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RESEARCH PAPER

Is there a market for trusted car data?

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Abstract

The used-car trade is characterized by information asymmetries between buyers and sellers leading to uncertainty and distrust, thus causing market inefficiencies. Prior research has shown that blockchain offers a solution: a transparent, trustworthy and verified car history that addresses these issues in the market for 'lemons'. Yet, whether or not there really is a market for trusted car data remains an open question. In particular, it is unclear if trusted car data increases transparency in the market for lemons and how market participants value increased transparency. Hence, through a market game with 50 participants, we explored the effects of trusted car data on the sales price of the cars, and the relative revenue of buyers and sellers. Additionally, we conducted interviews with the participants to elicit the perceived customer value. The results show that blockchain enables an increase in transparency and creates value for both buyers and sellers.

Keywords Blockchain · Market for lemons · Value creation · Data and information products · Data-driven business models

JEL classification O33 · O39 · D82

Introduction

Information asymmetries and the lack of trust between buyers and sellers are prevailing today's used-car market (Akerlof 1970). Sellers have more information about the quality of their cars than buyers (Levin 2001). Hence, the lack of information - or an asymmetric distribution of information, resulting in the problem of products' quality uncertainty - causes market inefficiencies (Akerlof 1970). On the broader macro level, this leads to bad products driving out good products – the adverse selection problem – or it forces sellers to sell peaches for peanuts due to their inability to prove the quality of the car. From the perspective of buyers, the less-informed party, they bear the risk of buying a lemon, since the market will average the value of the peaches and lemons resulting in an average market price ($p_{peach} > p_{avg} > p_{lemon}$). Besides market inefficiencies, at the micro level, buyers and sellers struggle with inefficiencies during the sales process that result from quality uncertainty and a lack of trust (Bond 1982). To resolve information gaps and to help deal with quality uncertainty, institutions have developed measures like guaranties, brand-names that signal quality, or licensing models (Akerlof 1970). Additionally, buyers and sellers can apply their own individual strategies, such as requesting specialist check-ups, or browsing reviews and specialist magazines, use price signaling (Wolinsky 1983) . However, these strategies are costly and time consuming. On the one hand, they are costly for the individual who bears the individual expenses of the effort to assimilate the quality. On the other hand, these strategies are inefficient from a market perspective, since these efforts are multiplied by the number of prospects. Again, the lack of trust between strangers about data validity and reliability makes it hard to share personally gathered information about the quality of an offer with another prospect. These issues are also

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reflected in practice. In Germany, for example, a consumer study ranked the automotive market among the top three markets with the least trust (Lades 2017). In the EU, the odometer is estimated to be rolled back on up to 50% of the traded used cars. This leads to fraudulent increases in the cars' prices by €2000 - €5000 on average and overall fraud costs for customers and businesses of €5.6 - €9.6 billion a year (European Parliament 2018). Besides the relevance of this problem for economics research, the resolution of information asymmetries through the application of information systems is also gaining interest from Information Systems research. Blockchain, also referred to as "the trust machine" (The Economist 2015), has often been argued to possess the potential to disrupt and reshape key economic principles and, with that, market structures and business models. The most predominant example is probably Bitcoin, the first entirely decentralized cryptocurrency, that is claimed to have the potential to disrupt the role of financial intermediaries (Nakamoto 2009). Acting as a transparent, trust-free and secure transaction system, researchers further argue the potential of blockchain to reduce transaction costs drastically and enable decentralized asset management systems that would greatly benefit current large and costly supply chain systems (Naerland et al. 2017), and also small but high-scale coffeeshop payment solutions (Beck et al. 2016). Finally, the technology's key characteristics of decentralization and trust (Seebacher and Schüritz 2017) have also shown to reduce information asymmetries and mitigate adverse selection effects in the market for lemons (Notheisen et al. 2017a). Notheisen et al. (2017a), for example, proposed a blockchain-based information system that enables the creation of a transparent, trustworthy and verified record of a car. Bridging both ends, on the one hand, prior research and practice clearly show the issues prevailing the used-car market, today, while on the other hand, studies show that blockchain can offer a technological solution to these problems. However, how the market for used cars will react to the introduction of a blockchain-based information system that provides trusted car data, and what effect it will have on the market, particularly how the individual user groups (buyers and sellers) will value such a system, are open question for both academia and practice (Notheisen et al. 2017a; Notheisen et al. 2017b). Motivated by the enormous potential in the used-car market and the promises of blockchain technology, we raise the following research questions:

RQ: What is the role of blockchain for trusted car data in the market for lemons?
RQ1: Can we increase transparency in the used-car market through trusted car data?
RQ2: How do market participants value trusted car data?

In this paper, we review prior research and show how IS research propose the technical potential of blockchain as an enabler for providing trusted car data to address the problems of information asymmetry in the market for lemon. Next, we take this view a step deeper and put the IT artifact into the context of economic applications. Through an exploratory market game, we analyze (1) the effect of trusted car data on market transparency, as well as (2) the value of increased transparency for individual user-groups (buyers and sellers). Following prior studies, for this research by market transparency we mean and refer to the level of opaque product quality on the market (Akerlof 1970; Granados et al. 2006; Stahl and Strausz 2017). More specifically, according to Granados et al. (Granados et al. 2006, p.3) the concept of market transparency includes *"the accuracy and completeness of market information, in addition to the level of bias"* .

All in all, we respond to the calls of prior IS research and contribute with an exploratory analysis of the technology at agent level (Notheisen et al. 2017b). Further, we support used-car market designers trying to understand the potential of blockchain technology in light of uncertainty in its market potential, acceptance and customer value. Businesses question who the potential customers will be and what each user group (seller and buyer) values from such a blockchain-based solution. In general, we shed light on the market potential of trusted car data. The remainder of this paper is structured as follows. The related work section introduces the economics of the used-car market today that also serves as the basis for the design of our market game. Further, we summarize current IS research that addresses the problems in the market for lemons and introduces the key constructs our research builds on. In section 3, we describe the applied methods for our quantitative and qualitative analysis. Section 4 then presents the results and, in section 5, we discuss what the results mean for the potential of a market for trusted car data. Section 6 concludes the paper by summarizing the results, highlighting the limitations, and giving an outlook for future research.

