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Value Creation and Capturing from a Decentralized Car Ledger

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The Faculty of Business, Economics and Informatics of the University of Zurich hereby authorizes the printing of this dissertation, without indicating an opinion of the views expressed in the work.

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ABSTRACT

Blockchain is often named one of the most disruptive technologies of the last decade and claimed to provide a solution to many of today's unresolved economic challenges. Besides the well-known example of bitcoin and similar attempts in the finance industry, another promising application of blockchain technology appears to be in the ecosystem of a car. Through comprehensive and trustworthy documentation of a car's history, researchers and practitioners expect to resolve information asymmetries between buyers and sellers in the used car market and optimize processes and customize services around the car. While there is general agreement about the potential of the technology to enable economic benefits, specifically in the car ecosystem and more broadly in many other industries, we are yet to understand *how* businesses can create and capture value from the technology. Instead, in practice, we observe that businesses developing blockchain information systems get lost in the complexity of their projects. These complexities, in many cases, lead to project delays and increasing development costs that hardly bear visible fruits. Consequently, businesses are increasingly questioning the value of blockchain and the value of their projects.

Without a clear understanding and corresponding design of blockchain information systems, the realization of business value from the technology is doomed to failure. Thus, motivated by the enormous potentials and equally sobering reality, this dissertation's goal is to address this research gap by studying *how value can be created and captured from blockchain technology, along with the example of a decentralized car ledger*. While it is clear that novel technologies can impact organizations and economic activities and thus enable them to create and capture business value, researchers argue that these achievements depend on the market environment and the specific socio-technical interactions that need to be understood and purposefully designed.

Applying explorative Design Science Research methods, this dissertation addresses the research gap through five essays that are guided by a socio-technical artifact framework (Chatterjee et al., 2020) and that jointly concatenate to an overarching in-depth understanding of how value can be created and captured from

a decentralized car ledger. To this end, **essay I** will first take a broad view of the technology's potential for the car ecosystem by analyzing the problems and potentials for businesses developing a decentralized car ledger. Based on these insights, a characterization of the specifics of blockchain value creation and guidelines and management approaches to realize these will be derived. By narrowing the focus on one of the identified value potentials (i.e., distributed product innovation), **essays II, III, IV, and V** will then explore, design, and evaluate the application of a decentralized car ledger (taking the form of a car history certificate) in a specific market context (i.e., the used car trade) through the means of a series of experimental market games. For one, **essay II** will prove that a market for car history certificates indeed exists and show how it enables the creation of value for its users (buyers and sellers of used cars). **Essay III** will deepen the insights on the value of multi-party certificates for users and show that multi-party car history certificates, as I will coin them, afford sellers the action potential to send signals of significantly higher fit. Further, essay III confirms and specifies that the increased ability to signal product quality reduces information asymmetries and increases market fairness in the used car market. Building on the insights from essay III, a novel design proposal for the offering and pricing of the multi-party car history certificates will be introduced in **essay IV**. The design will be evaluated regarding trade and revenue for its providers, thus offering valuable insights into how the created value can best be captured. Finally, **essay V** will again confirm the findings on the increase of market transparency, achieved through the introduction of multi-party certificates. It will specify how this affects transaction costs associated with bargaining and thus what overarching consequences we can expect for established and future businesses.

Jointly, these five essays contribute to academia and practice an *overarching understanding of the value potentials of blockchain technology for the car ecosystem and specific insights into how the application of a decentralized car ledger – in the particular market context of the used car trade that is currently suffering from information asymmetries – will enable businesses to create and capture value*.

On the one hand, this dissertation contributes to academia in-depth, well-grounded insights on the phenomena of interest (value creation and capture from blockchain) and paves the way for more substantial research on the value of blockchain information systems. On the other hand, these insights help businesses developing blockchain information systems to better understand the source of value creation from the technology and advance their development efforts through more targeted approaches.

ZUSAMMENFASSUNG

Blockchain wird oft als eine der bahnbrechendsten Technologien des letzten Jahrzehnts bezeichnet und soll eine Lösung für viele der heutigen ungelösten wirtschaftlichen Herausforderungen bieten. Neben dem bekannten Beispiel von Bitcoin, und ähnlichen Versuchen in der Finanzbranche, scheint eine weitere vielversprechende Anwendung der Blockchain-Technologie im Ökosystem eines Autos zu liegen. Durch eine umfassende und vertrauenswürdige Dokumentation der Autohistorie erhoffen sich Forscher und Praktiker, Informationsasymmetrien zwischen Käufern und Verkäufern auf dem Gebrauchtwagenmarkt zu reduzieren, Prozesse rund um das Auto zu optimieren, sowie Dienstleistungen für Kunden zu individualisieren. Obwohl allgemeines Einvernehmen über das Potenzial der Technologien zur Schaffung wirtschaftlicher Vorteile besteht, insbesondere im Auto-Ökosystem, aber auch in vielen anderen Branchen, ist die Frage, wie Unternehmen mit der Technologie Wert schöpfen und gewinnen werden, offen. Statt gezielten Entwicklungen, beobachten wir in der Praxis daher, dass Unternehmen, die Blockchain-Informationssysteme entwickeln, sich immer mehr in der Komplexität ihrer Vorhaben verlieren. Diese Komplexität führt in vielen Fällen zu Projektverzögerungen und noch mehr steigenden Entwicklungskosten. Infolgedessen stellen Unternehmen den Wert der Blockchain und den Wert ihrer Vorhaben immer mehr in Frage.

Es ist zwar klar, dass neuartige Technologien sich auf Organisationen und wirtschaftliche Aktivitäten auswirken können und sie somit in die Lage versetzen, geschäftlichen Wert zu schaffen und zu erfassen, die Forscher argumentieren jedoch, dass diese Erfolge vom Marktumfeld und den spezifischen soziotechnischen Interaktionen abhängen, die verstanden und zielgerichtet gestaltet werden müssen. Ohne ein klares Verständnis und ohne ein entsprechendes Design der Blockchain-Informationssysteme ist die Realisierung des geschäftlichen Nutzens der Technologie somit zum Scheitern verurteilt. Motiviert durch das enorme Potenzial der Technology, aber auch durch die ernüchternde Realität vieler derzeit laufenden Blockchain Vorhaben, ist das Ziel dieser Dissertation die

Untersuchung, wie mit der Blockchain-Technologie im Automobil-Umfeld Werte geschaffen und erfasst werden können.

Unter Anwendung von Design Science Research Aktivitäten adressiert diese Dissertation die Forschungslücke durch fünf Aufsätze. Diese fünf Aufsätze sind geleitet durch ein sozio-technisches Artefakt-Rahmenwerk von Chatterjee et al., (2020). Die Ergebnisse der fünf Aufsätze ergeben dann gemeinsam ein zusammenhängendes, tiefgehendes Verständnis über die Wertschöpfung und -erfassung von einem Blockchain Informationssystem im Automobil Ökosystem. Konkret wir zu diesem Zweck in **Aufsatz I** zunächst ein breiter Überblick über die Potenziale der Technologie für das Auto-Ökosystem gegeben. Dazu werden zunächst die aktuellen Probleme von Unternehmen im Automobil-Umfeld und die Potenziale der Technologie diese zu adressieren, analysiert. Darauf aufbauend wird eine Charakterisierung der Besonderheiten der Blockchain-Wertschöpfung, sowie Richtlinien und Managementansätze zu deren Realisierung abgeleitet. Die nachfolgenden **Aufsätze II, III, IV** und **V** fokussieren sich auf eines der identifizierten Wertschöpfungspotenziale (konkret verteilte Produktinnovation) und erforschen, gestalten und bewerten dessen Einflüsse in einem spezifischen Marktkontext (konkret: die Auswirkungen eines Fahrzeug-Historienzertifikates im Kontext des Gebrauchtwagenmarktes). Zum einen wird in **Aufsatz II** nachgewiesen, dass ein Markt für Fahrzeug-Historienzertifikate, die auf Basis des Blockchain-Informationssystems erstellt werden, tatsächlich existiert und dass diese einen substantiellen Mehrwert für dessen Nutzer (Käufer und Verkäufer von Gebrauchtwagen) schaffen. In **Aufsatz III** werden die Erkenntnisse über den Mehrwert von Fahrzeug-Historienzertifikaten für die Nutzer vertieft, indem genauer beleuchtet wird, wie Fahrzeug-Historienzertifikate erstellt werden und wie diese Verkäufern das Handlungspotenzial bieten, Signale von höherer Passgenauigkeit über der Qualität der Fahrzeuge zu senden. Daraus wird auch die Definition der Mehrparteien-Zertifikate abgeleitet. Zum anderen wird gezeigt, wie diese zu einer Reduktion der Informationsasymmetrien auf dem Markt und zu einer Erhöhung von Fairness auf dem Gebrauchtwagenmarkt führt. Aufbauend auf den Erkenntnissen aus Aufsatz III wird im folgenden **Aufsatz IV** ein neuartiger Gestaltungsvorschlag für das Angebot und die Preisgestaltung der Mehrparteien-Zertifikate vorgestellt. Er wird im Hinblick auf dessen Handel und die daraus resultierenden Einnahmen für dessen Anbieter evaluiert. Dies bietet wertvolle

Erkenntnisse darüber, wie der neu geschaffene Wert am besten erfasst werden kann. Schließlich werden in **Aufsatz V** die Ergebnisse zur Erhöhung der Markttransparenz durch die Einführung von Mehrparteien-Zertifikate nochmals bestätigt und spezifiziert. Konkret wird geprüft, wie sich erhöhte Markttransparenz auf verhandlungsbezogene Transaktionskosten auswirkt und welche übergreifenden Konsequenzen sich daraus für etablierte und zukünftige Unternehmen ableiten lassen.

