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A Case Study of a Shared Platform with Blockchain Technology

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Abstract

Product-centric information management is a key concept in understanding the interoperability between increasingly intelligent and autonomous goods in distributed computing architectures. In the same way as consumers are an important source of data in contemporary platforms, products — especially durable and capital goods — can be considered equally valuable for industries that have not yet been platformatized. By exploiting a blockchain technology approach, this paper makes an effort to combine product-centric information management with platform literature in order to understand possible development trajectories for multi-sided platforms, across industry sectors.

Through a novel perspective, this paper offers new insights into product-centric information management and shows that blockchain technology can have interesting and useful applications in the architectural design of industrial platforms. The paper concludes with some managerial implications about the nature of multi-sided markets for durable and capital goods. Furthermore, some policy implications are presented regarding the free flowing of information, as well as the role of the public authority in fostering platform development.

Though the examination of an inductive case study, this paper aims to provide a clearer understanding on the ambiguous phenomenon of blockchain technology. The formulation of this particular case study will also assist other scholars in presenting their respective use cases in later studies. Furthermore, the presented case study will also prepare scholars for the complexities that companies face when designing blockchain-based applications and architectures.

This paper suggests that understanding blockchain technology is essential when considering the implementation of the product-centric information management approach in practice. The inductive case study herein provides some bottom-up evidence suggesting that companies operating in the markets for durable and capital goods could build multi-sided platforms as a response to the prevalent consumer-centric platform trajectory. For practitioners, our detailed argumentation suggest that companies should consider use cases very carefully to determine which technology generates the broadest network effects in each particular situation.

Keywords – Product-centric Information Management, Intelligent Products, Product Life Cycle Management, Platforms, Multi-sided Markets, Blockchain Technology

1 Introduction

At present, digitalization and the development trajectory of consumer-centric platforms are challenging the contemporary value chain structures across industries[1]. In addition, systemic digital innovations, such as blockchain technology, are disrupting existing organizations, institutions and the behavior of the markets at large[2]. By reconfiguring information asymmetries in industrial value chains, platforms and systemic digital innovations are repositioning the arrangements of competitive advantage. As a result, the entire competition environment in general has become a complicated, multi-sided struggle across industries and organizational boundaries.[3]

Over the life-cycles of durable and capital goods, many different parties need to use and update the product data related to the goods[4]. In many cases, it is a different party that creates the data from the party who needs to use it, and the party who could produce useful information often fails to do so. Currently, each party creates a partial copy of the product data suitable for their own needs. As a consequence, each party is also responsible for its own costs of creating the imperfect copy and for the failures resulting from inaccurate and obsolete product data.

To overcome this problem, the "product-centric" approach was devised. The idea of product-centric information management is that product data is not fragmented to several organizations over the life-cycle of the product but rather shared in a complete form between the organizations. Each product individual is represented by one matching information agent over its entire lifecycle. The agents can be distributed between organizations and do not reside in a single system.[5]

The product-centric approach is, however, constrained by an inherent lack of digital trust and multi-version concurrency control. As the product data is distributed between various organizations, there is a risk that the data becomes outdated or inaccurate. For example, how can

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[1] We define platforms as systems of systems that allow the various actors – users, providers and other actors across organizational boundaries – to engage in value-adding activities. Typical of the platforms is that the individual actors create, offer and maintain mutually complementary products and services for various distribution channels and markets within the framework of common ground rules and user experiences. A typical characteristic of a platform is to attract and lock in a range of actors keen to harness the economic benefits offered by indirect and direct network effects (Seppälä et. al., 2015). For further platforms literature, see Cusumano & Yoffie, 1998, Cusumano & Gawer, 2002; Gawer & Cusumano, 2002; Gawer & Hendersson, 2007; Gawer & Cusumano, 2008; Gawer, 2009; Cusumano, 2010; Kenney & Pon, 2011; Gawer & Cusumano, 2014; Pon et. al., 2014, 2015; Evans & Gawer, 2015; Kenney & Zysman, 2016; van Alstyne et. al., 2016.

[2] According to a recent industry state report, the venture capital funding of blockchain startups focusing on applications outside FinTech surpassed the funding of FinTech-focused blockchain startups. This, amongst, other things hints that the technology stack of blockchain-based applications is starting to reach maturity in other fields besides FinTech as well. Hileman and Lim, 2016.

[3] Rochet, & Tirole, 2003; Parker & van Alstyne, 2005; Rochet & Tirole, 2006; Amstrong, 2006; Hagiu, 2009; Hagiu & Spulber, 2012; Hagiu & Wright, 2012; Hagiu, 2014; Mattila & Seppälä, 2015; Kenney & Zysman, 2016; van Alstyne et. al., 2016.

[4] Rink & Swan, 1979; Anderson & Zeithaml, 1984; Aitken et. al., 2003; Kärkkäinen et. al., 2004.

[5] Kärkkäinen et. al., 2003a; Kärkkäinen et. al., 2003b; Kärkkäinen et. al., 2004; Främling et. al., 2007; Meyer et. al., 2009; Tiwana et. al., 2010.

an organization trust that the product data managed by another organization is correct and not to be corrupted or erased?