Related work

Economics in today's market for lemons

In his seminal work "Market for Lemons", Akerlof (1970) exemplifies the problems of quality uncertainty resulting from an asymmetric distribution of information in the used-car market. Used cars that are traded between buyers and sellers vary in their quality, but only the seller possesses enough information to truly assess the product's quality. Due to a lack of reliable information in the market, potential buyers can only apply heuristic approaches like statistical estimates or evaluation of price signals in order to assimilate the product's quality (Wolinsky 1983). Yet, residual uncertainty remains, and since buyers have little chance to tell the difference between "good" cars (peaches) and "bad" cars (lemons), equilibrium prices even out and reflect the average quality of all cars on the market (Wilson 1980). In this equilibrium, sellers of lemons earn informational rents that are as high as the difference between the market price and the cars' actual value. Sellers of peaches pay negative rents since the actual value of their cars is higher than the average market price (Wilson 1980). Equilibrium prices are not only an effect caused by buyers' fears of dishonest sellers, but also the result of honest sellers' inability to prove the good quality of their cars (Pavlou and Dimoka 2008). This not only causes unfairness and inefficiencies for individual buyers and sellers but also sets wrong incentives, eventually resulting in the so-called *adverse selection* effect at the macro level. Drawing on Graham's Law, Akerlof (1970) argues that lemons tend to drive out peaches because sellers of good cars bear the costs of equilibrium prices, thus have no incentives to enter the market. He further argues that in a continuous world - a cascading effect - would come into play where marginally lower quality cars would drive out marginally better ones until the extreme case of a market collapse because neither demand nor supply is left. However, despite information asymmetries and negative rents, in reality, a substantial trading volume remains (Peterson and Schneider 2014). This might be due to counteracting measures mostly provided by institutions. Such measures include guaranties, licensing and certificates to signal product quality (Akerlof 1970; Genesove 1993). This measure enables the hedging of risks to a certain degree. However, inefficiencies and quality uncertainty still remain (Bond 1982). Additionally, these measures are often costly and time-consuming, and sellers may sometimes overinvest in signaling (Akerlof 1976; Bond 1982).

Reponses from IS research addressing the market for lemons

Rising from and mainly discussed in the field of economics, the problems associated with the 'market for lemons' have gained increasing attention in information systems (IS) research as well. With the advent of online markets, researchers started analyzing how the problems of information asymmetries and adverse selection are reflected in online markets (Dimoka et al. 2012; Dimoka and Pavlou 2006; Huston and Spencer 2002; Lewis 2011; Pavlou and Dimoka 2008). While they argue that uncertainty about product quality increases in online markets due to the inability to physically evaluate the products' quality - resulting in "cyber lemons" (Huston and Spencer 2002) - they also position product uncertainty as an information problem that can be mitigated with IT-enabled solutions and hence reduce product uncertainty in online markets (Dimoka et al. 2012). One such example Dimoka et al. (2012) provide is the use of online vehicle history reports like CARFAX or Autocheck in the US, or Eurotax or Carpass in Europe. The German online advisor 'Motor Talk' says that cars with good history documentation can be sold, on average, for € 2800 more than cars without any history record (Bergander 2017). However, reasons why such systems have not been widely adopted yet might be the lack of trust towards one single provider and, relating thereto, the lack of trust in data quality, inconsistency and incompleteness of a central registry, and high costs that do not justify the benefits (Notheisen et al. 2017a; Zavolokina et al. 2018a). Since the advent of blockchain, a technology that by design is expected to provide an infrastructure for truly decentralized markets and create transparency and trust in transactions (Avital et al. 2016), IS offers another technical approach to address the problems. Thus, researchers started exploring the potential of the blockchain technology in today's used-car market. Analyzing the blockchain infrastructure, (Notheisen et al. 2017a) provide a first technical approach that shows how blockchain can reduce transaction risk through the irreversibility of transaction and by replacing a centralized register with a decentralized autonomous alternative. They build on the Danish Motor Registry and develop a prototype of a blockchain-based transaction system running on Ethereum, where users can invoke smart contracts to register and trade vehicles securely on the DMR marketplace. Besides this design science approach, Brousmiche et al. (2018) also present a similar technical infrastructure of a blockchain system. However, they focus on the secure sharing of vehicle data across multiple stakeholders like car manufacturers, insurance companies and private car owners. Zavolokina et al. (2018a) take a top-down approach and specifically evaluate the buyer's perspective. They argue that key problems buyers currently face during information seeking are: (1) the uncertainty about information quality from a single source, (2) the uncertainty of information quality with respect to completeness and correctness, and (3) the costs of information seeking. Addressing the buyers' needs, they formulate requirements for a blockchain-based system to fulfill the promise of the technology, contributing to current blockchain research in the market for lemons by taking deeper view of the application infrastructure. One major issue all researchers point out, is the issue of data quality. A blockchain-based vehicle record is only as good as the data that is in it. Blockchain can ensure the integrity of transactions but not the quality of input data. Addressing this issue, Zavolokina et al. (2018b) propose incentive system features for a blockchain-based digital car certificate. Taking a more applicational view, they provide specifications for features to govern different organizations in such a system and incentivize good data quality. Again addressing the topic of governance, Ziolkowski et al. (2018) study the impact of blockchain governance for inter-organizational coordination. Finally, from a business perspective, there has been study regarding how such a blockchain-based IT artifact for the car ecosystem should be designed to allow businesses to profit and leverage current development expenses (Bauer et al. 2018). Despite the increasing research interest in this topic form a variety of perspectives (infrastructural, applicational governance and business), nothing is known about the impact of such a system on markets and market participants. However, since a system is only worth as much as it is used and valued by its customers, we acknowledge prior research and build on the calls that emphasize the need to explore the effects the technology has on markets and agents (Notheisen et al. 2017b).

Besides these use-case oriented approaches, IS research, in general, evaluated the impact of IT (especially with the advent of the internet and with that the emergence of electronic markets) on market information, transparency and market structure (Granados et al. 2006). Based on the electronic markets hypothesis, which argues that IT reduces coordination costs leading to new markets and proliferation of existing ones (Malone et al. 1987), Granados et al. (2006) proposed a unified framework that explains how IT facilitates or inhibits the emergence of transparent electronic markets. In short, they argue that IT alone does not lead to increased transparency through electronic markets, rather that the enhancement through an electronic representation of products as well as competitive and institutional forces also play an important role. Thus, focusing on the effects of enhanced electronic representation of physical goods of high value (cars), we evaluate whether trusted car data from a blockchain-based system can have similar effects and increase transparency even further than the advent of the internet did, enabling further market proliferation or even opening avenues for new markets.