Gemeinsam bieten diese fünf Aufsätze für Wissenschaft und Praxis ein übergreifendes Verständnis der Wertepotenziale der Blockchain-Technologie für das Auto-Ökosystem und spezifische Erkenntnisse darüber, wie die Anwendung eines Mehrparteien-Zertifikates im Kontext des Gebrauchtwagenhandels, der derzeit unter Informationsasymmetrien leidet, Unternehmen in die Lage versetzen wird, Werte zu schaffen und zu erfassen.

Einerseits liefert diese Dissertation der Wissenschaft fundierte Erkenntnisse zu den unerforschten Phänomenen (Wertschöpfung und -erfassung durch Blockchain) und ebnet den Weg für weitere tiefgehende Forschungsarbeiten über den Wert von Blockchain-Informationssystemen. Andererseits helfen diese Erkenntnisse Unternehmen, die Blockchain-Informationssysteme entwickeln, die Quelle der Wertschöpfung durch die Technologie besser zu verstehen und ihre Entwicklungsbemühungen durch gezieltere Ansätze voranzutreiben.

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Research is a collaborative endeavor, and I was lucky enough to work with many great researchers during my dissertation, especially from the Information Management Research Group (IMRG) of the University of Zurich and other groups at UZH, or even from other Universities.

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SYNOPSIS

1 Introduction

1.1 Research Context: Blockchain Hype vs. Reality

Blockchain technology is expected to revolutionize businesses or even entire industries (Tapscott & Tapscott, 2016). Blockchain or, in broader terms, distributed ledger technology (DLT) (Babich & Hilary, 2020), is a combination of technologies (Treiblmaier, 2019), including, at its core, a distributed system architecture, a decentralized network-based consensus mechanism, and an inherent cryptographic logic (Zheng et al., 2017). Jointly, these mechanisms enable the recording of transactions in a decentralized and tamper-proof manner (Avital et al., 2016), create unique digital records (Miscione et al., 2020), and ensure traceability and trust in transactions (Marella et al., 2020). Thus, the technology creates economic benefits by reducing transaction costs and dissolving information asymmetries (Beck et al., 2017). Businesses in various industries are joining forces and forming blockchain consortia (Gratzke et al., 2017) to experiment with the technology, aiming to transfer its potentials to their domain and create some form of new business value for markets and customers (Schlecht et al., 2021). The tremendous and still increasing investments in the technology confirm and quantify these interests and the hopes of businesses. According to the International Data Corporation (IDC), worldwide yearly blockchain spending is forecast to reach nearly $6.6 billion, indicating an increase of more than 50 percent from 2020 to 2021.

Despite the great promise of the technology for various businesses and the ever-increasing investments made by these businesses, we are yet to see any successful real-world application achieve wide-scale adoption and create substantial business value beyond that of cryptocurrencies (Schlecht et al., 2021). Rather, many blockchain projects are running behind expectations, and many practitioners and academics are struggling to understand *how they will create and capture business value from blockchain technology* (Frizzo-Barker et al., 2020; Melis, 2019). The problem stems from the powerful but highly complex nature of blockchain information systems (The Economist, 2021). Blockchain consortia tend to lose development focus and get lost in the promising but complex nature of their projects (Upadhyay, 2020). This results in untargeted development expenses and project delays, and it makes the stakeholders of blockchain projects question the necessity and value of blockchain technology (Angelis & Ribeiro da Silva, 2019). Consequently, blockchain projects get discontinued, and the spending up to that point is lost.

While it is clear that novel technologies can have a direct impact on organizations and economic activities, and thus business value can be created and captured from them, researchers argue that the effects do not occur automatically but are the result of specific design decisions (Hevner et al., 2004; Klein & Alt, 2015). Particularly for complex problems, like the one at hand, there is no “one best” solution, but a set of heterogenous arrangements that depend on the market environment and the specific socio-technical interactions that need to be understood and purposefully designed (Sarker et al., 2019).

This dissertation addresses this gap in research through five tightly connected essays on the topic of value creation and capturing from blockchain technology, along with the example of a decentralized car ledger. The essays are guided by a socio-technical artifact framework and jointly concatenate to an overarching in-depth understanding of how value can be created and captured from a blockchain information system, using the example of a decentralized car ledger. Chapter 1.2 will introduce the specific context (i.e., the application of blockchain in the car ecosystem) that this dissertation studies and the practical problems observed in a real-world blockchain project (i.e., the Cardossier Project) that motivated this dissertation. Next, chapter 1.3 introduces the socio-technical artifact framework that guides the solution approach and enables merging the individual essays' contributions in an overarching understanding. Finally, the research goals will be specified in chapter 1.4.

1.2 Blockchain in the Car Ecosystem: The Cardossier Project

Introduced along with the case of peer-to-peer (P2P) electronic cash by Nakamoto (2008), blockchain technology has found its way into various business domains. One prominent example that has gained major attention from academia and practice is the application of blockchain to mitigate problems of information asymmetries in the used-car market (Notheisen, Cholewa, et al., 2017). The challenges prevailing in today's used car market are the lack of transparency and trust, which cause market inefficiencies and, as a result, a decreasing value generated in these markets (Akerlof, 1970). Building on blockchain technology, data integrity and compatibilities can be ensured, fostering data sharing among businesses while controlling transaction costs (Sarker et al., 2021; Zavolokina, Ziolkowski, et al., 2020). This enables multiple parties to collaborate and create trusted, decentralized product history certificates that draw on the data sources of many agents (Bauer et al., 2020). Developing a vehicle history certificate for each car is expected to mitigate problems of information asymmetries between buyers and sellers of a used car (Bauer, Zavolokina, & Schwabe, 2019), but also to increase the efficiency of sales-related processes for used car dealers (Baumann et al., 2021) and to fight fraud, such as insurance fraud (Beck et al., 2017). Experts from the car ecosystem are certain about the technology's disruptive potential. They claim only those who can understand these potentials and adapt their business models accordingly will survive (Jones et al., 2018). However, without a clear understanding of the technology's potentials for the respective ecosystem and a corresponding design of its application(s) in the market context, the realization of value from the technology is doomed to failure (Zwass, 2021).

The Cardossier Project is a real-world blockchain project that exemplifies how the problems of businesses (involved in the development of a decentralized car ledger) unearthing the value of blockchain technology instantiate in practice. The Cardossier project was initiated as an Innosuisse (Swiss Innovation Agency) research project in November 2017 to transfer the potentials of blockchain technology to the automotive ecosystem. By building a decentralized car ledger that documents all relevant events that occur during the life cycle of a car (as also proposed by prior research (Notheisen, Cholewa, et al., 2017)), the involved stakeholders hoped to create novel business opportunities. The initial founding members included car-related businesses (the importer and car retailer AMAG, the insurance company AXA Winterthur, and the mobility service provider Mobility), a governmental agency (the Road Traffic Authority from the canton of Aargau), a software consultancy (AdNovum), and two universities (the University of Zurich and the Hochschule Luzern). While the initial goal of the consortium was to address the issues of information asymmetries during used car sales (more generally known as the “Market for Lemons” problem initially formalized by Akerlof, (1970)), the scope quickly expanded, and the development focus got blurred as the consortium started prototyping with the technology. On the one hand, the members discovered many problems or prerequisites that needed to be resolved to achieve their initial target case. On the other hand, businesses found various business potentials with the technology, such as resolving cross-organizational inefficiencies (Bauer, Zavolokina, Leisibach, et al., 2019), which quickly became more interesting for the involved business stakeholders than the initial use case. This business value tension (improving integration and operational efficiencies vs. improving market transparency (Zavolokina, Ziolkowski, et al., 2020)) led the consortium to jump back and forth between the development of different applications, and the development costs increased rapidly without delivering any visible results. To continue to finance the development costs after innovation funding ended, an association was founded and further car-related businesses and public agencies were invited to join the consortium, which, in turn, provided new funds through the means of membership fees. While this provided a short-term solution for the Cardossier consortium, the question of whether and how businesses can sustainably create and capture value from a decentralized car ledger remains open. It increases in urge as the consortium is again running short on funding. Besides the risk of running short on capital, the risk of essential stakeholders leaving the consortium rises as they increasingly question whether and how their investments are worthwhile.

Thus, studying *how value can be created and captured from a decentralized car ledger* is of great academic and practical relevance, which is where this dissertation commences.

1.3 Guiding Socio-Technical Perspective

Technology per se never has a direct impact on businesses; it is rather the socio-technical interplay that can unleash technical potentials in specific social contexts (Briggs et al., 2010). Thus, for the purpose of this dissertation, the socio-technical perspective, which lies at the heart of the information systems discipline, is best suited to structure and guide the study *of value creation and capturing from a decentralized car ledger*.

