. I developed two interview guidelines, one for the hubs and one for the spokes. The guidelines consist of pre-defined questions, that were designed based on the framework in the last section, and general questions regarding the interviewee and the company. Nonetheless, the interviews were held in a semi-structured manner to ensure that new insights and model refinements could be explored after each interview. All the interviews were recorded and transcribed in English. In order to increase the internal validity of the transcribed data, triangulation of data was implemented by using the public documents from the companies' website (Yin, 2009).

C. *Data Analysis*

The first step in analyzing the data was to assess the significance of five P1 factors in the refined framework. The NVivo software version 11 was used to structure the analyzing work. As suggested by Miles & Huberman (1994), I used the coding technique to code the transcribed data into five nodes, which represent five determinants in the pre-defined framework: modularity, token, security, entry barrier, and governance. Table II presents the five nodes with their definitions and exemplary indicators. Totally, 104 references were coded from this first step.

After coding and assessing the relevance of the five determinants, I tried to look at each case individually and wrote up stories for them. The purpose of this step is to understand the relevance importance of every single factor within the context of each case (Miles & Huberman, 1994). Solely depending on the qualitative analysis, I could not assess the significance of each determinant across the data set. Yet, I was able to gain insights into the perception of each spoke regarding each technological or governance factor. Some significant variance in several factors was found. Interestingly, some results are contradicting with the original framework.

In order to have a quantitative assessment of the qualitative data, I graded every reference to subjectively measure the significance level of each factor in every case. The detailed coding was done three times to reduce the errors in analyzing. In detail, the scores for each reference range from -2 to 2. The former means the spoke feels strongly negatively influenced by the factor, the latter means the spoke feels strongly positively influenced by the factor. Zero means the aspect does not influence the spoke's platform choice at all.

In the last step, I divided the spokes into two groups according to the number of layers in their products. I used the data from the interviews together with the public information on the spokes' websites to appraise whether their products have one or two layers (Miles & Huberman, 1994). The score and the number of references for each determinant in each group were then recalculated to reflect the new categorization. With this result, I could see if there is any significant difference between the two groups and further identify potential patterns regarding the interactions between P1 (a-e) and P2.

V. RESULTS

This section presents the findings of the research. As a result of the analysis, a refined framework for the DLP choice model of spokes will be proposed in the end accordingly

TABLE II
NODES EXPLANATION AND EXEMPLARY INDICATORS

Node	Definition	Exemplary indicators
Modularity	There is a pluggable consensus mechanism in the DLP.	Spokes prefers a DLP with a pluggable consensus mechanism
Token	There is a native cryptocurrency tie to the DLP.	Spokes prefers a DLP with a native cryptocurrency
Security	The hub provides the spokes with a secure, immutable DLP.	Spokes prefer a DLP, which is proven to be secure.
Entry Barrier	The programming languages of the smart contract are newly developed domain specific languages (DSLs).	Spokes hesitate to participate in a DLP with only limited choices of newly developed DSLs for the smart contract.
Governance	The governance model is a community-managed governance model.	Spokes prefer to participate in a DLP with a community-managed governance model.

A. *Technological Factors*

The pluggable consensus mechanism (Proposition 1a): the empirical analysis showed that the pluggable consensus algorithm plays an important role in the decision criteria of the spokes in joining a DLP ecosystem. Yet, the analyzed spokes showed some variance in how important this factor is to them.

Spoke A is a software development firm that was founded in 2001. Since 2016 the company is offering blockchain solutions and consultancy for its customers. From the start, they have actually been very active hub 3, contributing not only to the application layer but also to the fabric layer of the ecosystem. When being asked about the motivation to join hub 3, the head of blockchain stated that the modularity architecture of the DLP, in general, and the pluggable consensus mechanism, in particular, are essential reasons for that. As an example, the blockchain head provided a case from his company, where a private blockchain solution for 20 participants was designed. Yet, he pointed out that there might be use cases, where architecture for 100 nodes is required and therefore a different consensus mechanism might be needed.

Since its establishment in 2016, spoke F is building a trading and clearing platform for financial instruments on blockchain. They have been participating and testing in multiple DLPs, nonetheless they have built their product in hub 3's ecosystem since the inception of hub 3. The CEO of spoke F indicated that the pluggable consensus mechanism is essentially an important factor that influenced F's platform choice. Especially at this early phase of blockchain technology, with many novel consensus mechanisms being in an under-development status, it is a very good choice because the architecture can be changed when another technology comes out.

The native cryptocurrency (Proposition 1b): while the original prediction is that the spoke would be motivated to join and contribute to a DLP ecosystem when the system is designed with a native token tied to it, the empirical analysis showed a very high level of variation between the spokes' opinions in the sample. Some spokes demonstrated great enthusiasm in participating in a hub with a native token tied to it, whereas other even expressed high concerns regarding this feature and try to stay away from it. Two typical case stories from spoke B and spoke E are explained in detail below to illustrate the two opposing thoughts of the spokes' motives.

Spoke B is a startup that is building a marketplace on top of a public blockchain. The initial development of their software was done in hub 1 in 2014. However, they later changed to hub 2 and released the alpha and beta version of their software in 2015 and 2016, respectively. A live-software running on top of the public DLP from Hub 2 is still in development. Noticeably, spoke B's crowdsale in 2015, using the native token of Hub 2, is one of the highest funded startups of all time. For them, hub 2 offered a unique method in the market to raise fund in their bootstrapping phase. That is why B's blockchain developer mentioned that he only considers DLPs that have a native token. Furthermore, they prefer coins with high a market capitalization and a high hashing rate. Spoke B not only used the native coin of hub 2 to raise fund but also built their own token on the hub 2's public blockchain. Another aspect pointed out by the product manager is the security of the network enabled by the native token. If there were no token in hub 2, they would have to use a private blockchain from hub 3 and build a path to the public blockchain from hub 1 in order to use the native token there. Given these points, the existence of token is really B's primary motive to join any DLP, said the product manager. In conclusion, the native token firstly provides a bootstrapping mechanism for startups, which B could use especially well. Secondly, the cryptocurrency is currently the only way to incentivize validators to keep the integrity and the security of the network. Lastly, the cryptocurrency itself can be used as a payment method for all the applications in the same ecosystem.