This paper contributes to a new understanding on design patterns for managing product life-cycle information through blockchain technology[6]. An effort is made to analyze how blockchain technology could be applied to overcome the digital trust and data-synchronization issues related to the product-centric information management architectures. Essentially, solving these issues would enable the creation of multi-sided platforms in industry for broader network effects[7]. Our key motivation to examine blockchain technology in this regard stems from its unique properties as a new way to produce and to coordinate distributed databases between a high number of participants[8].

The results of the qualitative case analysis show that blockchain technology could be a suitable architectural basis for a product-centric data management platform. It would significantly enhance the data transparency, data traceability and the verifiability of the product-centric information model, allowing different organizations to effectively trust each other's product data. By creating a distributed database of all the information agents, the participants of the value chain could produce the platform on an equal footing, without having to relinquish any value-capturing potential outside the value chain of the product. Moreover, this could significantly enhance the capabilities for product data collaboration, thus enabling additional complementarities and broader network effects between the parties involved.

Furthermore, emerging trends in blockchain technology suggest that it may even be possible for parties to jointly store and operate on each other's private product data while keeping the content of the data itself encrypted[9]. This could have implications for data governance in cases where the content of the data is restricted by agreements between the sharing organizations or any other third parties.

The paper proceeds as follows: Section two explains the methodology and describes the data. Section three elucidates the inadequacies of previous studies and outlines the research question. It also goes over the previous research on design patterns for managing product lifecycle information, and multi-sided platforms for product-centric data management. In section four, we present the empirical analysis on the applicability of the proposed use case, as well as the results of this analysis. The concluding section discusses some managerial and policy implications, and suggests further research opportunities.

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6 For introduction to blockchain technology and its applications, see Nakamoto, 2008; Mattila & Seppälä, 2015; Mattila, 2016.

7 Katz & Shapiro, 1994; Yoffie & Kwak, 2006; Dahlander & Wallin, 2006; Eisenmann et. al., 2008; Garcia-Swartz & Garcia-Vicente, 2015.

8 Ahluwalia, 2014; Mattila & Seppälä, 2015.

9 Zyskind et. al., 2015.

2 Methodological description

Qualitative research methods in general, and inductive case studies in particular, begin with detailed observations of the world, e.g. the blockchain technology trajectory. These detailed observations serve as a starting point for gaining more knowledge on the possibilities of blockchain technology. Evidently, inductive case studies have been used for a diverse array topics, such as technology management[10].

The research material for this study has been gathered from public sources which are then supplemented with 15 interviews and workshops with industry representatives as well as blockchain technology developers. The information presented in this paper is mostly based on those interviews and workshops with representatives from companies such as IBM, BitPay, Blockstream, Vaultoro, Colu and Bitreserve in Barcelona in October 2015; with representatives from Google, 21 Inc and Stellar in San Francisco in February 2016; with representatives from Eris Industries and Ascribe in Berlin in March 2016; and with representatives from Prasos Oy (Bittiraha.fi, Coinmotion, Denarium), Robin Hood Minor Asset Management Cooperative, Fortum Oyj and Euroclear Oy in Finland in March - May, 2016.

The paper then proceeds towards more abstract ideas, as presented in the sections 3.1 to 3.4. Through inductive reasoning, further empirical generalizations are then made on the applicability of blockchain technology as the architectural basis of shared platforms.

3 The gaps in previous studies and the research question

In the past, it has proven challenging to determine where the data accrued by products over their life cycles should in fact be located and stored. Without a shared platform for product data management, it can be difficult to resolve how the data should be accessed, updated and distributed between the parties of a supply chain. This served as a motivation for the creation of product-centric information management and the respective architectures.[11]

All types of goods – non-durable, durable, and capital alike – are becoming more intelligent and connected to the Internet through many different technologies. Enabled by these technologies, the participants of a supply chain currently store, access, update and distribute the data related to a particular product over its life cycle on their company-specific data management systems[12]. The technical foundation of intelligent goods is based on automatic identification and embedded processing, information storage, and an agent-based system[13].

[10] Eisenhardt, 1989; Yin, 2014; Eisenhardt & Greabner, 2008.
[11] Kärkkäinen et. al., 2003b; Främling et. al., 2007; Mayer et.al., 2009.
[12] Kärkkäinen et. al., 2003b; Främling et. al., 2007; Mayer, et. al., 2009.
[13] Mayer et. al, 2009.

The creation of platforms for non-durable goods has resulted in a restructuring of the current demand-supply network structures. Platforms have also reconfigured information asymmetries in existing industrial supply chains with centralized platform control (see figure 1)[14]. In doing so, platforms have effectively transferred the ownership of data from the consumers and the incumbent companies to the emerging platform companies. This has also led to new control mechanisms and coordination structures in consumer-centric industrial supply chains[15].

The division between two-sided and multi-sided platforms, is one of the key concepts in understanding the trend of consumer-centric platform development. Two-sided markets are roughly defined as markets in which one or several platforms mediate interactions between end-users and try to get the two sides to interact through the mediator's pipeline by appropriately charging each side[16].

Conversely, multi-sided markets enable direct interaction between multiple different markets sides, without those parties needing to go through the choke point pipeline of the mediator. Instead, the mediator simply monitors the trading between the market participants, and the revenue is split according to predetermined contract and business rules[17]. In platform literature, the implementation of boundary resources, such as these contract and business rules, has been recognized as an enabling feature for lower barriers of entry onto the platform[18]. This, in turn, encourages the development of complementarities and the fostering of broader network effects[19].