The socio-technical perspective is often described as the distinctive and coherent foundation of the information system's discipline (Sarker et al., 2019). It regards equal relevance to the technical artifact and the tasks and structures of the group of developers and users of the artifact in the social context. Besides that, information is regarded to impact and be impacted by this socio-technical interaction (Sarker et al., 2019), and the outcomes are described as the results of the interaction between these two central systems (Briggs et al., 2010). To help researchers practically apply a socio-technical perspective and structure their research, the use of an IS/IT artifact is often proposed (Akhlaghpour et al., 2013; Benbasat & Zmud, 2003). However, many IS/IT artifact conceptions today lack the very essence of the IS discipline, namely information (Hassan, 2011; Mingers & Standing, 2018). Yet, especially today, with the growing relevance of information in areas such as artificial intelligence, blockchain, and big data (Agarwal & Dhar, 2014), a proper understanding and analysis of the information element is essential. Addressing this research gap and aiming to help researchers practically apply a socio-technical IS perspective, Chatterjee et al. (2020) introduced a theoretical conception of an IS artifact, thereby granting information an explicit role (see Figure 1). This conception of an IS artifact follows the notion of the socio-technical view, and even more concretely integrates and explains the role of information. While general agreement exists that next to the interaction of the social and technical ends, information represents a central element of the IS field, it has so far mainly been neglected or not addressed adequately given its importance. In line with prior research (Nunamaker et al., 2015; Nunamaker, Jr. & Briggs, 2011), however, Chatterjee et al. (2020) argue that even if technologies fade or get replaced, information persists and gains increasing relevance that needs to be adequately addressed.

Figure 1 below represents the reference model, which serves as a compass for this dissertation by directing the elements that need to be studied and providing a frame in which the individual findings documented in the essays can merge. Its elements are explained in more detail below.

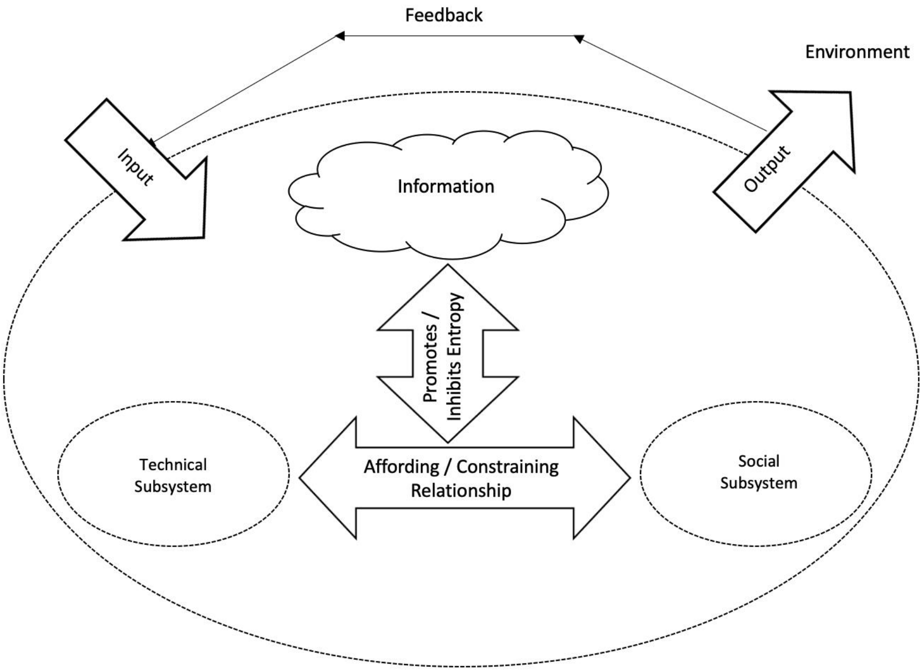

Figure 1. IS Artifact Reference Model (adapted from Chatterjee et al. (2020))

The core components of the reference model are the technical subsystem (i.e., the necessary techniques, tools, and systems that enable us to transform inputs to outputs to enhance organizational performance) and the social subsystem (i.e., the individual actors or groups and their knowledge, skills, structures, and relationships, etc.), as well as the information that shapes and is shaped by the interaction of the two subsystems. While the social and technical subsystems are in an affording/constraining relationship with each other, information is positioned as *"a defining and emergent property of the superordinate system that shapes, and is shaped by, how the social and technical subsystems interact."* (Chatterjee et al., 2020, p.7). Thus, information is a fundamental systemic character of the interaction of the social and technical subsystems and can play multiple roles (Henfridsson & Bygstad, 2013). Information can be a medium, mediator, or outcome of the interaction of the social and technical subsystems. Regardless of its role, the fundamental salience of information is to reduce entropy (i.e., the level of uncertainty and disorder in the system) (Swanson et al., 1997). While both high and low entropy are beneficial, it is important to note that they produce different outcomes. When entropy between the social and technical subsystems is high, subsystems find innovative ways to reduce entropy and thus create innovations. In contrast, *“when entropy is low, subsystems work in tandem and produce outcomes”* (Chatterjee et al., 2020, p.11).

Further, as represented through the dashed lines, the subsystems are malleable and interact with the surrounding and changing environment and, potentially, with other subsystems. Finally, represented at the top of the model, the feedback loop emphasizes an IS artifact's dynamic nature and the exchange with the environment through receiving inputs and producing outputs. More precisely, it allows information to be fed back regarding the system's output as new input, which might lead to changes in the transformation process affecting subsystems and/or information.

In the context of this dissertation, the IS artifact will serve as a reference model that guides the approach to address the goals of this dissertation and structures the findings of the individual studies.

1.4 Research Goal

Motivated by the highly praised potential of the technology, and specifically the potential it offers for the car ecosystem set against the equally sobering reality the overarching goal of this dissertation is to study *how value can be created and captured from a decentralized car ledger*.

To achieve this goal, first and foremost, a comprehensive understanding of the environmental context that initiates and drives engagement with the technology needs to be developed (Sarker et al., 2019). This includes a thorough understanding of the specific driving problems (i.e., input) and the desired value potentials (i.e., outputs) that businesses aim to achieve with the technical characteristics and capabilities of the technology (i.e., the technical subsystem). For my dissertation, I have chosen to study the value potentials of blockchain along with the example of a decentralized car ledger introduced above, as it is one of the furthest developed blockchain projects so far and currently one of the most promising in the European market (Zavolokina, Ziolkowski, et al., 2020). Thus, the first sub-goal of this dissertation is to:

(1) Develop an understanding of the value potentials of a decentralized car ledger for the car ecosystem.

Providing a comprehensive understanding of the environmental context and, specifically, in-depth insights into the technology's versatile yet unique value creation potentials establishes the necessary ground to dig deeper afterward (essay I).

As mentioned, blockchain technology offers a variety of potentials to businesses in general, and the insights from this first study (essay I) will also suggest potentials specifically for the car ecosystem. Thus, based on a thorough understanding of the value potentials and approaches that enable realizing and leveraging these, this dissertation will pick one of these potentials and more closely study how value can be created and captured in the specific narrowed context. I have chosen the application of a decentralized car ledger to mitigate the problems of information asymmetries in the used-car market first because it offers one of the greatest areas of potential for all participating businesses working on the development of a decentralized car ledger (essay I). Second, it reflects the peculiarities of a larger class of problems (i.e., markets characterized by information asymmetries (Akerlof, 1970)). Thus, it will provide valuable insights for a variety of businesses working on developing a decentralized car ledger and businesses working on similar projects that aim to address issues of information asymmetries through the adoption of blockchain technology. Having identified and narrowed the environmental context, the specific socio-technical interactions need to be understood and purposefully designed (Chatterjee et al., 2020) to achieve the goal of business value generation. This incorporates an iterative analysis of the affording constraining relationship of the technical and social subsystems and the information element while considering the output that is again fed back as input and helps narrow the solution space. Thus, the second sub-goal of this dissertation is:

(2) Study how the application of a decentralized car ledger in the used-car market will enable businesses to create and capture value.

This second sub-goal will be addressed as proposed iteratively through four essays and thereby iteratively develop an in-depth understanding of how the socio-technical interactions shape each other and how they enable businesses to create and capture value (essays II, III, IV, and V). The individual studies will build on each other and the insights gained from one study will be deepened in the next. Respectively some studies will focus on some elements of the socio-technical IS artifact framework more than others. However, jointly these essays will form an in-depth, comprehensive understanding and address the second-sub goal of this dissertation.

All in all, addressing these two goals will contribute to both academia and practice a profound *understanding of the value potentials of blockchain technology* from a more general perspective and provide more specific insights and generalizable guidelines on *how the application of a decentralized car ledger in the used-car market will enable businesses to create and capture value.*

2 Methods

2.1 Guiding Research Paradigm

Departing from the above described abstract problems of businesses involved in blockchain projects in unearthing the value of blockchain technology, which I also find evidence for in the instance case of the Cardossier project (Lee et al., 2011), Design Science Research methods (DSR) are the best suited to guide the task of solving practical problems with the design of new IT artifacts (Hevner et al., 2004; March & Smith, 1995). DSR originates from the computer and engineering sciences and embodies an iterative process that may result in concepts, models, or instantiations of the targeted IT artifact or parts of it (Hevner et al., 2004; Peffers et al., 2007). This iterative process incorporates three related cycles – Relevance, Rigor, and Design (Hevner, 2007) – that iterate between or within three pillars (Environment, Design, and Knowledge Base) (Hevner et al., 2004). The *Relevance Cycle* concerns the gathering of requirements from the field. It thereby provides insights from the environment pillar (application domain and problem space) to the actual design pillar and, in turn, designs for and tests the built and designed artifacts in the environment. The *Rigor Cycle* provides grounding theories, frameworks, and methods from the knowledge base to inform the design and, in turn, adds new knowledge to the knowledge base through design actions. Finally, the core *Design Cycle* centers around constructing and evaluating artifact designs within the design pillar.