Having an opposing opinion, Spoke E is an established multinational organization providing professional services in multiple industries. Their current business model in the area of blockchain is building solutions and giving consulting services to their corporate customers worldwide. From their first blockchain project in 2014 until now, they have been participating in both hub 2 and hub 3, with hub 2 being the main platform for their solutions. Interestingly, E mainly worked with the private version of hub 2's blockchain, not the public one because many of their customers have big concerns with cryptocurrency from a tax and accounting perspective. E's global head of blockchain explained it like this: "so, when you use [hub 2's token] for example to represent an asset, that might be fine if you stay in the same jurisdiction in the same country. But if you use that to move assets between countries, you might be in a situation where [hub 2's token] represents the assets and you have a tax implication of using that token […] Bitcoin in the U.S. is considered as an asset. What is means is that if I get Bitcoin from you and I am buying a Pizza with those Bitcoin. And if by the time, I buy the Bitcoin from you and the time I buy the Pizza the price of Bitcoin goes up, the difference is considered as the capital gain and I need to pay tax on it." Altogether, for Spoke E using a cryptocurrency "opens up kind of worms from the tax point of view that are pretty big." Therefore, they hesitate to build solutions for their customers on a public blockchain with that nature hurdle. Unless the native token is globally recognized as a currency rather than an investment so that their customers do not have to pay very high tax on it when the token price increases.

The security of the DLP (Proposition 1c): As the groundbreaking innovation of blockchain technology is its ability to provide trust between untrusted parties, immutability is often viewed as a blockchain's entire raison d'être. Amplifying this accepted wisdom, my empirical analysis disclosed that the security of a DLP is the primary criterion for joining a DLP ecosystem across all cases. This is also the most common theme during all interviews. De facto many spokes have taken the hardforks of hub 2 blockchain as the typical example of the violation of the immutability of a DLP. In turn, the whole security of the hardforked blockchain is in danger. Three exemplary case stories are presented below to illustrate this motivation.

Spoke G is actually the most extreme case where the hardfork of hub 2's public DLP led G to a hasty exit from the ecosystem. G was founded in 2015 and started to build applications in hub 2 since the early days. The startup focuses on issuance and administration of financial instruments on blockchain. Being asked about the decision criteria in choosing a DLP, spoke G's CEO gave the following response: "well, as a financial service regulated firm, so as somebody that is regulated by the Financial Conduct Authority […] for us, security is the ultimate goal. If we can't promise security, we will fail as a company." Security is, in fact, the most critical factor that determined G's decision to join and stay in a DLP. In 2016, when hub 2 decided to rollback their blockchain due to a security hole in one application built on top of it, spoke G's CEO was publicly expressing his contrary opinion against the hardfork. G also announced to not only exit the ecosystem but also to support the pre-forked blockchain in case hub 2 destroys the immutability of the original network with the rollback. Finally, G did leave hub 2 and is currently leading the development in the pre-forked DLP.

Existing since 2015, spoke D's current business model is offering currency issuance solutions, built on top of a public blockchain. Their protocol sits on top of hub 1's DLP and uses it as a settlement layer. In other words, they are renting mining services from hub 1 by paying miner fees. Hence, the security of a DLP is the most important determinant to them when it comes to the platform choice decision. According to spoke D's vice president of product, security is an on-going issue for every blockchain and the best decision now is to use hub 1's DLP because it is by far the most secure blockchain ecosystem in the world. In addition, he stated that the network must be openly battle tested in a public environment in order to increase the confidence in the security of the network. Nonetheless, his company also considers building their applications on other blockchains in the future, if these are proven to be secure, emphasized the vice president of product.

Spoke I offers a know-your-customer (KYC) solution, running on the public blockchain of hub 1. The startup was founded in 2014 and started developing its applications on top of hub 1 ever since. In response to the question about the reason behind their initial decision and on-going development on the DLP, the CEO of the startup replied the following way: "we wanted to have a solution that could be put in the production today not waiting until the blockchain matures. So, we were choosing the blockchain that is mostly mature at the moment that we could use in production. That is our first criterion." To him, a blockchain must be proven to be secure in order to put into production today. He later explained his motive further by calling the hardforks of hub 2 a scary event, which destroyed the trust in the immutability, and thus the security of the network.

The programming languages of the smart contract (Proposition 1d): My empirical analysis showed that the entry barrier with respect to the DSLs of the smart contract is a factor that negatively influences the participation decision of spokes across the cases. Yet, the weight of this factor in the decision-making processes varies from case to case.

Regarding the question about the decision criteria of the platform choice, spoke A's head of blockchain commented that the programming language of hub 3 plays a big role in their DLP decision. When clarifying his statement, he took the example of the new DPL in hub 2, which has several limitations with respect to the memory, the number of variables, and most negatively the availabilities of libraries. The programming languages for smart contracts in hub 3, in contrast, are pretty mature and that helps him to save a tremendous amount of time. He expressed it in the following way "and I'll be honest with you, I doubt that I can do anything really complex with [hub 2] for that matter. It will take me months and months to rewrite the same kind of library in [the smart contract programming languages of hub 2]."

The global head of blockchain of spoke E, instead, saw the DLPs of the smart contract in hub 2 as an obstacle, from a resource perspective. This factor has a negative effect on E's participation decision because it is really a challenge for E to recruit people who can actually code in the new DPLs. According to him, "it was a really big question for his company" because they needed a very big blockchain development team. Overall, he concluded his position: "if I look for [hub 3's smart contract programming language] programmer, I have like thousands."