[14] Cusumano & Yoffie, 1998, Cusumano & Gawer, 2002; Gawer & Cusumano, 2002; Gawer & Hendersson, 2007; Gawer & Cusumano, 2008; Gawer, 2009; Kenney & Pon, 2011; Pon et. al., 2014, 2015; Evans & Gawer, 2015; Kenney & Zysman, 2016; van Alstyne et. al., 2016.

[15] van Alstyne et. al., 2016.

[16] For the definitions, see Rochet & Tirole, 2003; Rochet & Tirole, 2006; Hagiu, 2014; and van Alstyne et al., 2016.

[17] Rochet & Tirole, 2003; Rochet & Tirole, 2006; Gawer, 2009; Hagiu, 2014; and van Alstyne et al., 2016.

[18] Gawer, 2009; Ghazawneh & Henfridsson 2013.

[19] Gawer, 2009; Ghazawneh & Henfridsson 2013; Ghazawneh & Mansour, 2015; Garcia-Swartz & Garcia-Vicente, 2015.

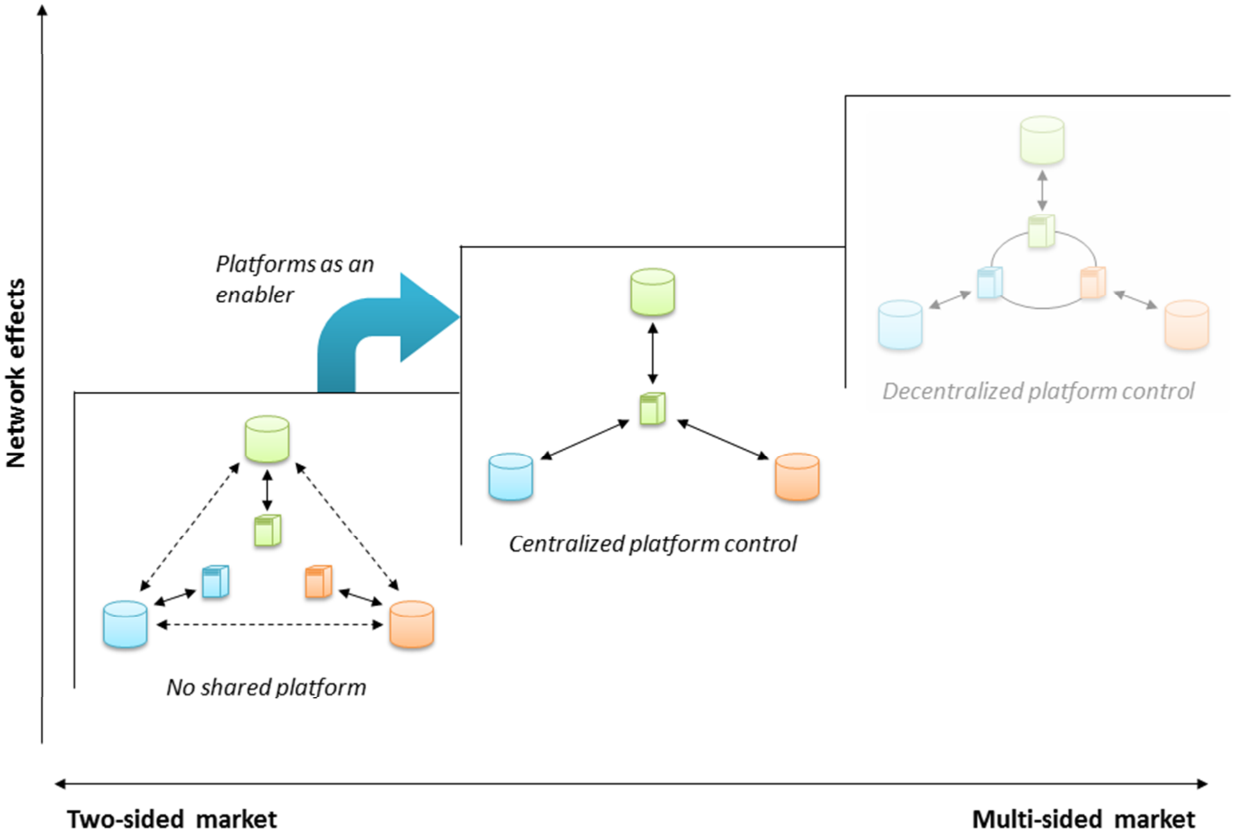

Figure 1. *Platforms as an enabler in the market for non-durable goods*

This paper is motivated by the shortcomings in platform literature regarding non-durable and capital goods in industrial supply chains. By utilizing a blockchain technology approach, the paper makes an effort to integrate product-centric information management with platforms literature. The objective herein is to understand the possible development trajectories of multi-sided markets in non-consumer-centric industry sectors. The paper focuses on the the following research question: *What are the implications of blockchain technology on the platform economy, and how can it be used to create multi-sided markets?*

Next, we outline three hierarchies for a product-centric information management platforms: 1) no shared platform (i.e. company-specific platforms); 2) a shared platform with centralized control; and 3) a shared platform with decentralized control.