Overall, the essays presented in this dissertation each iterate through these three cycles and build on the three pillars. Thereby a deep understanding of the phenomena of *value creation and capturing from a decentralized car ledger* is established, and design know-how is iteratively derived and deepened. More specifically, to address the first research goal (1) in **essay I** of this dissertation, I apply a long-term exploratory case study analysis along with a real-world blockchain project (the Cardossier project) and focus on eliciting the problems and defining general objectives for the solution design. This allows me to discover and describe blockchain value potentials along with the case of a decentralized car ledger but also enables generalization to other contexts. To address the second goal (2), I apply a series of experimental market games (CarMarket Game) that allow to concatenate in-depth insights on the design for value creation and capturing from a decentralized car ledger in the specific used-car market context. The findings and the evolution of the insights from these market games are documented in **essays II, III, IV,** and **V** of this dissertation. At their core, these essays draw on theoretical concepts or use theoretical modeling to guide the design and apply exploratory experiments to evaluate them. The subsequent chapters detail the DSR activities and introduce the studies that served data collection.

2.2 Approaches to and Studies of DSR Activities

<u>Exploratory Long-term Case Study Analysis along with the Cardossier Project</u>

Motivated by the general problems of businesses in practice, struggling to understand the specifics of value creation from blockchain technology, and interested in the specifics of the car ecosystem, I conducted a long-term exploratory case analysis of a real-world project. The case under investigation was the Cardossier project introduced above. I studied the Cardossier project with two another Ph.D. candidates (Dr. Liudmila Zavolokina and Dr. Rafael Ziolkowski). As mentioned, the Cardossier project was initiated as an Innosuisse project, including four industry partners, a public agency, and two universities. The Innosuisse project lasted for 27 months, starting in October 2017 to December 2019. After that, in March 2019, the Cardossier association was founded. The research team that had co-initiated and worked in the Cardossier project remained a member of the Cardossier association until the end of 2020. The Cardossier went live in 2020, and the number of members is growing steadily.

To explore the value potentials of blockchain technology in the car ecosystem and the approaches required to realize them, I conducted three rounds of interviews and workshops together with my collaborators on this project. These were conducted over a period of two years, with industry and blockchain experts from four diverse stakeholder groups. For this exploratory long-term case study, I utilized theoretical concepts from prior theoretical research (the value lens of Treacy & Wiersema (1993)) to inform my analysis and developed these further concerning blockchain technology. These activities allowed me to contribute to the first goal of my dissertation, the development of an understanding of the value potentials of blockchain, along with the example of a decentralized car ledger (essay I). A detailed description of the specific methodological approach is provided in essay I.

Within the Cardossier Innosuisse project, I had two core roles. In the first, I was responsible for driving the business model-related work packages. In the second, together with my research team, I acted as a business analyst translating business requirements into technical demands. In addition to these core roles, I acted as Scrum Master for the development team and supported further operational activities within the project, such as preparing and conducting project meetings and marketing the project as a speaker in various workshops, seminars, and conferences. Next to the findings documented in essay I and published in a conference paper and subsequently developed further into a journal publication, my engagement in this project resulted in two other co-authored publications that have shaped my knowledge in this field:

(1) Oliveira, L., Zavolokina, L., **Bauer, I.,** & Schwabe, G. (2018), *"To Token or not to Token: Tools for Understanding Blockchain Tokens."* International Conference on Information Systems (ICIS). Proceedings. 5. https://aisel.aisnet.org/icis2018/crypto/Presentations/5
Note: The publication got the second runner-up best paper award at the ICIS conference.

(2) Zavolokina, L., Ziolkowski, R., **Bauer, I.,** & Schwabe, G. (2020), *"Management, Governance, and Value Creation in a Blockchain Consortium,"* MIS Quarterly Executive Vol. 19, Iss. 1, Article 3, (March 1, 2020). DOI: 10.17705/2msqe.00022.

CarMarket Game Experiments for Exploration, Design, and Evaluation

To study the specific value creation and capturing processes from a decentralized car ledger applied to the used-market context, and thus to address the second research goal (2) another core activity during my dissertation comprised multiple exploratory experiments. These exploratory experiments built on the insights derived during the first activities and documented in essay I, and explored, designed, and evaluated the most promising application of a decentralized car ledger (a car history certificate) in the market context. Also, building on further well-founded theoretical concepts and frameworks, these experimental activities allowed me to explore the effects of different design choices, test propositions, and reveal previously unknown phenomena and patterns of correlations by concatenating knowledge from the sequence of experiments. The findings of these activities are documented in essays II, III, IV, and V of this dissertation. To conduct sound experimental research, together with a colleague from the information management research group (Andreas Engelmann), we developed an experimental market game.

The experimental market game, in the following called **CarMarket**[1]**,** simulated the used-car market. CarMarket allowed us to embed a simplified version of an

[1] Please note, that the naming of the market game differs in essay II. Initially, and thus in essay II the market game was named Gooo. Later, and therefore in essay III, IV, V it was renamed to CarMarket.

application of the decentralized car ledger, in the following called **CarFile**[2], into the market and to evaluate different features and designs of it, test theoretically derived propositions, and explore its market effects. Experimental techniques within DSR research enable the designer to explore market dynamics and agents' behavior, informing early the design of novel systems (Briggs & Schwabe, 2011; Roth, 2002). CarMarket was implemented as a rebuilt of the existing and well-established used-car market platform AutoScout24. For this, we were granted access to all relevant information by AutoScout24. While AutoScout24 offers a variety of additional services in addition to buying and selling used cars, for our study, we minimized the rebuilt platform to the core functionalities relevant for testing the IT artifact CarFile. The specific functions varied according to the research objectives of the individual studies and were constantly refined and reevaluated as new insights emerged. A specification of these and a thorough description of how the validity of the individual experiments was assured can be found in essays II, III, IV, and V, respectively.

For three years, I was the project lead for the CarMarket study. Also, I was primarily responsible for the system design, the preparation and execution of experiments, and the analysis of the data for the respective studies included in this dissertation. Next to the findings documented in essays II, III, IV, and V and published or submitted articles, my engagement in these experimental activities also resulted in two other co-authored publications that have shaped my knowledge in this field:

(1) Engelmann, A., **Bauer, I.**, Dolata, M., Nadig, M., & Schwabe, G., *"Promoting Less Complex and More Honest Price Negotiations in the Online Used Car Market with Authenticated Data*," Group Decision and Negotiation (January, 2022). https://doi.org/10.1007/s10726-021-09773-8

(2) Engelmann, A., **Bauer, I.**, & Schwabe, G., *"Exploring and designing the used-car market of the future."* **Note**: working paper.

[2] Please note, that the naming of the IT artifact differs in essay II. Initially, and thus in essay II the artifact was named cardossier. Later, and therefore in essay III, IV, V it was renamed to CarFile.

3 Overview of Research Essays

3.1 Dissertation Structure

As mentioned earlier, rather than being rigid, a socio-technical system is a constantly evolving system that, in turn, changes socio-technical interactions through new inputs and can lead to new or better outputs. In my dissertation, I use the socio-technical artifact framework of Chatterjee et al., (2020) as a guiding frame to develop a comprehensive understanding of *how value can be created and captured from a decentralized car ledger*. Therefore, the socio-technical artifact framework for a decentralized car ledger is subsequently developed through the insights gained in each essay and constantly refined through concatenation of the insights. In the following, the five essays are introduced.

Essay I address the first sub-research goal (1) through the means of a long-term, exploratory case analysis of the Cardossier project. It contributes an overarching understanding of the environment in which the socio-technical interaction is to evolve and be embedded; the current problems that businesses in the car ecosystem face, and which consequently serve as driving inputs to experiment and innovate with blockchain technology (i.e., the technical subsystem); and, consequentially, the specific value creation potentials (i.e., targeted outputs) that businesses seek with the technology (i.e., technical subsystem). This analysis results in a characterization of the blockchain value potentials, which are: Distributed Product Innovation, Shared Operational Efficiency, and Controlled Customer Intimacy. Besides that, recommendations for businesses regarding how to leverage each blockchain value potential and how blockchain projects should approach multiple blockchain value potentials are derived.

The subsequent essays II, III, IV, and V, as mentioned, utilize exploratory experiments and address the second sub-research goal (2). They analyze one of the value potentials and iteratively study the narrowed context and the specifics of the socio-technical interaction that will enable business value creation and capturing. More specifically, essay II instantiates and analyzes the blockchain value potential distributed product innovation regarding the application of a decentralized car ledger offering car history certificates in the used car market to address information asymmetry problems. Thus, essay II digs deeper into the narrowed environmental context of applying a decentralized car ledger to mitigate the problems of information asymmetry (i.e., input/output) and develops a first general understanding of the socio-technical interaction from which value will be generated and leveraged. The results provide the first evidence that the promised and desired output of increased market transparency in the used car market can indeed be achieved by introducing trusted car data provided by a blockchain. Besides that, essay II offers the first indication of the value-generating socio-technical affordances (e.g., signaling product quality or informed decision-making and bargaining) for sellers and buyers of used cars. Building on the promising results of essay II, essay III deepens the proposed value-generating action potential of blockchain-based car history certification (i.e., trusted car data) for sellers to signal product quality by analyzing in-depth the socio-technical interaction that affords this action potential. This results in a theoretical model that studies the induced changes in the social subsystem and information element through the introduction of multi-party certification (blockchain-based car history certification) and provides hypotheses about market outcomes that are then experimentally confirmed. Essay III thus deepens prior results with regard to increased market transparency and refines them by showing how specifically they are achieved. While a thorough understanding of how value can be created from a decentralized car ledger applied in the used-car market context is established through essays II and III, essay IV follows up on these insights and studies how this value can best be captured. It builds on the insights from essay III, which specifies that value is generated by affording sellers the action potential to send signals of higher fit, and incorporates it into the application design (technical subsystem). A user-controlled offering and pricing concept for the offering of car history certificates (technical subsystem) is thus proposed and evaluated. The results from the experimental market game confirm that trade and revenue for the certificate providers can indeed be increased (output) by granting sellers control over offering and pricing, and thereby increasing their ability to signal product quality. Besides that, essay IV explains why the new possibility of trading information goods can be related back to the tokenization property of the data provided by the blockchain. Finally, essay V rounds up this dissertation by ensuring that saturation is reached regarding the insights on increased market transparency and its value for users. Further, essay V zooms out from the socio-technical interaction by taking up prior indications about the consequences of increased market transparency for established businesses (that base their business on mediating the market) and future businesses. It deepens these insights by taking another loop through the socio-technical system and analyzing the impact of increased market transparency, achieved through multi-party certification (i.e., tokenized information), on the bargaining activities of buyers and sellers. In short, essay V shows that the overarching consequences of increased market transparency (i.e., new input) leads to lower barging costs and more efficient outcomes (i.e., new output), and thus deters established intermediaries, which in turn favors the establishment of decentralized market platforms (i.e., changes in the environment that are fed back again as new input).