B. Governance Factor

The community-managed governance model (Proposition 1e): It is consistent across all the cases as a common topic that the extent to which the governance model of a DLP is community-managed actually plays a big role in the platform choice of spokes. The two cases of spoke A and spoke E are two exemplars that show how important it is to have a decentralized governance model.

Speaking of his motivation in contributing to hub 3, A's head of blockchain stated that it is very important that hub 3 is openly governed. That means the platform is "governed by merit, by how much you contribute to it" (A's head of blockchain) rather than in the hand of a centralized foundation that decides the fate of the entire project. This is also very much aligned with the principals of representation and decentralized decision-making in the community-managed governance model that was introduced earlier in this paper (O'Mahony, 2007). The head of blockchain later amplified his company's motivation by saying that this governance model has been proven to be successful in many open source projects. This convinces him that it is the right model to pursue in an open source blockchain ecosystem.

While spoke E started with Hub 2 in 2014, the company has been building software in both hub 2 and hub 3 ecosystems since the emergence of hub 3 in 2016. One of the main motivations for the participation decision in hub 3 is the governance model. The global head of blockchain commented the following way: "what I would say is when you own [hub 2's token] and you own a piece of the asset that you are governing, I think your level of independence is not that big as if you don't use the assets into the standard that you are trying to develop […] And some of them are pushing the technology into a direction, which is profitable for them as individuals because they own [hub 2's token]." The governance model of hub 3 can prevent that from happening because the people who govern the project do not own any cryptocurrency that is associated with the platform, he said. Finally, he concluded that at the end of the day, it is not a question about which ecosystem has the best technology and architecture but rather which has the best and most transparent community and governance to make it works. Again, the model that he described combines many aspects of a community-managed governance model. One of the key pillars of the model is a transparent development model which offers a publicly available model of problem handling (O'Mahony, 2007). For instance, hub 3 has an independently acting technical committee to foster resolutions when technical conflicts occur. To spoke E, the open governance model of hub 3 is really influential because it is very transparent and has been proved to be successful in the open source industry.

C. Qualitative Assessment

The pure qualitative analysis showed supports for the five propositions P1 a-e to a certain degree. The extent to which the DLP governance model is community-managed (P1e), and the security of the blockchain (P1c) are consistently important criteria for all spokes regarding the decision of which blockchain to join, whereas the empirical findings for the entry barrier, the native token, and the pluggable consensus mechanism draw a quite different picture. De facto there was a significant variance in the opinions of the analyzed spokes on the subject of the advantages that a native cryptocurrency could bring to them. While some spokes consider the native token as the primary decision to join any DLP, some see it as a strong burden and try their best to avoid it. The data analysis also revealed variation in the extent to which the spokes are motivated to join and exert efforts to a platform that has a pluggable consensus algorithm (P1a). In spite of the fact that all of them see modularity as a benefit, the level of motivation differs between different cases. Finally, the case analysis showed that a new DPL of the smart contract in a DLP is clearly a barrier that affects the spokes negatively (P1d). Despite this negative perception, not all spokes' platform decisions are influenced by it.

TABLE III
EVALUATION OF INTERVIEW FRAGMENTS (NUMBER OF REFERENCES EACH INTERVIEW/ LEVEL OF SIGNIFICANCE AND DIRECTION, FROM -2 TO 2)

Cases	Modularity	Token	Security	Barrier	Governance
Spoke A	3/1.67	2/0	n.a.	2/-2	3/2
Spoke B	1/0	3/2	4/2	3/-1	3/1.33
Spoke C	2/1.5	2/-1	4/2	1/-1	n.a.
Spoke D	3/0	1/0	6/2	1/0	4/1.25
Spoke E	3/2	5/-2	1/1	3/-2	3/2
Spoke F	1/1	2/-1	n.a.	3/0	n.a.
Spoke G	2/1.5	5/2	3/2	2/-2	4/2
Spoke H	1/0	1/0	4/2	1/0	n.a.
Spoke I	1/1	1/0	5/2	1/0	2/2
Spoke K	1/0	1/-2	n.a.	1/0	1/2
Average	**1.8/0.87**	**2.3/-0.2**	**2.5/1.3**	**1.8/-0,8**	**2.0/1.26**

D. *Quantitative Assessment*

The next step of the case analysis was to do a quantitative assessment by grading the strengths and directions of all the references among the nodes. This analysis is aligned with the qualitative assessment and elaborates on the paper's findings. Table III illustrates the strengths and the directions of each criterion in all cases. In every cell, the first number is the total number of references; the second number is the average score ranging from -2 (very negative) to 2 (very positive). The bottom row shows the average results across the whole sample.

In depth, the security of the DLP is the most important technological factor. It was most mentioned among cases with 2.5 times in average. The security aspect also has the greatest positive influence on the platform decision of the analyzed spokes with an average strength of 1.3. Being slightly less important than the security aspect, the degree of which the governance model of a DLP is community-managed is also proven to be a strong influential motive of spokes. This governance factor is mentioned 2 times in average and has the strength of 1.26. The entry barrier due to the DPLs of the smart contract and the pluggable consensus mechanism are equally significant in the 3rd place after the security and the governance determinant. While they were equally mentioned in all cases (1.8 times in average), the relative strengths, although in opposite directions, are both fairly close to each other (0.97 and -0.8). For the native cryptocurrency aspect, the picture is totally different. Despite the fact that it is the second mostly mentioned aspect with 2.3 times in average, its score is nearly zero (-0.2 in average). With the purpose of explaining these interesting preliminary results, I will introduce a typology of the analyzed spokes in the next section.

E. *Typology of Spokes*

This section presents the results of the analysis when the interaction between the technology and governance aspects, and the typology of spokes are tested. In the end, a refined framework resulting from the analysis is presented.