3.1 Problems with the existing data infrastructure in supply chain

As a certain product item passes through the manufacturing chain, and further on to the end of its life cycle, the product data related to that product item needs to be accessed and updated by many different companies and individuals, constituting a heterogeneous group of different kinds of information systems and software platforms. The product data consists of information such as the design, the materials and the production and service history of the product throughout its life-cycle.

In the current arrangement, each party that comes in contact with a certain product item creates their own partial copy of the product data. Each party stores this data into their company-specific information systems, fulfilling their own informational needs. In many cases, however, the party that creates a piece of data is different from the parties who later on may develop a need to use that particular piece of data. Due to the disparity of the information systems and the informational asymmetries between companies, the party who in theory could provide another one with useful information often fails to do so.

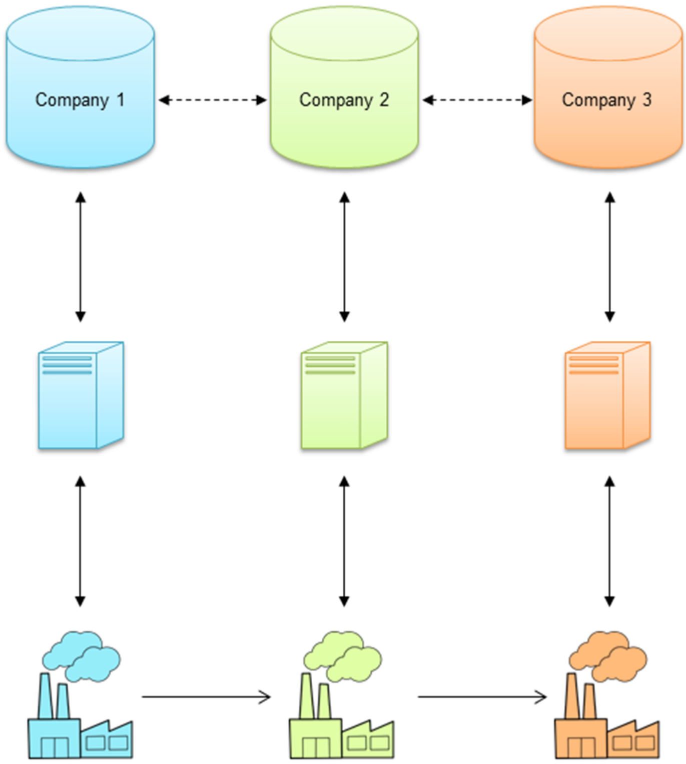

Figure 2. *In a situation where there is no shared platform for managing product information, information asymmetries are likely to occur over time.*

As each party maintains their own imperfect copy of the product data, failures may occur in the updating of the data. Therefore, not only is the required product data occasionally unavailable, but the data that is available may be obsolete or otherwise inaccurate. As a consequence, each party is responsible for its own costs of creating the imperfect copy and for the failures resulting from inaccurate and obsolete product data. Moreover, relaying information manually between companies can be unreliable, cumbersome, and expensive.

Quite obviously, this arrangement depicted above can easily lead to suboptimal results for the entire value-chain. For some value-chains, it may well be the case that all the parties coming in contact with a product item produce some product information which quickly becomes irrelevant to themselves but would be valuable to preserve from the perspective from another party in the value-chain. However, due to the information asymmetries involved, the parties end up destroying each other's information resources because its inherent value is not recognized.

3.2 The product-centric data approach

On a general level, product life-cycle management is becoming increasingly complex due to the growing demands for interoperability. In products, the role of software is constantly becoming more significant, as products entail an increasing amount of configurable software components. As a result of these developments, products are becoming more personalized – not only in the consumer market, but also in industry. This introduces new types of requirements for managing product information on the level of individual product items.

In response to these developments, the “product-centric” approach was devised. The idea of product-centric information management is that product data is not duplicated over the life-cycle of the product but rather shared between different organizations. Each product individual is represented by one matching information agent over its entire lifecycle. The agents can be distributed between organizations and do not reside in a single system. [20]

3.3 Individual platforms vs. shared platform architecture

One can pose the question how the platform architecture for a product-centric data management system should be arranged. One possibility is that each company (or consortium) constructs their own platform, each one with its own internal database. The databases of all the various platforms would then be connected through assorted API solutions. Another option would be to construct one shared product-centric data management platform with one shared database.

While the first method is certainly easier to employ in practice, there are two reasons why multiple disparate platforms are not an optimal solution for product-centric data management on industry-wide and cross-industry levels.

The first reason has to do with the challenges of interoperability. If the architecture of the product-centric data management systems at large were to consist of countless such company- or consortium-level platforms, the interoperability between all these platforms bubbling into and out of existence would be problematic from the standpoint of seamless large-scale functionality.[21] The "API spaghetti" would have to be constantly maintained and updated, and even in the case that a suitable API solution existed for a particular required connection, it could be very time-consuming and difficult to even find it in the first place, not to mention harnessing it for use.

Conversely, if a small number of such product-centric data management platforms managed to foster enough network effects to grow into universal hubs for product-centric data, such centralized solutions could easily be turned into vertical silos. Herein lies the other reason. A company in control of a platform could intentionally reduce its interoperability with other platforms in order to enforce a stronger customer lock-in to its own domain of products and

[20] Främling et. al., 2007.
[21] Filament 2015.

services. While this might be good for the platform provider as a company, from the perspective of the life cycle of individual products, this would be a drastically sub-optimal solution.