In sum, these five essays develop an in-depth understanding *of how value can be created and captured from a decentralized car ledger*. Table 1 provides a summary overview of the associated journal articles (partly published, partly under review) that the five essays build on and their contributions.

Table 1. Thesis Structure

Associated papers that the essays build on	**Contributions**
I. Bauer, I., Zavolokina, L., Leisibach, F., & Schwabe, G. (2019), "*Value Creation from a Decentralized Car Ledger,*" Frontiers in Blockchain (January 23, 2020). https://doi.org/10.3389/fbloc.2019.00030 **Note**: Previously published in the proceedings of the Hawaii International Conference on System Sciences (HICSS), then developed into a journal publication for *Frontiers in Blockchain*.	• Development of an understanding of the car ecosystem (environmental context), the driving problems of businesses and individuals (inputs), and the technical characteristics and capabilities (technical subsystem) that eventually enable blockchain value creation (outputs). • Characterization of the specifics of blockchain value creation, resulting in the three value potentials: Distributed Product Innovation, Shared Operational Efficiency, and Controlled Customer Intimacy. • Recommendations for businesses for leveraging each blockchain value potential and how blockchain projects in ecosystems should approach multiple blockchain value potentials.
II. Bauer, I., Zavolokina, L., & Schwabe, G., *"Is There a Market for Trusted Car Data?"* Electronic Markets Journal, September 13, 2019. https://doi.org/10.1007/s12525-019-00368-5	• Instantiation and in-depth analysis of the blockchain value potential (distributed product innovation) in the used car market. • Development of a general understanding of the socio-technical interaction in the narrowed environmental context of the used-car market. • Confirmation that the promised and desired output can indeed be achieved (the reduction of information asymmetries in the used car market). • The first indication of the value-generating socio-technical affordances (signaling product quality) for sellers and buyers of used cars.

III. Bauer, I., Parra-Moyano, J., Schmedders, K., & Schwabe, G., *“Multi-party Certification on Blockchain and its Impact in the Market for Lemons,”* Journal of Management Information Systems, 39 (2), Spring 2022.	• Deepening of prior indicated affording action potential of blockchain-based car history certification (i.e., trusted car data) for sellers to signal product quality by analyzing socio-technical interaction in-depth. • Theoretical analysis of the induced changes in the social subsystem and information element through the introduction of multi-party certification (blockchain-based car history certification). • Experimental confirmation and deepening of prior results concerning increased market transparency and fairness.
IV. Bauer, I., & Schwabe, G., *“Value Capturing from Tokenized Asset Histories.”* **Note**: working paper.	• Deepening the insights about the affordance of blockchain for sellers to better signal product quality by incorporating it into the application design (technical subsystem). • Design proposal for a user-controlled offering and pricing concept of tokenized asset histories in the market for lemons (technical subsystem). • Evaluation of its business implications for platform providers. Confirmation that trade and revenue for platform providers can indeed be increased (output).
V. Bauer, I., Parra-Moyano, J., Schmedders, K., & Schwabe, G., *“No Room for Argument: The Impact of Tokenized Information on Bargaining.”* **Note**: working paper.	• Experimental confirmation of prior results concerning increased market transparency and efficiency. • Deepening of the implication of increased market transparency through the introduction of multi-party certificates (i.e., tokenized information) regarding transaction costs stemming from bargaining and its consequences for established and future business models. (Feedback-Loop/Environment).

3.2 Essay I – Value Creation from a Decentralized Car Ledger

While the potential of blockchain technology for the car ecosystem is uncontested, little is known about how the technology enables businesses to create value and how businesses will be able to exploit this business value best. However, to create and capture value from blockchain in the car ecosystem, a deep understanding of the underlying problems businesses face today and a corresponding analysis of blockchain technology's potentials in this context is necessary. Thus, this first essay explores the problems and needs of businesses working in the car ecosystem today. Further, it applies the theoretical value lens of Treacy & Wiersema (1993) to explicate generalizable characterizations of blockchain-specific value potentials and derive guidelines for how to best approach and leverage these.

First, to gain a clear understanding of the environmental context and the problem and solution space, I[3] conducted two semi-structured interview rounds with the stakeholders of the Cardossier project individually and with the consortium jointly. While the first interview round resulted in several process diagrams documenting current business processes, the second interview round validated and refined the resulting business process diagrams and the data and system architecture models. Next, I derived proposals for future business concepts based on these insights and in combination with existing theoretical concepts. The identified 15 high-level business concepts centered around one of the value disciplines of Treacy & Wierseman (1993) and considered the future car ecosystem where a decentralized car ledger is available. These business concepts were then evaluated with the stakeholder of the Cardossier. A year later, I revisited, refined, and reevaluated these concepts again. This iterative exploration, design, and evaluation process resulted in an explication of the initiating problems and needs in the car ecosystem (Information Asymmetries, Competitive Pressures, Data and

[3] Please note, that, throughout the synopsis mainly the pronoun "I" instead of "we" will be used in order to tell the dissertation from the perspective of the author. The usage of "I" does not indicate that all tasks were conducted individually it goes without saying that co-authors, or others mentioned in the acknowledgements, contributed to, the paper that the essays build on. An overview of the contributors of to the papers that each essay builds on, can be found in table 1. In the essays the pronoun "we" will be used to be in line with the associated publications.

Process Fragmentation) and the pervasive character of blockchain-enabled value creation. More specifically, it demonstrated how the blockchain capabilities, enabled by the blockchain characteristics, enable the manifestations of the blockchain value disciplines: *Distributed Product Innovation, Shared Operational Efficiency, and Controlled Customer Intimacy*. Figure 2 summarizes the socio-technical insights gained from this essay. Next to the key insights regarding the driving inputs and outputs of the system, Figure 2 specifies the *blockchain characteristics* (Fabric Layer: Decentralized Consensus, Distributed Storage; Transparency, Immutability; Application Layer: Versatility/Programmability, Autonomous Services), and *blockchain capabilities* (Data Access, Data validity, Standardized & Reliable Infrastructure) identified from prior research. Finally, the involved stakeholder groups were identified and described (Private Users, Car-related Businesses, Infrastructure Provider). Building on the insights from the Cardossier project, in this study, I also discuss the learnings for businesses in other domains aiming to leverage value from blockchain technology and derive guidelines for approaching each blockchain value potential and recommendations for managing multiple blockchain value potentials.

These insights address the first sub-research goal and provide an *understanding of the value potentials of a decentralized car ledger for the car ecosystem*. Thus, this essay contributes to this dissertation an overarching understanding of the car ecosystem (i.e., environmental context), the driving problems of businesses and individuals (i.e., inputs), the technical characteristics and capabilities (i.e., technical subsystem) that eventually enable the different stakeholder groups (i.e., social subsystem) to create unique to blockchain values (i.e., outputs). Further, this essay provides the necessary grounds to dig deeper and study the application of a decentralized car ledger in the market context. It shows that there are unique blockchain value potentials worth further analysis.

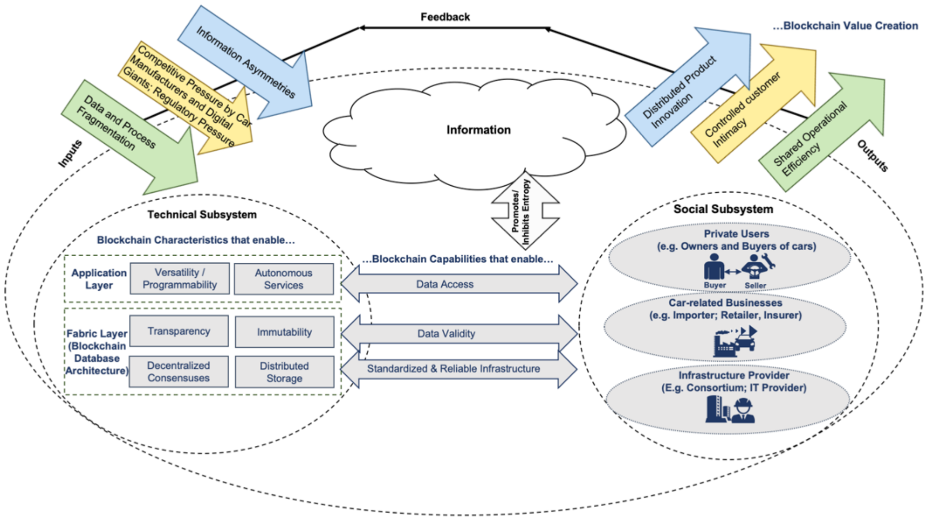

Figure 2. Key Insights on Value Creation from a Decentralized Car Ledger

3.3 Essay II – Is there a Market for Trusted Car Data?

Essay I identified distributed product innovation as one of the value potentials of a decentralized car ledger. As it will be explained in essay I in more detail, this can take the form of a car history certificate that offers trusted data about the life-cycle of a car by drawing on the data sources from multiple distributed businesses. Addressing the problems of information asymmetry prevalent in the used car market and many other areas, it is one of the greatest areas of potential for all participating businesses developing a decentralized car ledger. It is out of question that blockchain technology can technically offer this solution to address information asymmetry problems and thus provide value creation opportunities for businesses through distributed product innovation. Hoewever, whether there is a market for such a solution remains an open question. In particular, it is unclear if trusted car data (i.e., blockchain-based car history documentation) achieves increased transparency in the market for lemons and how market participants value increased transparency. Thus, studying the introduction of a car history certificate in the narrowed context of the used car market can validate and detail the findings of essay I and provide essential foundations for the second-sub research goal.