1) *Analysis*

Following the current discussion in the blockchain world concerning permissioned versus permissionless DLPs, I scrutinized the business model and products of each spoke using both the interview data and the public information on their websites to categorize the cases into two groups. Precisely, a company that is writing most of its applications on top of a public blockchain is defined as a 1-layer-product spoke. A firm developing the majority of its products by leveraging private chains is defined as a 2-layer-product spoke, as it has to write and manage both the fabric and the application layer in the products. For example, spoke D uses the DLP of hub 1 as a settlement layer for their marketplace application. Their application is entirely dependent on that DLP because if it stops functioning, so does the product of spoke D. The marketplace that spoke D is currently operating, therefore, belongs to the 1-layer-product category. On the other hand, spoke C offers a decentralized insurance platform that utilizes hub 2's private blockchain. Notably, their platform runs independently regardless of the existence of hub 2's blockchain. For this reason, I put spoke C in the 2-layer-product group. Table IV illustrates the two categories in detail.

Following the last step, I thoroughly examined the two groups above to see if they behave differently in choosing a DLP to contribute to. In order to discover a prospective interaction effect, I created Table V to compare the average references and strengths of the two spoke groups in all five dimensions: barrier, governance, modularity, token, and security.

Interestingly, the proposed typology suggests a possible explanation for the questions raised earlier on the subject of the native cryptocurrency (token). In addition, it also reveals some plausible interpretations for the pluggable consensus mechanism (modularity) and the security of the DLP (security). For entry barrier and governance factors, the 1-layer-product and 2-layer-product spokes show similar results. That means the spokes' motives with respect to those two factors do not change regardless of the number of layers that their products have.

TABLE V
EVALUATION OF INTERVIEW FRAGMENTS, CLUSTERED ACCORDING TO THE NUMBER OF LAYERS IN THE PRODUCTS OF SPOKES (AVERAGE NUMBER OF REFERENCES/AVERAGE LEVEL OF SIGNIFICANCE AND DIRECTION)

	Modularity	Token	Security	Barrier	Governance
Average	**1.8/0.87**	**2.3/-0.2**	**2.5/1.3**	**1.8/-0,8**	**2.0/1.26**
1 Layer	1.6/0.5	2.2/0.8	4.4/2	1.6/-0.6	2.6/1.32
2 Layers	2.0/1.23	2.4/-1.2	0.6/0.6	2.0/-1.0	1.4/1.2

The 1-layer-product spokes' decision to join a blockchain is, in fact, influenced by the native token feature of that DLP. It was mentioned 2.2 times and has the score near to 1 (in average 0.8). In contrast, the 2-layer-product spokes do not want to join a DLP designed with a native token. The factor was mentioned 2.4 times and has a negative score of -1.2 in average.

In a less extreme magnitude, the influence of the security level significantly increases as the number of layers of that spoke's products decreases. Noticeably, the strength of this factor raises from only 0.6 to the maximum of 2. Similarly, the average references also increase more than seven times, from 0.6 to 4.4. To a spoke that built its products on a public DLP, the security of a blockchain is, in fact, the most important and significant factor with the highest scores so far.

Appraising the pluggable consensus mechanism feature, the empirical analysis shows that the influence of this modularity factor increases as the number of product layer that a spoke offers increases, i.e. from 1.6 to 2 in references per interview and from 0.5 to 1.23 in the strength score.

Inspired by these observations, I refined the framework in the next subsection by proposing three new propositions.

2) Framework Refinement

The interaction effect between the number of products' layers and pluggable consensus mechanism factor: the initial case analysis partially revealed that a pluggable consensus mechanism influences the DLP choice of spokes. Notably, the later analysis showed that the number of layers that a spoke's product has altered the intensity with which the pluggable mechanism was seen as advantageous by the complementors. For some spokes, the modularity-related feature does not affect their platform choice at all, whereas for the others it plays a big role in their decision-making process. This could be elucidated by the fact that if a spoke operates in a public DLP, they focus more on the application layer. The fabric layer, which incorporates the consensus mechanism, is not maintained by them. Hence, their platform preference is not affected by this feature. By contrast, a private blockchain-oriented spoke has to develop both fabric and application layers. A modular consensus mechanism, thus, provides them with additional flexibility to construct their core platform attributes. As a result, this type of spokes considers the factor as a decision criterion when choosing the DLP.

This observation is exemplified by the case of spoke E. The company uses primarily permissioned blockchains for writing applications. According to E's global head of blockchain, the technology is changing so fast with new innovation being built on top of another new innovation every day. They have to make sure that "if one piece of the technology gets obsolete, they can replace it very quickly by the other one" (Global head of blockchain of spoke E). Additionally, he also prefers a modular architecture for the other aspects of the platform, namely the way one manages accounts, or the way data is encrypted. Modularity, in general, and the pluggable consensus mechanism particularly represent one of the most essential decision criteria for spoke E. Likewise, the head of blockchain department in spoke A, a professional services firm that builds their solutions leveraging private DLPs, commented: "and if I have freedom in the choice of my consensus, then, of course, I would prefer a platform that lets me have a pluggable consensus." In opposition to that, spoke D, which offers currency issuance services in a public blockchain, does not see this as a compelling feature in their platform consideration. Taken all together, this leads me to the following proposition: *Proposition 2a: The higher the number of layers that the products of a spoke have, the stronger is the proposed positive effect of the pluggable consensus mechanism on the spoke's motivation to join and exert efforts to the hub's DLP.*

TABLE IV
THE NUMBER OF LAYERS IN THE PRODUCTS OF EACH SPOKE

1 Layer	2 Layers
Spoke B	Spoke A
Spoke D	Spoke C
Spoke G	Spoke E
Spoke H	Spoke F
Spoke I	Spoke K

The interaction effect between the number of products' layers and the native cryptocurrency factor: the empirical analysis did show great variance in how the spokes perceived the value of a native token in their participation decision. Strikingly, the typology of spokes has shed some lights in explaining this difference among spokes' motivations. On the one hand, the permissioned blockchain-oriented spokes often see tokens as a burden rather than a motivation. On the other hand, the token is one of the primary reasons for many public blockchain-oriented spokes when choosing a blockchain. Thus, this finding suggests that the native cryptocurrency is not a motive for spokes to join a DLP per se, but rather in combination with the public or private character of the product that spokes offer. The cases of spoke B and spoke G versus spoke E and spoke K illustrate this relationship.