Blockchain and trusted car data

Taking a deeper view at the infrastructure layer, blockchain, in simple terms, is defined as a decentralized database that is shared among a network of users who can transact publicly and pseudonymously without the need of a central intermediary (Glaser 2017; Risius and Spohrer 2017). More specifically, the distributed ledger processes transactional data according to a decentralized consensus mechanism and stores verified transactions in cryptographically interconnected data blocks. If the majority of the network participants agree to the validity of the database update, a decentralized time stamping algorithm concatenates the new blocks with the existing chain of blocks. Thus, a shared view of the state of the system is ensured at any point in time (Gipp et al. 2015). In addition to the advantages of decentralized record keeping, blockchain technology enables collection of data from multiple independent parties and creates a comprehensive and immutable record history. This intrinsically valid history of transactions facilitates trust among the network participants and the integrity of the shared ledger (Seebacher and Schüritz 2017). Finally, such a trusted social network (Chen et al. 2018) avoids single points of failure (Böhme et al. 2015), enables a consistent and complete record history (Hawlitschek et al. 2018) and enables trusted data provenance (Liang et al. 2017; Shrier et al. 2016). In sum, these key characteristics of blockchain enable multiple, eventually also competing participants, to collaborate and jointly create a comprehensive ledger of trusted car data.

Methods

DSR using experimental techniques to explore and evaluate

To study the phenomena of interest, we conducted an experimental market game in the course of an ongoing larger Design Science Research (DSR) project, the cardossier project. DSR originates from computer and engineering science and essentially focuses on solving problems with practical relevance through the design of novel IT artifacts (Hevner et al. 2004; March and Smith 1995). The specific problem our research focuses on is the lack of transparency in the market for lemons. Thus, the rationale for the design science approach is explained by the problem-centered initiation (Peffers et al. 2007) that we aim to address through trusted car data, provided by the cardossier as our IT artifact. The cardossier is a blockchain-based system that aims to collect, maintain and access car-related data from multiple relevant stakeholders in the car ecosystem (an importer and retailer, a road-traffic authority, an insurance company, and a car-sharing company) in order to create a complete car record. This is also in line with the DSR guidelines of Hevner et al. (2004), who argue that DSR must produce a viable artifact (Guideline 1), and that the objective of design-science research is the provision of a technology-based solution to the relevant problem (Guideline 2). Furthermore, the cardossier project follows the three closely related cycles (relevance, design, rigor) (Hevner 2007). For example, it utilizes the concepts introduced in the literature section earlier and is now close to finishing the first minimum viable product. Thus, the cardossier project is currently in the design cycle, aiming to explore and evaluate the IT artifact in the environment (Beck et al. 2013). For this purpose, we used experimental techniques in the form of a market game. Experimental techniques can be used to test the validity of theoretical models, but also to discover and describe phenomena and their correlations in the course of an exploratory research (Stebbins 2001). The use of experimental techniques within DSR research enable the measurement of an outcome that the designer wants to achieve with the IT artifact (Briggs and Schwabe 2011). With this market game we simulate the used-car market, thus enabling the exploration and evaluation of our artifact's effect on agents in the solution domain (Hevner 2007). Furthermore, testing our IT artifact in an early development phase enables us to avoid unfit design and minimize design costs (through late changes that require larger efforts due to dependencies). In what follows, we will first introduce the experiment setting, including the game design, as well as the integration of trusted car data provided by the cardossier and finally explain how both qualitative as well as quantitative data analysis was done.

Market game settings

Game design

Our market game is a web-based application[1] that is designed as an online market place for used cars (similar to Autoscout24 in Europe or cars.com in the US), which we called Gooo (Fig. 1).

Despite the international relevance of the market for lemons phenomena and the global reach of blockchain, for this study we focused on the Swiss market. One reason for this is the significant differences in the used-car markets of different countries (European Comission - Justice and Consumers 2014). Thus, simulating the Swiss used-car market, we relied on local studies to design the market as realistically as possible. On Gooo, users participate in two game rounds: a traditional round (traditional) that simulates the used-car market as it is today, and a blockchain-based round (cardossier) where trusted car data from the cardossier is introduced. In both game rounds, actors' key objectives were to buy or sell used cars for which they had 30 min in both settings. In both rounds, we ensured an equal number of car sellers and buyers - with 25 actors in each group - and the same number of available cars on the market. To enable comparability between the two game rounds, the same cars were used in both settings. However, to counteract the learning effect, the cars were mixed up between the sellers. The cars in the game were real cars currently offered on real online markets. However, we ensured that all fell in a similar range (e.g., only small, used passenger cars priced in a range between USD[2] 10′000 and 12′500). Onto reflect the real used-car market, cars in our market game differed in quality and, based on prior research, we ensured that approximately 25% of the second-hand cars were lemons. The roles were randomly assigned among the participants and in case a user got assigned the role of the buyer, they also got randomly assigned a used-car. To enable value exchange, sellers received a budget of USD 17.000 (see upper right corner of screenshot 1 in Fig. 1), enough to buy all available cars on the game market. Since the value of the cars varied within a certain range (USD 10′000–12′500), both actor groups (buyers and sellers) were incentivized to maximize their relative revenue from the trade. This way, we ensured that sellers were free in their choice between a more expensive or a cheaper car and all buyers had the same chance to maximize their profit. In other words, whether a participant bought an expensive or a cheap car was less crucial than the ratio between the sales price and the actual value of the car. The relative revenue was evaluated on the basis of the actual value of the car compared to the sales price for which the car was finally traded. During the second market game, the cardossier round, trusted car data from the cardossier was introduced. Thus, in addition, the expenses for information costs and the information revenue (for sellers only) were accounted in the relative revenues. Table 1 gives an overview of key terms used in the market game, their meaning and explains the source of the information and calculation methods.

Trusted car data from the cardossier

Prior to the cardossier market game, the participants were briefly introduced to the cardossier as a blockchain based system that creates and maintains trusted car data for each car on the market. As shown in Fig. 2, users had the chance to either buy a full cardossier (including both raw data and analysis), or only data and/or analysis from three different information categories: (1) Vehicle data, (2) Repair and Service, (3) Driver Dynamics. Raw data only showed the verified data entry, e.g. Mileage: "500′000 km" or Accident History: "No entries". Analysis represented the evaluation and a recommendation of the data: e.g. high mileage wear: "-10%" from market price. The analysis for each car was automatically calculated according to the same standard assessment table that was used for the approximation the actual value. The prices for the information products were again based on prior research and discusses with industries experts. While buyers had to pays for all kind of information products, sellers had free access to their own data but they had to pay for analysis.

Data collection and analysis

The market game was conducted in June 2018, at a Swiss university, and overall 50 students participated in both game rounds. For the study all students of an IS lecture class were invited to participate and incentivised by the possibility to earn bonus points. The selected IS lecture class is a mandatory class for all IS bachelor students in their 2nd year. The reliability of the use of students as study object can be justified by

[1] Within the cardossier architecture (Appendix 1) it is a web-app that we deployed for the experimental game. However, the core corda-platform was simulated using a central database. This is because for our experiment the data gathering and data management were not relevant. Yet, the data we offered through our cardossier App conform to those that will be provided via the real cardossier core.