Based on these reflections, it can be stated that, from the standpoint of industries and cross-industrial collaboration, a product-centric data management system should, where possible, be constructed as a shared platform rather than a network of multiple individual company-based platforms.

3.4 Centralized vs. decentralized platform control

Due to the recent innovations in distributed consensus algorithms, a shared platform for product-centric data management can either be built so that the control over the platform is centralized to one platform provider, or in such a way that the control is decentralized to a large number of equipotent participants.[22]

A centrally controlled platform design would entail a system where the data is stored in a server or a cloud which is controlled by one company operating as the platform provider. A small number of trusted parties can also be included in the group of controllers, but essentially, the control over the platform is unequally distributed between the participating companies.

While a centrally controlled platform design is undoubtedly the easier one of the two options to construct and to popularize, it has some non-trivial drawbacks. Companies are usually reluctant to submit into operating within technical frameworks that are controlled by other companies. This is due to the fact that getting locked into someone else's platform usually means becoming the underdog in terms of value capturing potential. Therefore, in many cases, companies would rather create their own company-specific systems despite of their sub-optimal performance.[23] The reluctance to submit may partially explain why successful product-centric data platforms have not yet been witnessed to emerge.

The product-data management platform can be offered by one of the companies in the value chain, but it can also be provided by a trusted intermediator who is not a participant in the actual value-chain of the product items in question. While this way the participants remained on an equal footing relative to each other, overall they would lose some of their value-capturing potential because the control over the platform would be relinquished completely outside the value chain of the product.

[22] The terminology used here is not to be confused with centralized and decentralized network architectures in platforms. While it has been possible to construct platforms with a decentralized cloud structure before, their control also, by necessity, has so far been centralized, either to one platform provider or a very small circle of trusted operators.

[23] Mattila-Seppälä 2015; Seppälä-Mattila 2016.

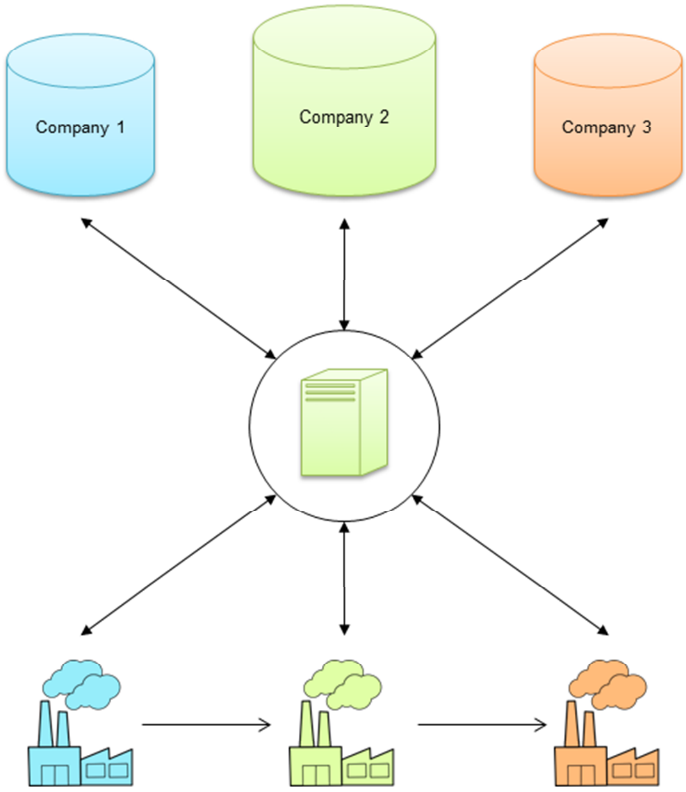

Figure 3. *In a situation where the control of the platform is centralized, companies not in control of the platform become the underdogs in value capturing potential*

Conversely, a decentralized design would be built on top of a fully distributed technology stack based on blockchain technology. Such a platform design would operate in a cluster of company servers or a distributed cloud without the need for any central authority to act as the platform provider. In such a design, the participants of the value chain all remain on an equal footing, but without having to relinquish any of their value-capturing potential outside the value chain of the product.