Spoke B is building a marketplace on top of hub 2's public DLP. The cryptocurrency, in fact, enabled them to raised fund, to build their own token, and to have a currency for trading

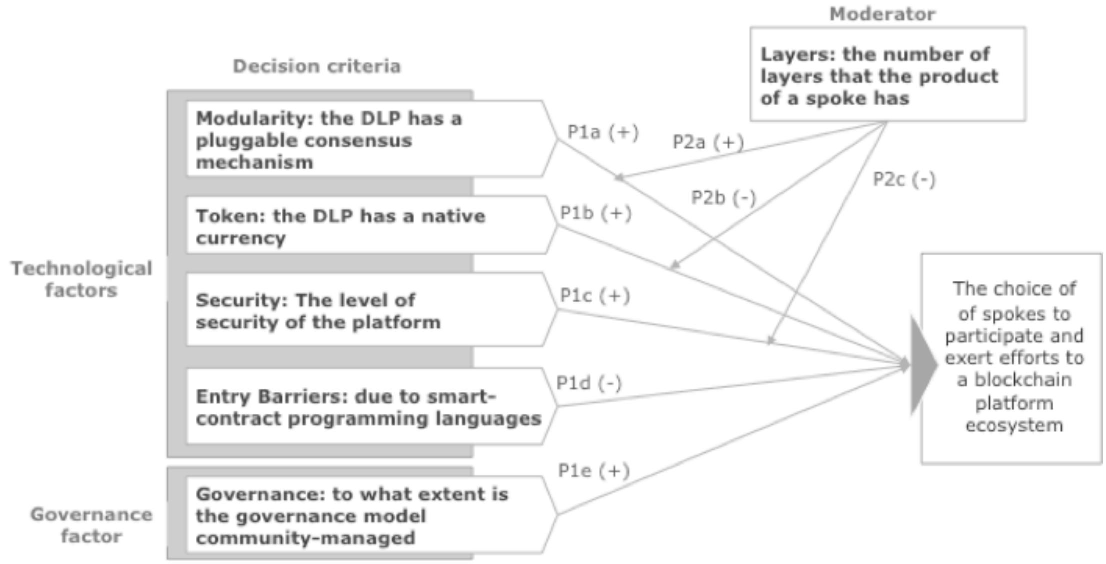

Fig. 3. A refined explanatory model of spokes' decision criteria to participate and exert efforts to a blockchain platform ecosystem

activities in their marketplace. The native cryptocurrency is clearly an important decision criterion for spoke B when joining hub 2. Similarly, spoke G's platform for issuance and administration of financial instruments is built on top of a permissionless blockchain. The CEO of spoke G considers native token as the only way to incentivize a public blockchain network to reach consensus. Answered to the question of whether the native token is a primary reason for his company to join a DLP, he stressed: "Yes. 100 percent. 100 percent!"

By way of contrast, for spokes utilizing private blockchains such as spoke E or spoke K, native currency is a pain point that threatens their customers. Especially from a tax and accounting point of view, the native currency is actually an obstacle because it is not treated as a currency in almost current accounting standards, said the global head of blockchain of spoke E. Equally, the CEO of spoke K, a company that builds a platform for administrating financial products leveraging permissioned blockchain, sees native cryptocurrency as a hurdle rather than a good feature for their customers in the corporate world. In line with the empirical findings, the following refined proposition is put forth: *Proposition 2b: The lower the number of layers that the products of a spoke have, the stronger is the proposed positive effect of the native cryptocurrency on the spoke's motivation to join and exert efforts to the hub's DLP.*

The interaction effect between the number of products' layers and the DLP's security factor: the empirical data revealed that the extent to which the security level of a DLP influences a spoke's platform choice varies across the sample cases. In fact, the spokes with one-layer-products evaluated the security and immutability of a DLP as the most innovative aspect of blockchain technology. Their participation decision is, therefore, heavily dependent on how secure a DLP is. This could be explained by the fact that if a spoke provides a cryptocurrency trading platform on a public blockchain, their whole business model, or even their whole assets are extremely dependent on the security of that DLP. Dissimilarly, other spokes' decisions are only partially affected by the security factor, when their products are built in a private blockchain environment. This is because they can independently manage the fate of their products. That said, security is still beneficial for them and indeed influences their platform choice model.

As an exemplar, spoke B's business model relies heavily on the security level of hub 2's public blockchain, as they build a marketplace using hub 2's fabric layer as the base layer. Likewise, the CEO of spoke H, a startup that develops applications to secure organizational processes leveraging hub 1's public DLP, stated: "we find that hub 1's network is the most stable, and also the most reliable network in terms of immutability." The picture is slightly different for spoke E, which utilize hub 2's private DLP. The global head of blockchain mentioned: "in some instances, we do not have a very strong security and privacy environment, which does not matter. But in some instances, we do." Taking into account the empirical differences between the two groups of spokes, the following revised proposition is formulated: *Proposition 2b: The lower the number of layers that the products of a spoke have, the stronger is the proposed positive effect of the security level of the hub's DLP on the spoke's motivation to join and exert efforts to the hub's DLP.*

F. Summary of Findings

A comprehensive picture of the refined theoretical framework is presented above in Figure 3. On the whole, the empirical analysis suggests that the number of layers that the product of a spoke has can be the moderator that influences the strengths of three motives of spokes to join a DLP: the pluggable consensus mechanism, the native cryptocurrency, and the security of a DLP. On the one hand, when the number of layers of a spoke's products decreases, the positive effects of a DLP's security become remarkably stronger, whereas the impact of a hub's native token feature moves from a negative to a positive effect. The moderator, hence, has a negative consequence on token and security features (P2b and P2c). On the other hand, the strength of the modularity factor slightly increases when the number of layers of a spoke's products shifts from one to two.