[2] Throughout our study all prices were shown and calculated in CHF to make it more understandable for the Swiss study group, that we used. However, to make it more relatable for a broader public throughout the paper we have converted all prices in USD (Exchange rate as of the 4th of July, 2019).

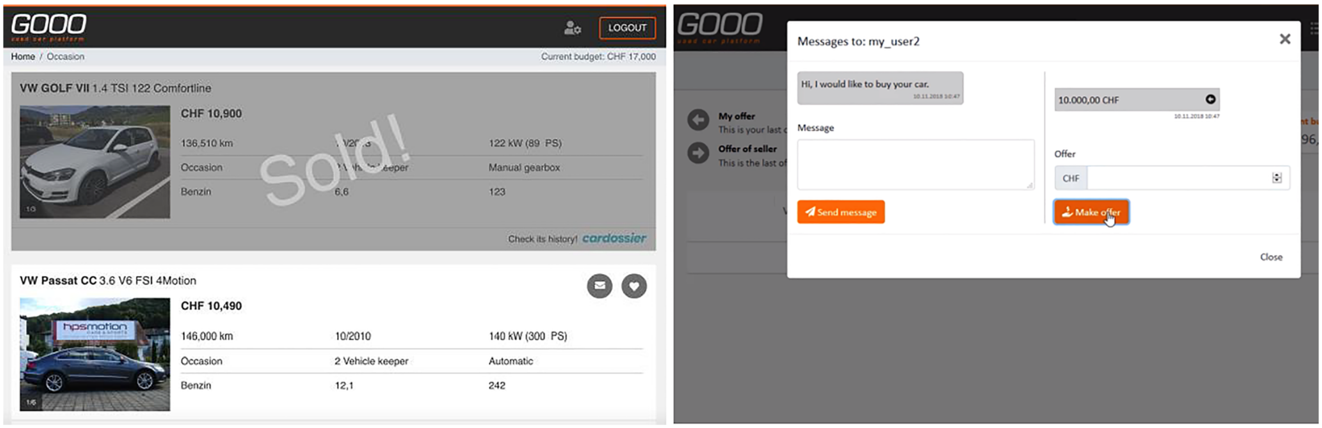


Fig. 1 Overview-page for the Online Marketplace Gooo and communication space for users

a comparative study conducted by Höst et al. (2000). According to them differences between the use of professionals and. Students as study subject in lead-time impact assessment are minor. Besides that, to justify the sufficiency of their background and knowledge, prior to the two rounds, the participants answered a questionnaire. From this we identified that our experiment included 20% female students and 80% male students. Two-thirds of the participants considered themselves to have 'good to expert' knowledge within the used-car trade. Besides that, one-third indicated that they had already participated in the sale of a used car. Furthermore, 80% indicated that they had driver's licences and 30% stated that they already own their own car. For the results presented below, the final achievement (e.g. sales price or relative revenue) that the participants attained during both game rounds, as well as the log-file (e.g. data purchases) were analysed individually and compared between the two game rounds. In the quantitative data analysis, 45 of the students also participated in an interview (lasting on average 30 mins) that was conducted either directly after, or within the time frame of 1 week after the experiment. The interviews were conducted in a semi-structured manner (Myers and Newman 2007), they were recorded and later transcribed and analysed with qualitative data analysis software. The code units were phrases, sentences and paragraphs (Weber 1990) for which an open coding process was used (Saldaña 2009). To ensure internal validity and inter-coder reliability, two of the authors cross-checked the codebook.

Furthermore, the design of the study had to make certain trade-offs in terms of internal and external validity. While controlled settings do not improve external validity, they allow for more fine-granular observations of the study participants.

Table 1 Overview of key terms and sources of information

Term	Description	Source
Actual Value (AV)	The value of a car that a well-informed user would assign to it.	Calculated on the basis of all available information about the car and according to a standard assessment table provided by a leading car importer in Switzerland[a]
Market Price (MP)	The average price of a car of a certain class.	Based on research of real car prices currently available on AutoScout24.ch or AutoRicardo.ch.
Sales Price (SP)	The price at which the car is finally traded.	Extracted from our database after the market game.
Information Costs (IC)	Money users spent on trusted car data from the cardossier.	Priced according to similar assessment tools and car reports currently available in Switzerland. The prices for trusted car data ranged between USD 20 and USD 100 depending on the selected category and amount.
Information Revenue (IR)	Revenue sellers received for selling the data about their car to potential buyers.	Sellers received a portion of the money that buyers spent on trusted car data, from the cardossier. The proportion distribution between seller and the cardossier was as follows: *Raw data (70:30); Analysis (0:100)*
Relative Revenue (RR)	The measure for the evaluation of users' achievements.	Extracted from our database after the market game and calculated as follows: $RR_{Buyer} = \frac{(AV - SP - IC)}{AV}$; $RR_{Seller} = \frac{((SP + IR) - (AV + IC))}{AV}$

[a] We acknowledge the fact that different assessment methods would yield different values. Our evaluation is one estimate that relies on the most common method used in the simulated market and was applied consistently. The assessment table considers different variables and relatively accounts their effect on the actual value of the car.