Starting with a thorough review of prior work, in this essay II, I first show how information systems research proposes 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, based on data collected through the means of the CarMarket game, introduced earlier, I explored the effects of trusted car data on the sales prices of the cars and the relative revenues of buyers and sellers. Additionally, I conducted interviews with the participants of the market game to elicit the perceived customer values. The results show that blockchain enables significantly increased market transparency and creates value for both buyers and sellers. Specifically, the results show that the cars were sold at a higher price where trusted car data was available than where it was not. Furthermore, comparing the sales prices to the actual value of the cars showed that the cars were sold at prices that were closer to their actual value in the market where trusted car data was available in contrast to where trusted car data was not available. Based on the insights from the interviews, I also concluded that both buyers and sellers valued this increase in market transparency. Sellers value the ability to signal the quality of their cars better. Buyers and sellers perceived the trade processes on the market where trusted car data was available as fairer and more efficient. Finally, buyers valued the reduced risk and uncertainty, increased transparency, and the ability to make better-informed decisions and arguments.

These insights (summarized and illustrated in Figure 3) address the second-sub research goal by developing a general understanding of the socio-technical interaction in the narrowed environmental context of the used-car market. Further, the insights prove and deepen prior identified findings regarding distributed product innovation by confirming that the promised and desired output can indeed be achieved (i.e., reduction of information asymmetries in the used car market). In other words, the socio-technical artifact framework for the value potential distributed product innovation is instantiated, and its marketability is proven in this essay. Finally, this essay provides first indication for the value-generating socio-technical affordances (e.g., signaling product quality or informed decision making and bargaining) for sellers and buyers of used cars.

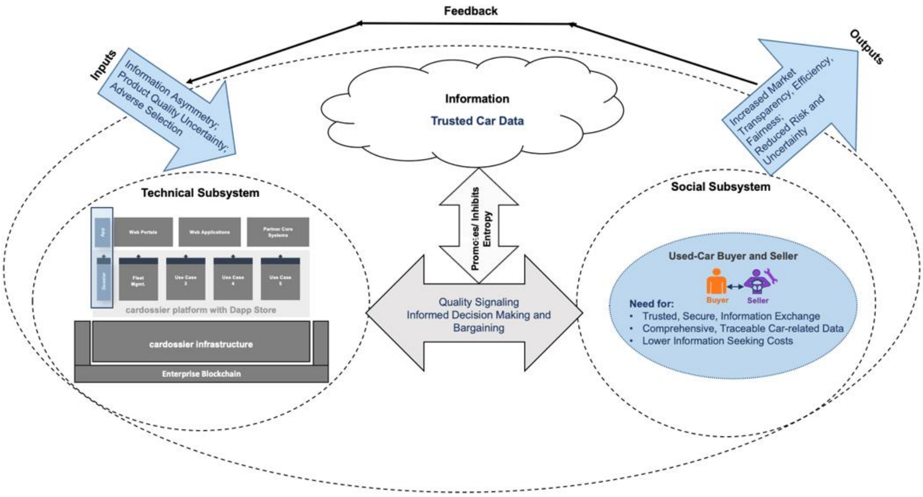

Figure 3. Prove of Market Value of Trusted Car Data

3.4 Essay III – Multi-party Certification on Blockchain and its Impact in the Market for Lemons

In general, signals are today the most effective measures to mitigate the problems of information asymmetries and their negative consequences in markets like the used-car market. While today used-car dealers have established themselves as trusted market intermediaries to signal product quality through the use of their established brand names or quality labels, the used-car market still functions well below its optimum. A large share of goods sold is overpriced, and most of the benefits are reaped by intermediary dealers. Thus, building on the insights from essay II, this essay III deepens our knowledge on the experienced value of sellers to better signal product quality through the use of car history certificates by analyzing in-depth the use and the effects of blockchain for signaling.

While the first two essays used the socio-technical artifact framework as a guiding mental model in this essay III, I go in-depth and apply it to explicate the role of blockchain for car history certification more thoroughly. This allowed me to entangle and conceptualize the affordances of blockchain for the variety of different actors involved in the *development* and the *use* of multi-party certificates in the used car market. For one, this conceptualization work provides a thorough understanding of how car history certificates are developed, enabling to coin and define the term *"multi-party certification"*. Further, it allows describing how blockchain-enabled multi-party certification (i.e., car history certificates) affords sellers the action potential to send signals that are more closely correlated to the unobservable quality of the underlying good (i.e., signals with a higher fit) than the signals they send today. Figure 4 summarizes these insights.

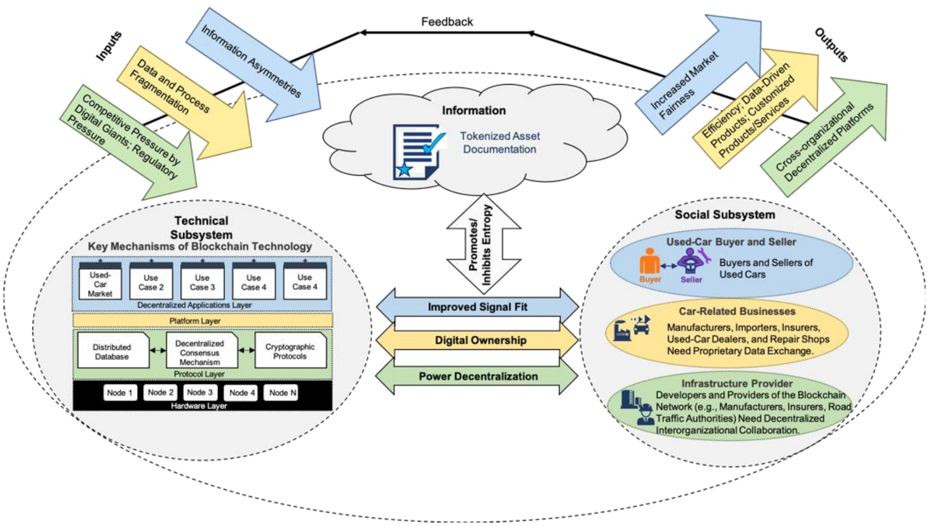

Figure 4. Key Insights on Blockchain-Enabled Certification in the Car Ecosystem

Next, I dive deeper into the buyer and seller subsystem and theoretically explore how the existence of multi-party certification might affect agent behavior and market outcomes. The theoretical model (illustrated in Figure 5) allows me to derive testable hypotheses, which I then tested through the experimental market game. The results of the experiments, conducted with 210 participants, confirm that blockchain-based trusted car history certificates enable sellers to send signals of higher fit than the signals they send today. This leads to a reduction in information asymmetries by reducing the entropy of the overall system and, consequently, to a more efficient allocation of goods and an increase in market fairness.

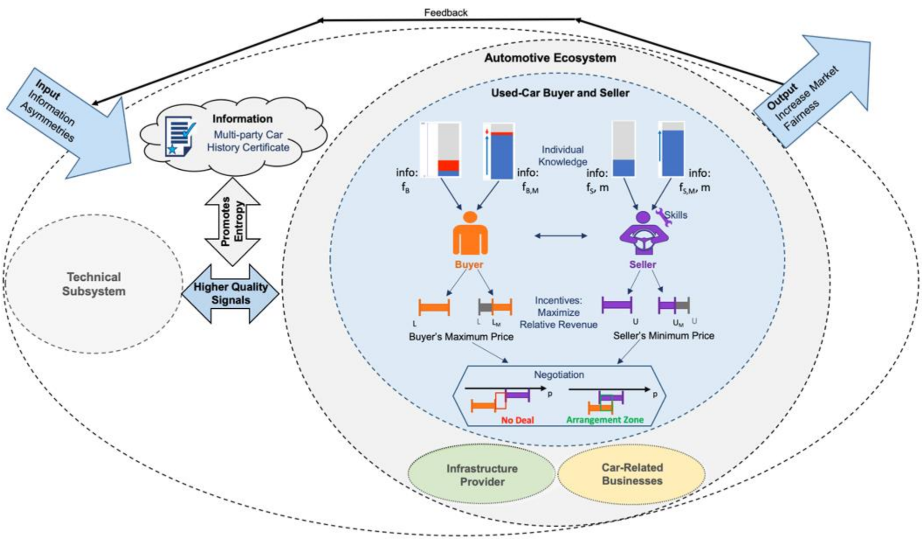

Figure 5. Effects of Multi-party Certification on Used-Car Buyer and Seller Subsystem

Overall this essay III confirms and deepens the prior indicated affording action potential of multi-party certification for sellers to send signals of higher fit through an in-depth analysis of the socio-technical interaction. Further, it verifies and deepens prior results about increased market transparency and fairness by explicating the induced changes in the social subsystem and information element that occur through the introduction of multi-party certification. Thus, this essay adds to the second-sub research goal by confirming that *value can be created* for sellers and buyers in the used-car market through the availability of blockchain-based multi-party certificates. Further, this study adds to this knowledge by *explaining how this is achieved* (i.e., through the sellers' use of multi-party certificates for signaling). While this study analyzes the dealer's use of multi-party certification for signaling, in the discussion of this essay, the disinter-mediating potential of the certificates is pointed out, which in turn again draws our focus to private sellers in the subsequent essay. Finally, these results suggest that signals may play a role in important functions such as pricing or offering multi-party certificates, which the following paper addresses and explores in detail.