VI. Discussion

This section initially points out the contributions of this paper to the current literature. Subsequently, some recommendations for the management practices are discussed. Eventually, some limitations of this study and suggestions for future research are presented.

A. Theoretical Contribution

The empirical insights regarding the DLP choice of spokes lead to three key contributions to the existing literature. First of all, this paper contributes to the general platform ecosystem literature. Previous studies normally focus on long-established industries such as mobile operating systems, social networks, internet browsers, and video gaming (Gawer & Cusumano, 2012, 2014). Yet, little attention has been paid to blockchain platform ecosystems.

Secondly, researchers in the topic of software developers' motivations in OSS projects have been taken an intrinsic-extrinsic motives perspective in understanding why developers join and participate in an OSS. My paper focuses more on the technology and governance perspective in exploring the decision criteria of companies in choosing a DLP, thus it specifically draws a clearer picture of how spokes perceive different architectural and governance models in evaluating various DLPs. Although some analyzed motives are more specific for a blockchain DLP, some determinants show similarities with previous literature. The former includes the native cryptocurrency and the security of the DLP. The latter consists of the entry barrier related to the programming languages, and the community-managed governance model (Koch & Kerschbaum, 2014; Puvvala et al., 2016). In addition, although modularity is an important subject in the software platform field, no study has treated it as a motivation to participate in a platform ecosystem. The empirical findings of this study have revealed that modularity is, in fact, an important motive for spokes in blockchain industry. This result might be generalized to other immature technologies, in which innovation management is a major task.

Lastly, in contributing to the distributed ledger literature, this study has shown the heterogeneity in the behaviors of permissioned-blockchain-oriented and permissionless-blockchain-oriented complementors. Hence, it helps to form the ontology of public and private blockchains in a more transparent picture.

B. Management Implications

The findings of this study have several managerial implications for blockchain platform managers, who aim to attract spokes to innovate on their ecosystem. In particular, hubs should try to sustain the immutability of the network in any case. Even when there are potential technical conflicts, the final decisions should be made democratically. The recent hardforks of hub 2 are big lessons for other hubs in the blockchain industry. The empirical findings showed that it is extremely important for spokes that the blockchain is immutable and therefore secure. Any endogenous or exogenous attempts to change what have been written to the blockchain could be considered as a danger to the immutability of the blockchain. An endogenous endeavor could be a 51% attack (an attacker controls 51% hashing power in a PoW based blockchain), or a group of developers that openly attempts to change the blockchain into a direction that benefits them individually. Accordingly, hubs are advised to follow a community-managed governance model to strictly preserve the immutability of their blockchain. By contrast, an exogenous attempt, which normally comes from external parties, could be a denial-of-service attack. Hubs are, thus, recommended to let their DLPs be battle tested in order to increase the spokes' confidence in the security of their blockchains. One possible way to do this is to build a permissionless blockchain with a built-in token for battle testing, and a private blockchain with a similar technology stack in parallel.

C. Limitations and Future Research

This research has several limitations that have to be considered when readers interpret the results. First of all, the use of cross-sectional data limits the ability to thoroughly observe of the unit of analysis, which is the spokes' decision to participate and exert efforts to a DLP. Given the immaturity of blockchain technology as well as the analyzed spokes, it will be very interesting for future research to explore how the spokes' contributions to their chosen DLPs change through time, or if they later exit one DLP and join another DLP like in the case of spoke G. Hence, a longitudinal study could be conducted to see how the spokes' behaviors develop in a wider time frame. With a richer data set, another viable next step could be to run a quantitative test for the developed explanatory model.

Coming in secondly, the data set of this study is limited to three blockchain ecosystems. Although the three chosen hubs cover a large proportion in the blockchain industry, incorporating other blockchain's niche players could richen the data set and enhance the confidence of the results. Moreover, diligence was ensured throughout the whole research, yet the analysis of data could be biased as there was only one researcher in this research. Further research could have more investigators with various responsibilities to improve the rigor of the study. Additionally, even though it is suitable for the purpose of this study to have more cases and fewer knowledge experts for collecting data, this approach might enlarge the risk of key informant bias (Kurma, Stern, & Anderson, 1993).

Thirdly, this study only observes one group of spokes: the companies that contribute to a DLP. There is still one major group of contributors, which consists of individual application developers, that also plays an important role in open source projects generally. Being different from the for-profit corporations in the sample of this study, individual developers have stronger enjoyment-based intrinsic motives, which are not related to financial gains (Koch & Kerschbaum, 2014; K. Lakhani & Wolf, 2003). They are also sometimes driven by community ideology, which includes specific norms, beliefs, and values (Stewart & Gosain, 2006). Therefore, further research could study the participation decision and contributions of individual contributors, thereby draws a complete picture with two major categories of complementors in an open source project.

As a final point, moving away from the spokes and hubs relationship, a fruitful avenue for future study would be to conceptualize the permissioned and permissionless DLP to provide researchers with an in-depth knowledge of blockchain architecture.

VII. Conclusion

The goal of this study is to explore the technology and governance-related factors of a DLP that influence companies to join a DLP ecosystem, and lead them to exert efforts in that respective DLP. After a literature review and collecting some facts regarding the currently renowned blockchains, a spoke's DLP choice model was formulated. The model proposed five decision criteria, which are related to the architectural design and governance model of a DLP. Moreover, when being combined with these five criteria, the fact that whether a firm builds their products mainly on a public or private blockchain could also influence the motives of the spokes to join and contribute to a DLP. In order to test these hypotheses, I utilized a multiple-case study approach, in which qualitative data is collected and rigorously analyzed from 12 spoke companies and 1 blockchain hub organization.