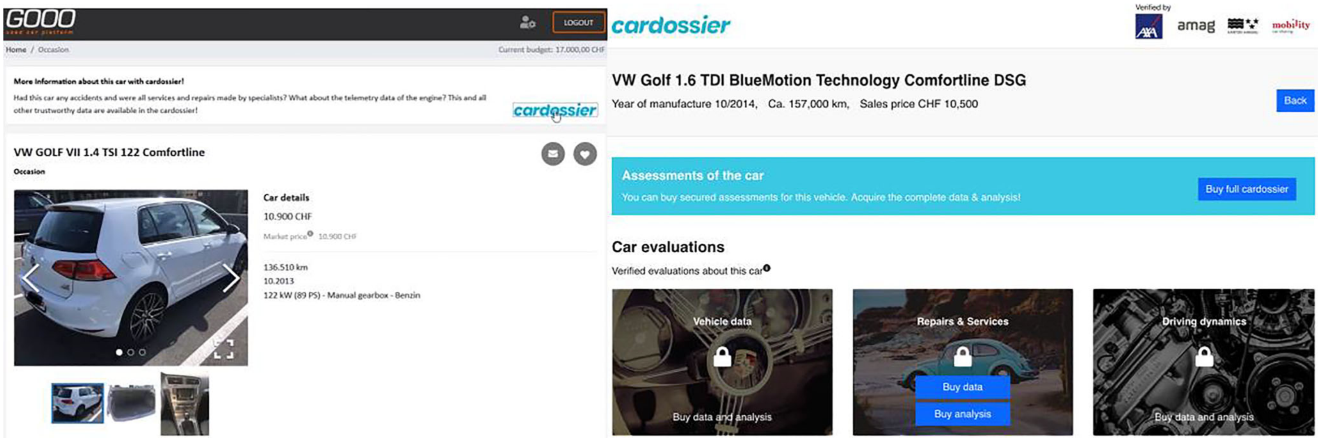


Fig. 2 View of the IT artifact in the cardossier market game

However, we did our best in designing the used-car marketplace as near to the real one as it was possible: the visual design of it was taken over from a real used-car platform. We acknowledge that truly externally valid results should be obtained from the integration of the cardossier with a real marketplace. We leave this for our future work. What for internal validity, we should admit that we used convenience sampling to pick up participants of a whole course instead of recruiting completely random participants. However, we controlled for randomization of assignment of roles and cars in the experimental settings to avoid any systematic bias. Furthermore, we triangulated both quantitative (log files) and qualitative (interview results) data to make sure that we do not misinterpret the obtained results. To control for construct validity, we used an established instrument, proposed by Granados et al. (2006) to measure market transparency. In our study we measure market transparency as the deviation of the sales price to the actual value.

Results

In what follows, we first present the results of the quantitative analysis. These results evidence the effects of trusted car data on market transparency in the used-car market, from the point of view of both (1) *the market* and (2) *the agent*. Second, we present the results from the qualitative analysis, where we elicited how market participants (buyers and sellers) value trusted car data.

Effects of trusted car data

Market view

As a point of reference for measuring the effects of trusted car data at market-level, we took the sale price and the actual value of the used cars and compared how much the cars were traded for on both markets (traditional and cardossier). As mentioned earlier, the only variable that changed between the two rounds was the availability of trusted car data in the cardossier market. In short, the results yielded *(1) an increase in market value* of the cars sold on the cardossier market compared to the traditional market. More specifically, the cars were sold at a higher price with the availability of the IT artifact than without. Furthermore, comparing the sales price to the actual value of the cars showed that *(2) the cars were sold at close to their actual value* in the market where cardossier was available. Table 2 summarizes the results, which are explained in detail below.

As shown in Table 2, column (a), the actual value of all cars was the same in both markets and was estimated at USD 242,894, prior to both games. This sum reflects the value of 24 cars which were traded on both markets and excludes one car (from both sets of analysis) that was not sold in the traditional market. This also mirrors our preconditions for car selection for the game, namely an average car value between USD 9000 and USD 11,000. Column (b) presents the total sale price that was achieved for the cars in each round and shows that the total sales price increased from USD 219,595 in the traditional round to USD 241,569 in the cardossier round. In column (c), we calculated the difference between the sales price and the actual value of the cars and see that on the traditional market, in total the cars were sold for USD 23,299 less than they are actually worth. Relatively speaking, the cars were sold for 9.56% less than their actual value. In the cardossier market, a deviation of only −0.55% from the actual value (or USD −1325 absolutely) was achieved. Hence, this result shows that the cars on the cardossier market were sold closer to their actual values. A two-sided paired sample t-test compared the sale price of a car between traditional (M. = 9150, S.D. = 1958) and cardossier (M. = 10,065, S.D. = 1448) markets. The result that the cars were sold closer to their actual values was significant ($p < 0.05$).

We also calculated the sum of spending (for both buyers and sellers) for cardossier products, with the information costs presented in column (d). In the traditional market, the information costs were zero since there were no cardossier

Table 2 Results of market view analysis

Game Round	(a) Total Actual Value (all Cars)[a] in USD	(b) Total Sales Price in USD	(c) Deviation of SP from AV		(d) Information Costs absolute in USD	(e) Mean deviation of SP from AV including IC (SP + IC-AV) / AV in %
			Absolute (SP – AV) in USD	Mean relative (SP – AV)/AV in %		
traditional	242,894	219,595	−23,299	−9.59	0	−9.59
cardossier		241,569	−1325	−0.55	5130.00	−2.66
Deviation of market value of cars sold between the games		21,974		+9.05	+5130	+6.93

[a] A total of 24 cars - one car was excluded from the analysis since it was only traded in one market.

products to purchase. In the cardossier round, the total information costs were USD 5130. Hence, in column (e), the results show that if the information costs were also considered, there was still an increase in market value of +6.93% from the traditional to the cardossier market.

By comparing the performance of each car on both markets individually, the results showed that on the cardossier market outliers were marginalized. While on the traditional market the sales prices ranged from USD 3000 to USD 11,900, on the cardossier market the sales prices only ranged from USD 7900 to USD 12,500. Therefore, this price range was reduced by 48% on the cardossier market.

Agent view

In contrast to the market analysis, where the cars served as our point of reference, when analyzing the effects of trusted car data at agent-level, we considered the market participants and their performance as our point of reference. More specifically, we analyzed the performance of both user groups (seller and buyer), and individual actors between the two rounds. The performance was measured on the basis of their relative revenue. Table 3 gives an overview of the total and mean relative performance of each user group in both game rounds. A detailed overview of the individual results is presented in Appendix 2a (sellers) and 1b (buyers).

In short, the evaluation of the relative revenue shows that sellers performed better on the cardossier market compared to the traditional market. More specifically, in mean they went from a relative revenue of −8.73% to a relative revenue of −0.09%. In the cardossier round, they spent USD 1′050 on analysis of their own car and received USD 780 in revenue for their data sales. Evaluating the performance of each seller individually, we could see that while on the traditional market the relative revenue ranged between −70.62% and 22.5%, on the cardossier market there was only a profit range between −14.85% and 17.53%. Furthermore, those sellers that were randomly assigned a lemon performed better than those with peaches, since there was a greater margin to make. This was evident in both game rounds, but most strongly in the traditional market. In addition to the evaluation of the relative revenue, we also analysed the relationships between purchases of trusted car data from the cardossier and game performance. However, whether a seller had bought analysis about his own car or not did not have any effects on their performance.

Contrary to that, on average, the buyers performed better on the traditional market compared to the cardossier market. On the traditional market, buyers achieved a total profit of USD 23,299, or in mean, a relative revenue of +8.7%, whereas in the cardossier market, they only achieved a total absolute profit of USD 3990, or mean relative revenue of −0,77%. Analyzing the buyers’ individually, the results show that on the traditional market there were a few very good buyers (relative revenue of top 3: 70.6%, 32.7%, 23.6%) and a few very bad buyers (relative revenue of bottom 3: −22.5%, −12.4%, −9.8%). On the cardossier market, the top three differed in their relative revenue only marginally (relative revenue of top 3: 13.0%, 9.01%, 8.1%). Similarly narrow were the differences between the bottom three buyers (relative revenue of bottom 3: −20.0%, −13.1%, −12.4%). In sum, these results showed that the revenue range was more compact in the

Table 3 Results of the agent view analysis

Game Round	Seller				Buyer		
	Total IC in USD	Total IR in USD	Total abs. RR in USD	Mean RR in %	Total IC in USD	Total abs. RR in USD	Mean RR in %
Traditional	0	0	−23,299	−8.73	0	23,299	+8.73
Cardossier	1050	780	−1595	−0.09	3990	3990	−0.07

cardossier market than in the traditional market. Rather than having big winners and great losers, as was the case on the traditional market, on the cardossier market the revenue margin was smaller and more equally distributed between both user groups.