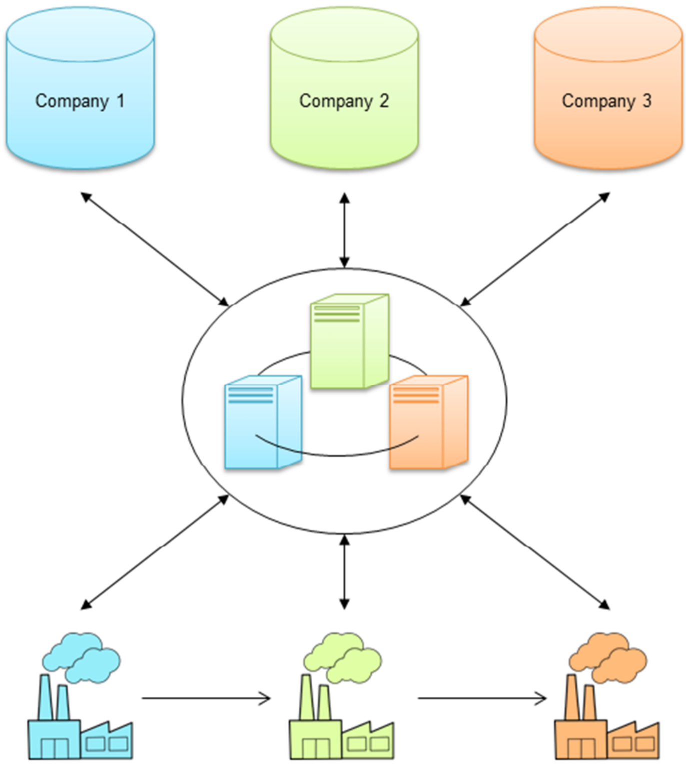

Figure 4. *In a situation where the control of the platform is decentralized, the platform is produced by all the parties together as equally privileged and equipotent participants.*

4. Empirical analysis, and results

4.1 Why blockchain technology?

Blockchain technology enables the creation of single version databases in a completely distributed manner. Despite having multiple writers who simultaneously modify a database in ways which might overlap, the network is able to maintain uniform consensus regarding the content of the database. Due to the cryptographic data structure and some refined consensus algorithms that blockchain technology entails, the consensus can be maintained without any central authority exercising multi-version concurrency control over the network. Instead, all the participants are equipotent and equally privileged, and the operational principles of the database are mutually decided.

In other words, instead of a central authority keeping everything in sync and dictating the modification history of the database, with blockchain technology every participant gets a say in what they think the true course of events has been. It is a new way of organizing and managing databases in a leaderless democracy of devices, algorithmically incentivized to work together for one shared consensus view.

Our key motivation for analyzing blockchain technology as a candidate for product-centric information management is that, because of these unique characteristics, it enables a transition from centrally controlled platforms to decentralized platform control. By allowing the democratization of platforms in terms of features such as access and boundary resources, blockchain technology emancipates companies from the platform dominance game. As explained before, this dominance game and the reluctance to submit may be holding back the emergence of shared platforms between companies and wider-range cross-industrial collaboration.

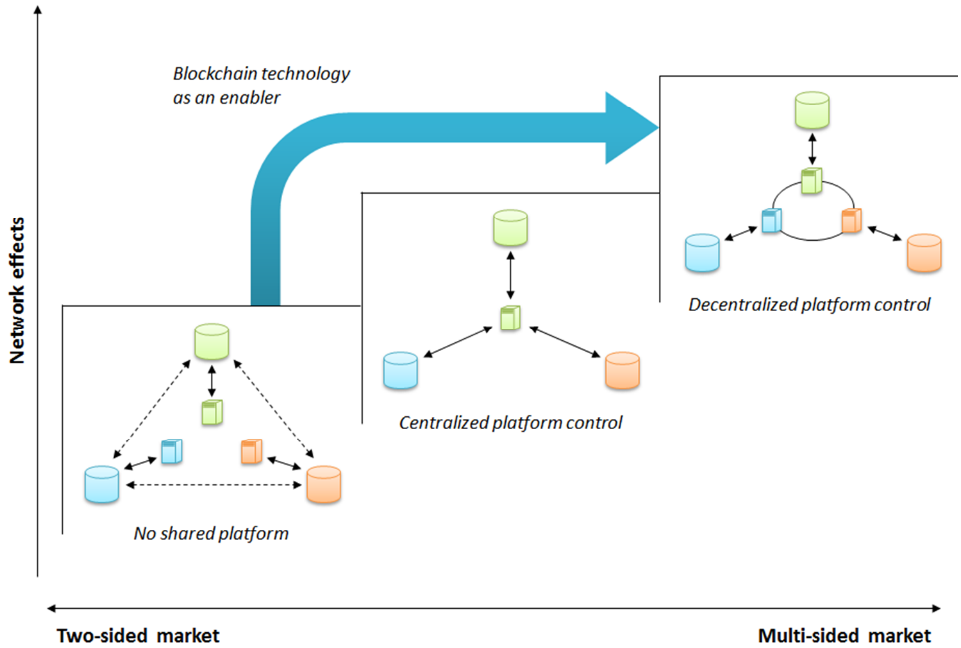

Figure 5. *Blockchain technology as an enabler in the markets for durable and capital goods*

4.2 The suitability of blockchain technology for product-centric data management

The fact that blockchain technology *can* be used to create a distributed platform for product-centric data management does not automatically mean that it is a good idea to do so. Certain conditions have been identified in industry discussions which need to be met in order for it to make sense to utilize blockchain technology for any particular purpose.[24] Moreover, these criteria have been further verified in our personal interviews with blockchain technology developers around the world.[25]

4.2.1 A database shared by multiple parties

The first requirement for the sensibility of a potential blockchain use case is that it entails an inherent need for a database to be shared between many parties. This is due to the fact that blockchain technology is by definition based on peer-to-peer network structure, and therefore it has no applicability whatsoever in a centralized database structure.

[24] Greenspan, 2015; Greenspan, 2016.
[25] See chapter 2.