3.5 Essay IV – Value Capturing from Tokenized Asset Histories

The preceding essays have shown that the identified blockchain value potential – distributed product innovation – that manifests in the used-car market as a multi-party car history certificate enables to create value through affording sellers the action potential to better signal product quality. This opens up the subsequent question of *how this value can best be captured?* As mentioned in the introduction, today, blockchain-based platforms face significant challenges in raising sufficient money to develop and sustain their operations. Further, they struggle with the question of how to achieve widespread adoption of their applications. Thus, studying how multi-party car history certificates (i.e., that can be classified as tokenized asset histories) can best be priced and offered to advance data trade and revenue for its providers is highly relevant for this dissertation but also beyond.

Building on the insights from essay III, which describes that value from multi-party certificates is created by affording sellers the action potential to signal product quality; this essay IV incorporates the ability of sellers to signal product quality into the design of the offering and pricing of multi-party certificates and evaluates how this affects their use and sales revenue. The idea is: rather than offering and pricing car history certificates as intermediary products as they exist today (e.g., Carfax or Eurotax reports), providers of multi-party certificates could strengthen the sellers' ability to signal product quality by granting them control over the pricing and offering of the data which in turn would increase their usage and the revenue generated by it. Due to the ability to tokenize data (i.e., creating unique ownership and ensuring the provenance of the data), sellers can be granted control over the offering and pricing of the data contained in the multi-party car history certificates without sacrificing trust in the reliability of the data. Today, product history certificates are offered as intermediary products due to a need for a trusted intermediary to ensure reliability and trust in the data. However, with blockchain, this need for trust is replaced through traceability and transparency in the record history. Hence, while technically this new design opportunity arises, it remains the question of whether it would be worthwhile from a business perspective. Thus, this proposed novel approach was then implemented and tested against established modes of intermediary pricing and offering of car history certificates through the means of another experimental CarMarket game. The results of the market game experiments, conducted with 102 participants, proved that by applying a user-controlled pricing and offering mode, both trade with multi-party certificates, and revenue from the multi-party purchases for the platform providers significantly increased.

Overall, this essay IV contributes to the second-sub research goal by proposing *how to best capture the value of* multi-party car history certificates, namely, through targeted design of the pricing and offering functions of an application of it which utilize the changing properties of the information element. Further, this study deepens prior insights about the effects (i.e., the effects in the social subsystem) of the affordance of blockchain for sellers to better signal product quality by incorporating it into the application design (technical subsystem). It evaluates its business implications for platform providers (social subsystem) and confirms that trade and revenue for platform providers can indeed be increased (output). Figure 6 illustrates how this essay contributes to the overall socio-technical understanding of value creation and capturing.

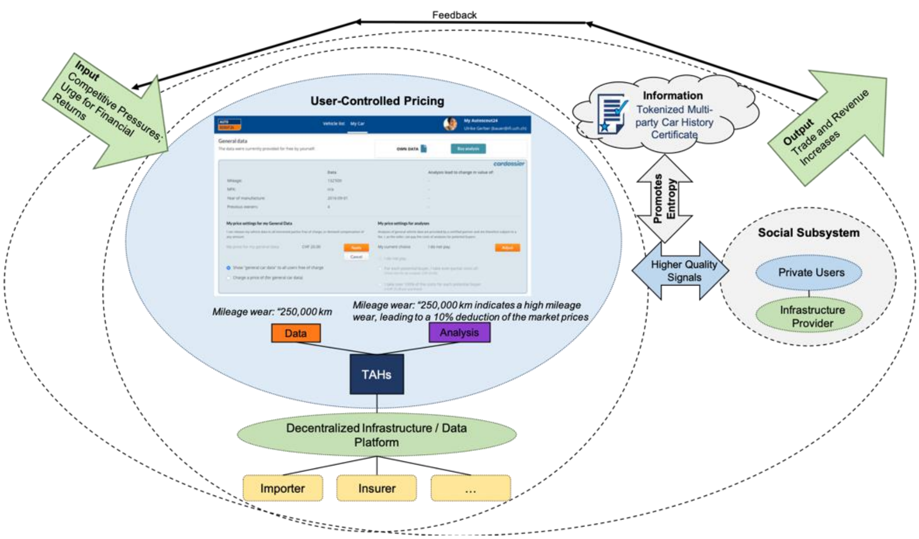

Figure 6. Key Insights on Value Capturing from Tokenized Multi-party Car History Certificates

3.6 Essay V – No Room for Argument: The Impact of Tokenized Information on Bargaining

In essays III and IV, I have analyzed in-depth the socio-technical interaction that enables businesses to create and capture value from the application of a decentralized car ledger. This essay V for one aims to ensure that saturation is reached regarding the achieved output of increased market transparency. Further, this essay goes one step further by taking up prior indications (e.g., essay III) about the consequences of increased market transparency for established businesses (who base their business model on mediating the market) and for future businesses. It will deepen indications about the disintermediating effects of a decentralized car ledger for current market mediators (i.e., dealer) by taking another loop through the socio-technical system and analyzing the impact of increased market transparency enabled through multi-party certification on bargaining activities of buyers and sellers. Today, bargaining activities are particularly associated with such costs, which in many cases stem from the information asymmetry between the agents participating in the bargain. Thus, they are of great relevance during the trade of a used car and an important source of revenue of current market intermediaries. In this essay V, I study how the availability of tokenized information (provided in the form of multi-party certification) affects these bargaining activities between buyers and sellers and what this means for current and future businesses acting, or aiming to act, in this market.

First, building on the classical transaction costs and bargaining literature, I developed a model, which serves as a sensitizing device to explain how the availability of tokenized information impacts bargaining processes. Next, using data from again a CarMarket experiment in which 668 negotiations over the price of used cars occurred, we empirically tested if the relationships that we derived from the literature are also observable. In other words, whether or not the availability of tokenized information has a significant impact on bargaining cost experienced by the agents. All in all, the results show that the availability of tokenized information results in lower bargaining costs and more efficient outcomes. Concerning the transaction costs associated with the bargaining activity, the results show that when agents have access to reliable and authenticated information about traded goods, the costs of gathering reliable information are smaller than in markets where such information is not readily available and needs to be sought out and verified. Consequently, I found that bargaining agents with better information tend to make offers that are closer to the actual value of the good that they are bargaining over. As a consequence of the observed changes in transaction costs, I derived that the establishment of intermediaries (e.g., dealers) who base their business models on the mitigation of information asymmetries might be deterred in the future. In turn, this incentivizes the establishment of decentralized, peer-to-peer market structures that novel platforms could offer.

In sum, these insights again validate prior findings (increase market transparency) and provide novel in-depth insights about the consequences of these identified findings for established and future businesses. This adds to the second-sub research goal – which questions *how the application of a decentralized car ledger in the used-car market will enable businesses to create and capture value* – by viewing the results again into the larger context and pointing out the overarching consequences for established intermediaries (i.e., output) and the opportunities for the establishment of decentralized market platforms (i.e., input). The oval contribution of this essay to the dissertation's goals is illustrated in Figure 7 below.

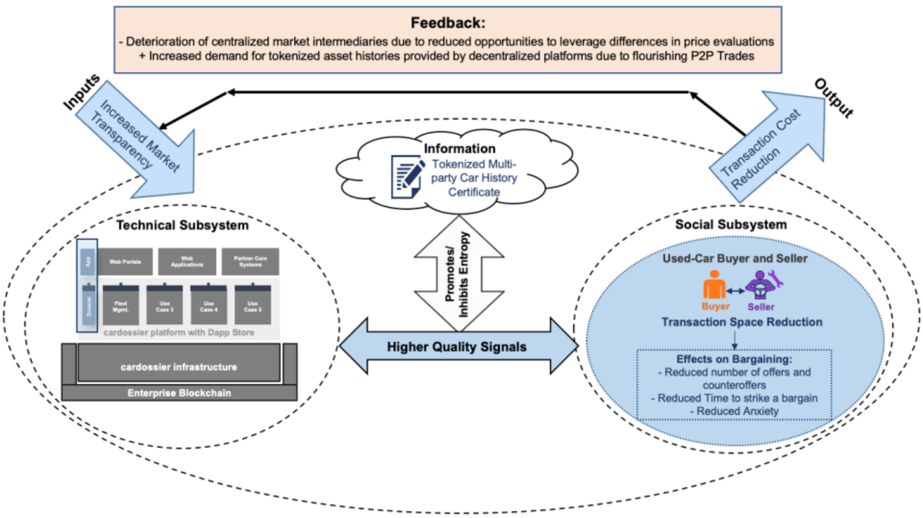

Figure 7. On the Consequences of Tokenized Information on Bargaining Costs and its Implications for Established and Novel Businesses

4 Conclusion

Businesses still have a long way to go until they can fully benefit from the promised potential of blockchain technology. However, this dissertation supports businesses in their efforts to create and capture value from blockchain technology by studying in-depth *how value can be created from a decentralized car ledger.* More specifically, this dissertation makes five essential contributions to this field.