Besides the relative revenue, for the buyers we also analyzed the number of information products they consulted from the cardossier. The results showed that, on average, those players who bought more trusted car data (independent of its form, raw data or analysis) performed better than those players who bought less.

Figure 3 presents the number of information products (data and analysis) that were purchased by each buyer from different cars. The buyers are numbered consecutively and ranked according to their achievements on the cardossier market. The horizontal line in Fig. 2 indicates that the average number of purchases of trusted car data was three.

Value of trusted car data

In this subsection, we present the results of the qualitative analysis. In short, from the interviews with the sellers, we learned that the greatest value they experienced from the induction of the cardossier was their ability to *signal the quality*. One interviewee, for example, said that he would even offer his data for free to buyers who express serious interest, just to have the ability to prove that he is not lying (Seller_RB). Buyers, on the other hand, *valued their ability to reduce risk and uncertainty*, both during the trade process and with respect to their decision. *They emphasized increased transparency* in the whole trade process *and valued their ability to make informed decisions*. Furthermore, both seller and buyer *stressed that they perceived the sales process on the cardossier market more efficient* compared to the trade process on the traditional market. Besides that, the majority of the interviewees *evaluated the overall situation on the cardossier market as fairer* for both user groups. Table 4 gives a detailed overview about the value experiences that emerged from the interview analysis, and it provides a description, as well as code unit, as an example for each value experience.

Discussion

The role of Blockchain for trusted car data

Information asymmetries and hence the lack of transparency on the market are the root cause of most issues that are prevailing today's used-car market. With the advent of the internet, we have seen a few solutions aiming to address these issues with the help of IT. Yet, while a simple IT-based electronic representation of the physical product might increase transparency and market efficiency in some industries (e.g. the travel market), this might not necessarily be true for others (mortgage market) (Granados et al. 2006). This is especially evident in markets where trust plays an important role. However, with the advent of blockchain technology, prior research has shown that this technology offers the capabilities to create trust-free solutions, hence increase transparency in the market for lemons through trusted car data (Beck et al. 2016; Notheisen et al. 2017a). While trust most certainly plays an important role between buyers and sellers in the second-hand car market, it is also relevant one level deeper, at the infrastructure layer. As we have learned from the review of prior literature, blockchain also facilitates trust between multiple (eventually competing) participants, and enables them to collaborate and provide comprehensive trusted car data, in the first place. Abstracting from our case it can be said that the need for blockchain must not only be for technical reasons but can also be explained by economic rationales. Blockchain enables multiple, also competing participants, to collaborate and jointly create a comprehensive and trusted data ledger without the threat of a novel centralized power. This is applicable to all ecosystems where the aim it is to digitize a good of high value and transfer the unique characteristics from the physical to the digital world and making the implicit knowledge explicit.

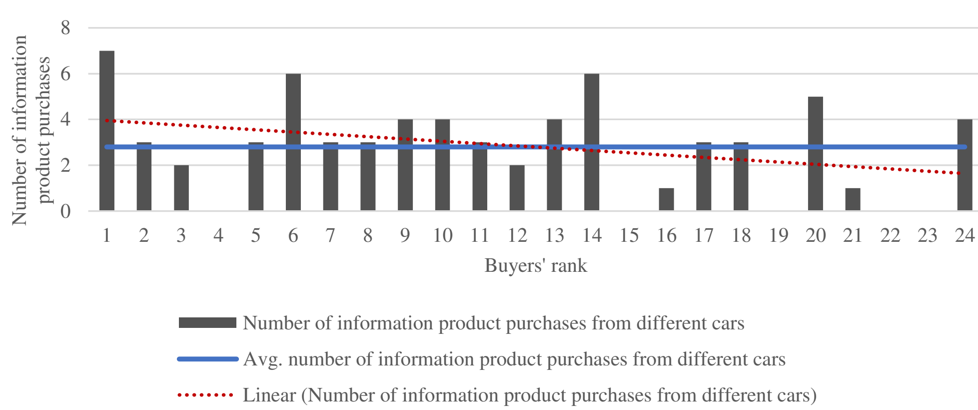


Fig. 3 Number of information product purchases by each buyer ordered according to their rank (Rank 1 = best performer, Rank 24 = worst performer)

Thus, building on these insights form prior research in our work, we explored the market potential of trusted car data through its ability to increase transparency in the market for lemons and the value it creates for market participants. In the following we will answer our research questions and discuss our results with in the light of prior research.

Increased transparency through trusted car data

In the introduction we raised the question whether or not we can increase transparency in the used-car market through trusted car data (RQ1). The results presented above show that we can. In particular. The increase in transparency in the market for used cars through trusted car data can be illustrated from both the buyers' and the sellers' perspectives. On the one hand, a lack of transparency and reliable information in the market for lemons makes it hard for buyers to tell the true quality and hence the real value of a car. This quality uncertainty results in the prices of used cars being either too high or too low (Wolinsky 1983). This effect was evident in the traditional round of our market game. The big variances in the prices for the used cars reflects the lack of transparency for buyers and hence their inability to evaluate the true quality of the used cars on the market. However, through the introduction of trusted car data, this changed drastically. The fact that the cars were now sold at prices that, in mean, deviated only −0.5% from their actual value, combined with the marginalization of outliers, greatly reflected the increase in transparency in the market and hence the ability of buyers to better evaluate the cars' quality. Besides that, a deeper assessment of the relationship between the performance of buyers and the number of information products that were consulted showed that those buyers who bought more trusted car data performed better than those who bought less. This leads us to infer that