In our proposed use case of a product-centric data management platform, we find that this condition is met because a database with a centralized structure would also by necessity have centralized control. As established earlier in this paper, platforms with centralized control create asymmetric configurations of competitive advantage in the supply chain. This, in turn, makes participation unattractive for the non-controlling parties, which renders such centralized platforms difficult to establish in practice.

4.2.2 Enabling multiple concurrent writers

An important question in determining whether it makes sense to resort to blockchain technology for a shared database is to ask how many parties need to be able to make modifications into the database at the same time. If no concurrent modifications are needed, there is little point in utilizing a blockchain architecture, as in such a case a centralized database or a regular file-storage would usually suffice.

Regarding a platform for product-centric data, as individual product items travel through various places and owners during their life-cycle, many different parties need to make modifications to the data concerning that particular product item. If all the product data related to the individual product items of even a single product are to be stored into a shared product-centric data management platform, there is no question about the fact that a large number of writers need to be able to edit the shared database simultaneously.

4.2.3 Maintaining consensus regarding the content of the database

When a database needs to be modified by multiple parties at the same time, every now and then some of their modifications may overlap with each other. In the event of such an occurence, either the overlapping modifications have to be somehow consolidated together, or multiple differently modified versions of the same database will emerge. For some databases, such as software code repositories, multiple versions pose no problems, as long as the different versions are tracked accordingly. Other databases, such as financial ledgers, however, rely on maintaining only one absolute version of their modification history and content.

Blockchain technology is especially well suited for distributed databases where one single version history needs to be maintained. Where multiversion concurrency control is not required, however, blockchain technology is most likely not the best solution.

As explained earlier, the idea of the product-centric information management approach is that product data is not fragmented over the life-cycle of the product but rather shared between different organizations. In order to do this, the data seen by all parties must remain uniform in its content. Therefore, since multiversion concurrency control is required, we conclude that this criteria is present in our discussed use case.

4.2.4 Interacting modifications

It is possible to envision a shared single-version database with multiple concurrent writers where, despite the presence of these features, blockchain technology would still not make for a rational option to go by. If there is no need for interaction between the different data in the shared database, and if the modifications made by all the different parties to the shared database are not somehow interdependent, blockchain technology is not necessarily the best choice for the job. For example, the validity of a transaction event in a financial ledger depends on the prior transactions in the ledger. The validity of a particular entry into a database for sports performance tracking, however, does not depend of the earlier sports performances of other people.

Considering the design of a potential product-centric data management platform, it could be easily argued that there is no real need for any interaction between the product data of all the individual products items. However, if the question is flipped on its head and instead we ask what would be the benefit of enabling interdependencies between the product data of all the individual product items, we can conclude that such a data structure would enable far more functionality and automatability than its alternatives.

To understand the full scope of the potential in this regard, another application of blockchain technology known as *smart contracts* needs to be acknowledged. Smart contracts are computer programs that are stored in a completely distributed manner on a blockchain database. Smart contracts are self-executing in the sense that their internal operational logic can automatically trigger certain functions to take place in the presence of some other predetermined events on the blockchain.

For example, assume the supplier of a product line wants to put out an engineering change order. Through smart contracts, this change order could be automatically updated to all the product items to which it is somehow relevant, no matter under whose ownership they currently are. Smart contracts could also be useful in terms of monetization of the product-centric data. An automatic contract proposal could be incorporated into the product data so that any agent — be it a human or an autonomous device — willing to pay a fee would automatically gain access to the product data of a desired product item. Another twist of the same example would be to simply track which parties and devices have accessed certain product data.

Furthermore, there is an interesting blockchain application currently under development which may yet become very relevant in regards to this specific point in the analysis. Enigma, as it is called, strives to enable parties to perform data science and machine learning on each others' encrypted data without actually exposing the content of the data to anyone. In practice, this could mean that more sophisticated algorithms could be developed from larger data sets for purposes that all parties stand to gain from, such as the safety in self-driving cars, for example. In the presence of applications such as Enigma, companies would not have to sacrifice the privacy of their data for the common good.[26]

4.2.5 The absence of trust

This condition refers to whether a party is happy to grant another party with unscrutinized permission to modify a certain piece of data that is vital to their operation. It may be the case that a party would stand to benefit from creating an artificial information asymmetry by deleting or falsifying data, and therefore cannot be trusted to safe-keep the data. Alternatively, it could simply be the case that the participants are unable to trust the data synchronization capabilities of the network and therefore one party could unknowingly delete or modify information which is still relevant to another party.

Blockchain technology is especially well suited to situations where a common ruleset is required to determine when a certain party can edit a certain piece of data in a distributed database. Conversely, in a situation where such a ruleset is not required, a simple distributed database without the use of blockchain technology, such as Cassandra or RethinkDB would usually suffice.[27]

In the case of a product-centric data management platform, a party performing operations on an individual product item could be very negatively affected if another party, either arbitrarily or unintentionally, deleted data from the system which would have been crucial to the performed operations. Therefore it is essential that a ruleset exists for governing the participants' authority to modify particular data entries in a product-centric data management platform. Hence, it can be concluded that, in this regard, blockchain technology is a well-suited candidate for the discussed effort.