The results of the analysis confirm that spokes are motivated to join and contribute to a DLP ecosystem caused by (1) the pluggable consensus algorithm feature of a DLP, (2) the native cryptocurrency of a DLP, (3) the security level of a DLP, (4) the low entry barrier with regard to the programming languages of the smart contract in that DLP, and (5) the degree of which a DLP governance model is community-managed. Furthermore, this study introduced an ontology that classifies complementors according to whether the spokes build their products in a permissioned or permissionless DLP. Precisely, when a spoke offers products based on a public blockchain, its products have one layer. When a complementor offers products utilizing a private blockchain, its products have two layers. As to the empirical findings, the strength of the last two motives (4) and (5) are not affected by the number of layers that a spoke's product has. However, the empirical results revealed that this product layer-related factor, in fact, moderates the strengths of three motives of spokes to join a DLP: (1) the pluggable consensus algorithm, (3) the native token, and (3) the security of a blockchain.

The findings of this paper enhance the understanding of how two types of spokes perceive different architectural and governance models in evaluating various DLPs. Hence, the decision makers of hubs can rely on the developed framework of this paper to guide their platform architecture design and governance model to attract external complementors.

References

[1] Amabile, T. M., Conti, R., Coon, H., Lazenby, J., & Herron, M. (1996). Assessing the Work Environment for Creativity. *Academy of Management*, *39*(5), 1154–1184.

[2] Anvaari, M., & Jansen, S. (2010). Evaluating Architectural Openness in Mobile Software Platforms. *4th European Conference of Software Architecture*, 85–92. https://doi.org/10.1145/1842752.1842775

[3] Arndt, J., & Dibbern, J. (2006). Co-Innovation in a Service Oriented Strategic Network. In *2006 IEEE International Conference on Services Computing (SCC'06)* (pp. 285–288). IEEE. https://doi.org/10.1109/SCC.2006.32

[4] Back, A., Corallo, M., Dashjr, L., Friedenbach, M., Maxwell, G., Miller, A., Poelstra, A., Timón, J., Wuille, P. (2014). Enabling Blockchain Innovations with Pegged Sidechains. *Blockstream*.

[5] Brown, R. G. (2016). Introducing R3 Corda™: A Distributed Ledger Designed for Financial Services. Retrieved from http://r3cev.com/blog/2016/4/4/introducing-r3-corda-a-distributed-ledger-designed-for-financial-services

[6] Buterin, V. (2013). Ethereum White Paper. Retrieved from https://github.com/ethereum/wiki/wiki/White-Paper

[7] Buterin, V. (2015). On Public and Private Blockchain. Retrieved from https://blog.ethereum.org/2015/08/07/on-public-and-private-blockchains/

[8] Buterin, V. (2016). *Ethereum: Platform Review*. Retrieved from r3cev.com/s/Ethereum_Paper-97k4.pdf

[9] Buterin, V. (2017). The meaning of decentralization. *Medium.com*. Retrieved from https://medium.com/@VitalikButerin/the-meaning-of-decentralization-a0c92b76a274#.e44sblqsj

[10] Cachin, C. (2016). Architecture of the Hyperledger Blockchain Fabric *.

[11] Chesbrough, H., Vanhaverbeke, W., & West, J. (2006). *Open Innovation: Researching a New Paradigm*. *Oxford University Press on Demand*. https://doi.org/10.1111/j.1467-8691.2008.00502.x

[12] Chesbrough, H. W. (2003). *Open Innovation: The New Imperative for Creating and Profiting from Technology*.

[13] Csikszentmihalyi, M. (1990). Literacy and Intrinsic Motivation. *Daedalus*, *119*(2), 115–140.

[14] Dion, D. A. (2013). I'll gladly trade you two bits on Tuesday for a byte today: Bitcoin, regulating fraud in the e-conomy of hacker-cash. *U. Ill. J.L. Tech. & Pol'y*, *1*, 165.

[15] Dube, L., & Pare, G. (2003). Rigor in Information Systems Positivist Case Research: Current Practices, Trends, and Recommendations. *MIS Quarterly*, *27*(4), 597–636. Retrieved from http://www.jstor.org/stable/30036550

[16] Eisenhardt, K. M. (1989). Building Theories from Case Study Research. *C Academy of Management Review*, *14*(4), 532–550. Retrieved from http://www.jstor.org/stable/258557

[17] Ethiraj, S. K., & Levinthal, D. (2004). Modularity and Innovation in Complex Systems. *Management Science*, *50*(2), 159–173. https://doi.org/10.1287/mnsc.1030.0145

[18] Evans, D. S. (2014). Economic Aspects of Bitcoin and Other Decentralized Public-Ledger Currency Platforms. *University of Chicago Coase-Sandor Institute for Law & Economics Research Paper*, *685*. Retrieved from http://www.law.uchicago.edu/Lawecon/index.html

[19] Gawer, A., & Cusumano, M. A. (2012). How companies become platform leaders. *MIT/Sloan Management Review*, *49*(2), 28–35. https://doi.org/Article

[20] Gawer, A., & Cusumano, M. A. (2014). Industry Platforms and Ecosystem Innovation. *Journal of Product Innovation Management*, *31*(3), 417–433. https://doi.org/10.1111/jpim.12105

[21] Glaser, F. (2016). *Pervasive Decentralisation of Digital Infrastructures : A Framework for Blockchain enabled System and Use Case Analysis*.