Table 4 Experienced value of the trusted car data for seller and buyer

Role	Value Experience	Description	Code Unit Example
Seller	Quality Signaling	Sellers valued the ability to better signal the (good) quality of the car.	Seller (AM): *"I could just say more solidly that it's really worth more. That it has not only subjectively more value for me but objectively more value overall and refer to the cardossier that shows it is actually worth more than the market price and not just because I have the feeling that it is worth more."*
Seller / Buyer	Fairness	Both seller and buyer valued the overall situation as fairer for both parties.	Seller (RK): *"So I can't think of anything more that now I was able selling the car at a fair price."* Buyer (PE): *"I have the feeling that the purchase price was more substantiated, so that the seller could not just purely set up an estimate, but one could understand it much better, so I had the feeling that you are paying a fairer price with the cardossier then if you don't have that."*
Seller / Buyer	Efficiency Increase	Both seller and buyer experienced and valued increased efficiency in the trade process.	Seller (LB): "*Yes, actually, it makes the whole administration easier. So, it's faster, otherwise you have to do it yourself. If it is very random, then I could buy the car somewhere and access the card file and could pretty quickly determine the price at which I can sell it."* Buyer (BJ): "*Yes, it can certainly speed up and simplify the preselection process. You don't have to look at so many cars anymore."*
Buyer	Reduced Risk and Uncertainty	Buyers valued the ability to reduced risk and uncertainty in the sales process and in their purchasing decision	Buyer (DF): *"(...) the tedious part of whether you can believe him or whether the salesman does what he wants falls away. A large part of the uncertainty disappears."* Buyer (PE): *"In round two I was willing to pay more if you know what you can have."*
Buyer	Increased Transparency	Buyers experienced and valued increased transparency in the whole trade process	Buyer (NK): *"It (the cardossier) of course makes it overall more transparent in my opinion."*
Buyer	Informed Decision Making and Argumentation	Buyers valued the ability to inform their decision making and used trusted car use data as grounds for discussion	Buyer (TC): *"The cardossier data definitely helped with pricing decision (...) you can see how much added value it is and that's very helpful."* Buyer (NC): *"Yes, I took some information from the cardossier to argue my price, why I want to pay less."*

these buyers had greater market transparency and hence were able to better assess the true quality of the cars on the market. On the other hand, while in theory Akerlof (1976) argued that in free markets the effects of adverse selection will come in to play, since the prospect of negative rents will drive out sellers of peaches, in practice, other reasons might force sellers to stay in the market and inflect market prices. This was the case in our market game. As sellers were incentivized to maximize their relative revenue, they were better off selling their cars for less than their actual worth than withdrawing cars from the market. The big deviation of the sale prices from the actual values of the cars (−9,6% in the traditional market), as well as the poor achievements of the sellers (a mean relative revenue of −8,7%), also mirrored the effects of a lack in transparency through the inability of honest sellers to prove the quality of their cars (Pavlou and Dimoka 2008). This changed on the cardossier market, as mentioned above, and led to an increase in the relative revenue of the sellers. From the quantitative analysis we can only infer that there was an increase in transparency also from sellers' perspective due the better approximation of the sale prices to the actual value, however *how* this was achieved will be discussed in the following subsection.

Now, what does this increased market transparency mean for the used-car market? In general, prior research on the impact of IT argues that through the reduction of coordination costs and an increase in transparency, IT can lead to new markets, or the proliferation of existing ones (Granados et al. 2006; Malone et al. 1987). In our market game, we experimented with a closed market and a fixed number of buyers and sellers, hence no "additional" sellers or cars were able to enter the market. However, in line with the theory of Akerlof (1976), it could be argued that an increase in transparency could resolve the effects of adverse selection and result in an increase in the overall market value of used cars. This is because not only sellers of lemons and sellers who are forced to sell their car given other reasons would enter the market. Sellers of 'good quality' cars, who would otherwise withdraw from the market due to negative informational rents, now have an incentive to enter the market. Besides this prospect of market proliferation (through additional good quality used cars), which we can only infer form theoretical knowledge, we could see the emergence of a new market. The new market that emerged in our game was the market for trusted car data. On the one hand, we could measure this new market through the spending's that buyers and sellers paid for trusted car data from the cardossier IT artifact. The absolute value of this newly created market was estimated at USD 5130 for the 24 cars that were traded in the market, making an average USD 214 for each used car that is traded. While the absolute value of this newly created market for trusted car data is little meaningful, given that little emphasis that was placed on testing and evaluating different pricing methods, the suggestion that a market for trusted car data exists is greatly informative also for other domains.

Abstracting from our case, given its ability to created trusted data and hence a new market for trusted data, blockchain can also be of high relevance in other cases, where trust in data quality plays an important role. However, to understand the value of such a newly created data market better and also to derive implications for other domains, on the other hand, we followed up on this and, in the subsection below, we discuss how the perceived customer value of trusted car data indicated the potential of new data markets.

The value of trusted car data for market participants

Next to the question of whether or not we can increase transparency, we were also interested in how the market participants value trusted car data. We can answer this second research question through the value experiences that we derived from our qualitative analysis (Table 4). For sellers, the ability to signal the quality of their car was what they valued from the cardossier IT artifact. Buyers valued the ability to reduce risk and uncertainty, increase transparency, and the ability to make informed decisions and argumentations. In addition to these role specific value experiences, both user groups value that through the availability of trusted car data the overall trade process was experienced as fairer and more efficient. These results show that a blockchain-based IT artifact, that provides trusted car data in the market for lemons, is valuable for both buyers and sellers. While quantitatively buyers might seem as the loser of the game, since their relative revenue decreased in the cardossier market and on average they paid more for the same car, the qualitative results show no perceived disadvantages. On the contrary, the sellers valued not only increased transparency, as the quantitative analysis might indicate but also for example the reduction of risk and uncertainty. Also, prior research identified that risk hedging is of value for buyers. Thus, certain measures like guaranties, licensing and certificates were proposed (Akerlof 1970; Genesove 1993). However, while these measures enabled to reduce risk and quality uncertainty to a certain degree, they did not reduce inefficiencies (Bond 1982). Yet, with trusted car data from the cardossier IT artifact, buyers also experienced an increase in efficiency in the overall trade process. Besides that, trusted car data from the cardossier provides additional value through increased market transparency, that prior solutions like guaranties and certificates cannot. Through the access to trusted car data for multiple different cars buyers valued the ability to better assess the whole market, rather than hedging risk for only one certain car. This was also quantitatively measured (Fig. 3) and the insights from both, qualitative and quantitative analysis allows us to infer that those buyers who bought more information products were better able to assess the quality of the cars, thus performed better on the cardossier market.

Besides the value for buyers, this qualitative analysis also showed that trusted car data is also of value for sellers. Thus, while prior research mainly focused on the buyers' needs (Notheisen et al. 2017a; Zavolokina et al. 2018a) we were able to elicit that such a blockchain-based IT artifact is valued also by sellers. More specifically, based on the quantitative analysis we showed that sellers were able to sell their cars on average to higher prices in the market where the IT artifact was introduced. Combining these quantitative insights with the results from the qualitative analysis, we are now able to understand *why*. The increase in transparency is also valued by sellers because this enables them to signal the quality of their car. The ability to refer potential buyers to trusted car data helps sellers to argument more solidly and improve their sales achievements. Additionally, also sellers perceived the trade processes on the cardossier market as more efficient. This, can again be argued as a positive effect of increased transparency on the market that besides higher profits, creates additional value for sellers.