4.2.6 The undesirability of intermediation

In many cases where all the aforementioned criteria are present, they can all conveniently be swept under the rug by simply introducing a trusted intermediator who maintains the joint database and facilitates the trust and the multiversion concurrency control for it as a provided service. In order for blockchain technology to be an option worth considering, a reason needs to exist why resorting to such an intermediator is not possible, or it is undesireable for another reason, such as high cost of service, for example.

Besides the obvious aspect of unnecessary costs of intermediation, one genuine problem related to the use of an intermediator to produce and to maintain a platform for product-centric data management is that in many cases, the product items may outlast any single platform provider. In such a scenario, any product data stored by the intermediator would quite possibly seize to exist.

[26] Zyskind et al., 2015.
[27] Greenspan, 2016.

Moreover, as discussed earlier in this paper, the number of data objects and the amount of stored data required in the product-centric data management approach is significantly higher than in the conventional approach. Even if the manufacturers do not go out of business, the cost of maintaining a company-specific platform architecture for the entire lifespan of each product would be disproportionately high relative to the price of the products in question. This holds true especially in industry where the possibilities of harnessing behavioral data for targeted advertising are more limited than in the consumer market. Consequently, there are no guarantees that a central architecture will be economically feasible for a product-centric data management platform in the long term.[28]

4.3. Results

In this chapter, the suitability of blockchain technology as the architectural basis of a shared product-centric information management platform with distributed platform control was analyzed. The analysis was based on general requirements of a rational use case for blockchain technology that have been identified in industry discussions.

In conclusion, no clear deficiencies were found in regards to the requirements of a sensible use case for blockchain technology. Most of the requirements outlined in industry discussions and in interviews with blockchain technology developers were adequately met, although some ambiguity remains as to whether interacting modifications are truly necessary for product-centric data management. However, the current development trajectories of blockchain technology suggest that if interdependencies between the product data of individual product items were made possible, significantly higher network effects could be attainable. Moreover, the utilization of blockchain technology may, at a later point, allow novel complementarities, such as data science and machine learning on encrypted product data.

5 Discussion

In this paper, a conceptual implementation of a distributed agent-based product-centric information management system has been discussed. Distributed agent-based information architectures make product information accessible in a controlled manner over the Internet. This decentralized platform model with trust opens up new avenues for discussion on the topic of multi-sided platforms, specially for durable and capital goods industry sectors.

It is important to make a distinction between platforms in the market for non-durable goods, and platforms in the markets for durable and capital goods. Moreover, another important dividing aspect to consider is the ownership of the product data[29]. In this regard, the ownership of the containing product itself is a critical factor. Therefore, in platforms which operate in the markets for non-durable goods, the development has lead to a situation where the owner of a product no

[28] Ahluwalia 2014.
[29] Wiens 2015.

longer has ownership over the accumulating product data. When it comes to durable and capital goods, the current owners have major reservations about respectively giving away this control.

The main technical foundations of blockchain technology, i.e. a cryptographic database structure and consensus algorithms providing distributed multi-version concurrency control were also discussed in this paper. Due to these technical features, the utilization of blockchain technology allows platform participants to collaborate while maintaining the ownership and the control over their product data. Through an inductive case study analysis, it was shown that blockchain technology can be employed for the purpose of advancing towards multi-sided markets in the specific context of product-centric information management.

Furthermore, it is our belief that distributed, agent-based information architectures will play a key role in the design of the next generation of product-centric information management systems. The decreasing price of embedding communication, storage and computing technologies into devices has made the implementation of intelligence possible into all types of products: durable, non-durable and capital goods. Through the evolution of distributed platform control via blockchain technology, new application domains, making use of new types of mass data, could be created in the area of machine learning used in next generation of cyber-physical systems.

As a general trend originating in the consumer-centric market for non-durable goods, platforms and new digital technologies are repositioning competitive advantages all around the economy. As a result, the entire competition environment in general has become a complicated, multi-sided struggle across industries and organizational boundaries.[30] For companies in the markets for durable and capital goods, the only effective way to respond to this multi-sided struggle may be to start thinking of individual products as a source of new mass data, much in the same way as consumers have been perceived in platform literature earlier.

It will also be interesting to see whether blockchain technology will reach the critical mass of a stable ecosystem and become a mainstream technology for the kinds of distributed platform architectures as described in this paper. The role of standardization is important in this regard, and should not be overlooked by the public authority. Moreover, interoperability between different industry sectors is also, crucial, especially for durable and capital goods.

As tens of millions of intelligent devices are expected to be connected to the Internet in the near future, the role of product-centric information management and interoperability between devices will become more important in terms of society utilizing its assets effectively. In this regard, however, the current trend of platform development in the consumer-centric market can be seen as architecturally insufficient, as the vast majority of the infrastructure in society is owned by industrial companies and nation states, rather than consumers. Therefore, one can pose the

[30] Rochet, & Tirole, 2003; Parker & van Alstyne, 2005; Rochet & Tirole, 2006; Amstrong, 2006; Hagiu, 2009; Hagiu & Spulber, 2012; Hagiu & Wright, 2012; Hagiu, 2014; Mattila & Seppälä, 2015; Kenney & Zysman, 2016; van Alstyne et. al., 2016.

question, who in fact should accept responsibility for the creation and the development of shared product-centric information management platforms[31]. So far, when it comes to product data, no party has taken initiative in creating such platforms for interoperability and broader network effects.

[31] Seppälä-Mattila 2016.

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