[22] Gray, M. (2016). Bletchley Whitepaper. Retrieved from https://github.com/Azure/azure-blockchain-projects/blob/master/bletchley/Bletchley-Whitepaper.pdf

[23] Hars, A., & Ou, S. (2002). Working for free? Motivations of participating in open source projects. *International Journal of Electronic Commerce*, *6*(3), 25–39. https://doi.org/10.1109/HICSS.2001.927045

[24] Hertel, G., Niedner, S., & Herrmann, S. (2003). Motivation of software developers in open source projects: An Internet-based survey of contributors to the Linux kernel. *Research Policy*, *32*(7), 1159–1177. https://doi.org/10.1016/S0048-7333(03)00047-7

[25] Hilkert, D., Benlian, A., & Hess, T. (2010). Motivational Drivers to Develop Apps for Social Software-Platforms : The Example of Facebook. *Americas Conference on Information Systems (AMCIS)*, 86. Retrieved from http://aisel.aisnet.org/amcis2010/86/

[26] Kiviat, T. I. (2015). Beyond Bitcoin: Issues in Regulating Blockchain Transactions. *Duke Law Journal*, *65*(3), 569–608. https://doi.org/10.1525/sp.2007.54.1.23.

[27] Koch, S., & Kerschbaum, M. (2014). Joining a smartphone ecosystem: Application developers' motivations and decision criteria. *Information and Software Technology*, *56*(11), 1423–1435. https://doi.org/10.1016/j.infsof.2014.03.010

[28] Kude, T., Dibbern, J., & Heinzl, A. (2012). Why Do Complementors Participate? An Analysis of Partnership Networks in the Enterprise Software Industry. *IEEE Transactions on Engineering Management*, *59*(2), 250–265. https://doi.org/10.1109/TEM.2011.2111421

[29] Kurma, N., Stern, L. W., & Anderson, J. C. (1993). Conducting Interorganizational Research Using Key Informants. *The Academy of Management Journal*, *36*(6), 1633–1651.

[30] Lakhani, K. R., & Hippel, E. Von. (2003). How open source software works : " free " user-to-user assistance. *Research Policy*, *32*(July 2002), 923–943.

[31] Lakhani, K., & Wolf, R. G. (2003). Why Hackers Do What They Do: Understanding Motivation and Effort in Free/Open Source Software Projects, (September). https://doi.org/10.2139/ssrn.443040

[32] Lee, A. S., & Hall, H. (1989). A Scientific Methodology for MIS Case Studies. *Source: MIS Quarterly*, *13*(1), 33–50. Retrieved from http://www.jstor.org/stable/248698

[33] Luu, L., Teutsch, J., Kulkarni, R., & Saxena, P. (2015). Demystifying Incentives in the Consensus Computer. In *Proceedings of the 22nd ACM SIGSAC Conference on Computer and Communications Security* (pp. 707–719). https://doi.org/10.1145/2810103.2813659

[34] Lyytinen, K., Yoo, Y., & Boland Jr., R. J. (2016). Digital product innovation within four classes of innovation networks. *Information Systems Journal*, *26*(1), 47–75. https://doi.org/10.1111/isj.12093

[35] Mainelli, M., & von Gunten, C. (2014). Chain Of A Lifetime : How Blockchain Technology Might Transform Personal Insurance. *Long Finance*, (December).

[36] Miles, M. B., & Huberman, A. M. (1994). Qualitative data analysis: A sourcebook. *Beverly Hills: Sage Publications*.

[37] Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System. Retrieved from www.bitcoin.org

[38] Nguyen, D. M. (2016). A literature review on innovation stimulation in platform ecosystems with a special case of blockchain. https://doi.org/10.1002/ejoc.201200111

[39] O'Mahony, S. (2007). The governance of open source initiatives: What does it mean to be community managed? *Journal of Management and Governance*, *11*(2), 139–150. https://doi.org/10.1007/s10997-007-9024-7

[40] Plassaras, N. A. (2013). Regulating Digital Currencies: Bringing Bitcoin within the Reach of the IMF. *Chicago Journal of International Law*, *14*(1), 377–407. https://doi.org/10.1525/sp.2007.54.1.23.

[41] Puvvala, A., Dutta, A., Roy, R., & Seetharaman, P. (2016). Mobile application developers' platform choice model. In *Proceedings of the Annual Hawaii International Conference on System Sciences* (pp. 5721–5730). https://doi.org/10.1109/HICSS.2016.707

[42] Roberts, J. a., Hann, I.-H., & Slaughter, S. a. (2006). Understanding the Motivations, Participation, and Performance of Open Source Software Developers: A Longitudinal Study of the Apache Projects. *Management Science*, *52*(7), 984–999. https://doi.org/10.1287/mnsc.1060.0554

[43] Ryan, R. M., & Deci, E. L. (2000). Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. *Contemporary Educational Psychology*, *25*(1), 54–67. https://doi.org/10.1006/ceps.1999.1020

[44] Sanchez, R., & Mahoney, J. T. (1996). Modularity, Flexibility, and Knowledge Management in Product and Organization Design. *Strategic Management Journal*, *17*, 63–76. Retrieved from http://www.jstor.org/stable/2486991

[45] Stewart, K. J., & Gosain, S. (2006). The Impact of Ideology on Effectiveness in Open Source Software Development Teams. *MIS Quarterly*, *30*(2), 291–314.

[46] Vukoli, M. (2015). The quest for scalable blockchain fabric: Proof-of-work vs. BFT replication. In *International Workshop on Open Problems in Network Security* (pp. 112–125). Springer International Publishing. https://doi.org/10.1007/978-3-319-39028-4_9

[47] Weber, B. (2015). Bitcoin and the legitimacy crisis of money. *Cambridge Journal of Economics*, *40*(1), 17–41. https://doi.org/10.1093/cje/beu067

[48] Yin, R. K. (2009). *Case Study Research: Design and Methods*. Sage publications.

[49] Yoo, Y., Henfridsson, O., & Lyytinen, K. (2010). The new organizing logic of digital innovation: An agenda for information systems research. *Information Systems Research*, *21*(4), 724–735. https://doi.org/10.1287/isre.1100.0322

[50] Zyskind, G., Nathan, O., & Pentland, A. S. (2015). Decentralizing privacy: Using blockchain to protect personal data. *Proceedings - 2015 IEEE Security and Privacy Workshops, SPW 2015*, 180–184. https://doi.org/10.1109/SPW.2015.27