These insights from agents' view supports the argumentation from above, namely the potential of a market for trusted car data. While from the quantitative analysis, the willingness to purchase trusted car data, we were able to measure an indication for the potential of a new market. Through the insights from the qualitative analysis we have seen that trusted car data is positively valued by both buyers and sellers.

Yet, going back to the question of the role of blockchain, we can argue that while it is the underlying technology that enables to create a comprehensive car history record, the users during the interviews did not specifically mention the use of blockchain technology as a key value proposition, for them. This leads us again to the normative that blockchain can be viewed as an enabler for new products and services processes, which eventually might lead to the proliferation of new markets. However, the technology per se does not increase market transparency, but it rather depends on the design of the products and its positioning in the market.

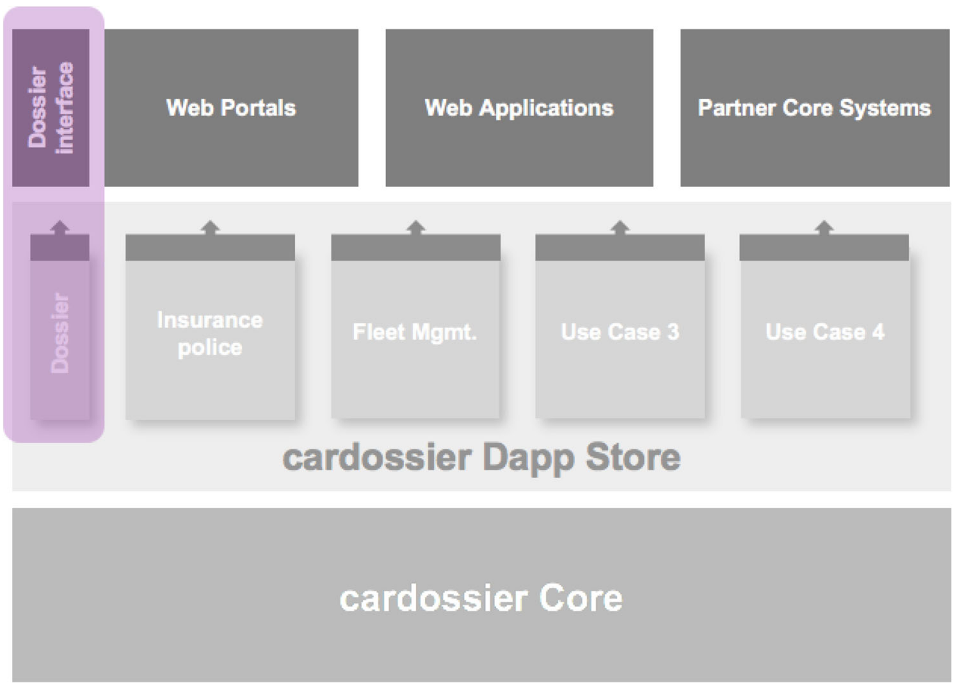
Conclusion

In this paper we have explored the market potential and the value experience of the application of a blockchain-based system in the used-car market. Through an exploratory study, including both quantitative and qualitative measures, we showed that there is a market for trusted car data that can increase transparency in the used-car trade, and answered RQ 1 (*Can we increase transparency in the used-car market through trusted car data?*). Further, we have deepened the understanding with respect to the core values of a blockchain-based application and provided an answer to our RQ 2 (*How do market participants value trusted car data?*) showing that both buyers and sellers value trusted car data. Finally, based on prior literature as well as the insight from this study, we respond to our overall question (*What is the role of blockchain for trusted car data in the market for lemons?*), and argue that the role of blockchain to be an enable for the creation of a novel product / service that was not possible before (e.g. a comprehensive, trusted car documentation). Hence, it rather indirectly affects the market through acting as facilitator between multiple stakeholder groups. These insights contribute on the one hand to academia, who claimed to lack rigorous scientific studies that qualify the disruptive potential of blockchain apart from its application as cryptocurrency. On the other hand, businesses for which we have shown that there is substantial market potential. Hence, supporting their ambitions and investments with respect to blockchain technology, by show that it eventually will pay off. Furthermore, from our research businesses can learn about user preferences and guide design directions that will enable to reap the value from the technology, in the used-car market, but also in other domains. However, this study needs to be seen in light of its limitations. Certainly, one shortcoming of this study is its reliance on one dataset (one user-group in one geographical location). While this might offer great insight for practitioners in and around Switzerland who specifically target young adults, it motivates further research in order to explore, for example, whether outcomes for other user groups (elderly not technically affine users) or other countries in Europe - or even world-wide – are similar. Despite our efforts to mitigate learning effects (by mixing-up the used cars that were assigned to the participants between the two game rounds), it could be argued that in the second round, the cardossier market users benefited from learning effects. However, since only one user-group (sellers) profited from higher relative revenues during the second round (while buyers lost significant amounts of their profits compared to the first round), we believe that the changes in car allocation, as well as the changes through the introduction of the IT artifact, mitigated any effects that might result from a repeated game. Nonetheless, we aim to address these limitations, continue our study, and test the result in other settings and reversed game ordering. Besides these methodological limitations, while we acknowledge the potential of blockchain, we also want to point the reader to the well-known saying: "garbage in, garbage out". For our study we relied on the fact that all data from the cardossier IT artifact is valid and can be trusted. While researchers have already started exploring these issues (Zavolokina et al. 2018b), we see further potential for research on a mechanism to ensure data quality in a blockchain system. Besides that, role of privacy is most certainly of great relevance when taking about trusted data that in great parts also includes (drivers') behavior data or data that can be related back to the car owner in some way or another. Thus, we encourage other researcher to study privacy aspects of car owners and mobility users with respect to blockchain-based systems. Finally, based on the assumption that all data and information products are of equal quality, we set the prices for equal and fixed. Another interesting aspect for future research can be to explore the effects of variable prices, for example. Overall, we believe that blockchain has the power to act as a key infrastructural resource, not only for trusted car data, but also data about other high value goods where trust is key. Therefore, with this study, we hope to inspire other researchers to explore the disruptive potential of blockchain on markets and its value for users.

Appendix

The cardossier Architecture

The figure below depicts the cardossier architecture. *Cardossier Core* is the blockchain-based storage and management of trusted car data. The *Cardossier Dapp Store* allow to develop decentralized applications which utilize the trusted car data from the core. In turn, these Dapps, are connected to external systems, such as web applications. However, in this study, we only used and focused on the effects of the cardossier as web app to support the buyers and sellers during the 2nd hand car sale.



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