First, by taking a broad view on the technology's potential for the car ecosystem, this dissertation shows the peculiarities that blockchain characteristics and capabilities bring for value creation (i.e., distributed product innovation, shared operational efficiency, and customer-controlled pricing) and proposes guidelines and management approaches to realize these.

Second, by narrowing the focus to one of the identified value potentials of the technology for the car ecosystem, this dissertation shows how this value potential (i.e., distributed product innovation) instantiates in the specific market context (i.e., the used-car market). It proves that a market for this novel product (i.e., trusted car data) indeed exists.

Third, by studying in-depth the socio-technical interactions involved in the development and use of trusted car data, this dissertation conceptualizes and defines the novel product innovation (i.e., multi-party certificates) and explains how specifically it enables businesses to create value (i.e., by affording sellers' the action potential to send signals of higher fit during used-car trades).

Fourth, by incorporating know-how about the signaling affordance that tokenized data provided by multi-party certificates enables into the design of the offering and pricing of them, this dissertation shows how the created value can best be captured (i.e., trade with and revenue from the sales of multi-party car history certificates for its developers can be increased through a user-controlled pricing concept).

Fifth, by taking another loop through the socio-technical system and studying how the increased market transparency through the introduction of multi-party certificates affects subsequent activates (i.e., bargaining), this dissertation shows how this affects current and future businesses (i.e., established intermediaries who base their business models on the mitigation of information asymmetries will be deterred, which, in turn, incentivizes the establishment of peer-to-peer market structures).

Jointly, these five essays contribute to academia and practice an *overarching understanding of the value potentials of blockchain technology for the car ecosystem, and specific insights into how the application of a decentralized car ledger in the specific market context of used the car trade that suffers from information asymmetries will enable businesses to create and capture value*. While this overview chapter summarizes the central approaches to and findings of the induced studies and shows how they form a whole, each of the essays presented in the subsequent chapters provides more in-depth contributions. Similarly, the limitations of each of the included studies are mentioned in the essays, respectively. However, in the following, I point out several limitations of the dissertation as a whole, which also open avenues for future research.

5 Limitations and Future Work

Early maturity stage: First, it needs to be acknowledged that the research activities in this dissertation were conducted at a time when blockchain projects (like the Cardossier) were still in a rather early maturity stage. Thus, the findings are subject to the current, relatively early stage of maturity of the blockchain project analyzed in this dissertation, as well as the current market-penetration goals for the value creation of the project. However, interest and goals might change as blockchain information systems get more established, and further evaluation and refinement of these findings would be worthwhile. Further, for future research, I recommend deepening know-how on business models that target the market penetration of blockchain-based information systems.

Generalizability: A large part of this dissertation focuses on the promised business value of a car history certificate in the used car market. While generalizable guidelines have been derived, the applicability of the presented results should also be tested in other contexts similar to that of the used-car market. For example, information asymmetries are also predominant in the employee recruitment market or the real estate market. Correspondingly, the insights gained in this dissertation, especially with regard to the application of a decentralized car ledger to resolve information asymmetries through the means of a multi-party history certificate, might be just as valuable in those contexts. Specifically, the insights gained regarding the value of asset history documentation for signaling, negotiation behaviors, and transaction cost economics can also provide helpful guidance for business value creation from blockchain in those markets. However, these markets might come with other peculiarities leading the proposed results to reach their boundaries and require refinement.

Further, while I identified multiple value potentials for businesses to generate value through blockchain technology in this dissertation, only one application was analyzed in depth. Exploring, designing, and evaluating other blockchain applications would be an interesting area for future research. In particular, looking into the development of a business-to-business (B2B) data market is of great relevance for the sustainable establishment of a blockchain information system and, consequently, a car history certificate.

Underlying datasets: While the long-term case study analysis is based on insights gained from experts in the field, for the series of experimental studies conducted in this dissertation, primarily students were used as study subjects. This allowed early insights that provided useful directions for academics and practitioners concerning an application's implementation and market introduction. While the use of students as study subjects can yield just as reliable results if methods are applied appropriately (e.g., it is ensured that students have sufficient knowledge about the simulated situation), it will be valuable to observe the actual use of the artifact in the market when large sums of money are at stake during an actual used car sale. Another methodological limitation of the experimental studies that needs to be mentioned here is that we conducted the experiments in only one geographical location (Switzerland). While this provides valuable insights into the preferences and behaviors of one geographical **population**, I would like to encourage future research to confirm these results in other geographical areas.

Despite certain shortcomings, it has to be noted that the insights gained from this dissertation have indeed proved valuable for practice. Drawing on my findings presented in this dissertation, an application of the Cardossier, namely a car history certificate provided to buyers and sellers for used cars, went live on October 4, 2021. While this is just a small step into the market, it marks a giant leap for the stakeholders involved in the Cardossier project and for other blockchain projects as it showcases that the potentials of bitcoin can indeed be transferred to other areas. I hope to have inspired further research continuing this road and studying how value can be created and captured from blockchain information systems.

ESSAY I – VALUE CREATION FROM A DECENTRALIZED CAR LEDGER

The content of this essay is based on the following publication:
Bauer, I., Zavolokina, L., Leisibach, F., & Schwabe, G. (2019). *"Value Creation from a Decentralized Car Ledger.",* Frontiers in Blockchain (January 23, 2020). https://doi.org/10.3389/fbloc.2019.00030

Abstract

Blockchain technology is expected to create a variety of new opportunities for businesses in general but especially for the car ecosystem, where many pilot projects have already started prototyping. Yet, little is known about how the technology actually enables to create value and how businesses will be able to best exploit this business value. However, without a clear understanding of the value creation potential from the technology, the realization of value is doomed to failure. Hence, this first essay addresses this research gap and provides a deep understanding of the underlying problems that businesses in the car ecosystem face today and a corresponding analysis of blockchain technology's potentials in this context. More specifically, this essay explores the problems and needs of businesses working in the car ecosystem today. It applies the theoretical value lens of Treacy & Wiersema, (1993) to explicate generalizable characterizations of blockchain-specific value potentials and derive generalizable guidelines for how to best approach and leverage these.

This is done in the course of an exploratory case study analysis, over a time period of 2 years, where three iterations of interviews and workshops with industry and blockchain experts from five diverse stakeholder groups were conducted. In brief, this essay provides early evidence that (1) blockchain enables value creation through: *Distributed Product Innovation, Shared Operational Efficiency, and Controlled Customer Intimacy.* Furthermore, this essay discusses the learnings for businesses in other domains aiming to leverage value from blockchain technology and derives guidelines for each blockchain value discipline, as well as

recommendations on how blockchain projects in ecosystems should approach multiple blockchain value potentials.

1 Introduction

Whenever a company embraces a new technology they aim for some form of value generation to either create or to sustain competitive advantage (Peppard & Ward, 2004). This also applies for blockchain, the technology that is expected to have great impact on a vast variety of industries (Morabito, 2017). Thus, since the introduction of bitcoin many companies started forming consortia, and spending time and resources exploring the potential of the technology with the hope of creating new business value for their companies. While on the one hand some sceptics warn of overhyped enthusiasm, the continuously growing worldwide spending on blockchain solutions show that there are quite a few others that still believe in the technology’s business potential. According to the IDC’s (International Data Corporation) statistics, between 2018 and 2019, the worldwide spending on blockchain solutions increased by 88.7% (from $1.5 billion to $2.9 billion). This amount is expected to continue growing with a compound annual growth rate of 76% and to reach $12.4 billion in 2022 (Shirer et al., 2019). We have seen many proof-of-concepts showing that blockchain can provide valuable solutions to existing problems, for example mitigating transactional risk in the Bill of Lading process (Naerland et al., 2017), solving information asymmetries in the market for lemons (Notheisen, Cholewa, et al., 2017) or increasing access to and incentivizes renewable energy sources through directly connecting consumers and prosumers via a decentralized market (Mengelkamp et al., 2018). However, despite great investments and promising benefits, it is not yet clear how companies will be able to exploit business value from the technology (Risius & Spohrer, 2017). Given this ambiguity, managers struggle in the adaption of blockchain to their businesses when moving from prototyping to implementation phase. However, the ability to understand how blockchain technology affects the business model and a corresponding adaption is key to achieve the aspired competitive advantage (Chesbrough, 2002; Teece, 2010). Taking a business perspective and focusing on the problems of managers, who aim to maximize the business value from the technology, we raise the following research question:

RQ: *How can companies create value from a decentralized car ledger?*

To answer this question, we conducted an exploratory study in the course of a larger Design Science Research Project (Hevner et al., 2004) called Cardossier and applied the theoretical lens of Treacy & Wiersema, (1993) to explicate the value potential from blockchain technology and derive generalizable characterizations of blockchain specific value potentials. Based on these insights we discuss our learning, of (1) how to manage each blockchain value discipline, and (2) how to approach multiple value disciplines.

Cardossier is a joint European project including multiple stakeholders in the ecosystem of a car, ranging from a car importer and retailer, a road-traffic authority, an insurance company, and a car-sharing company, each acting as representatives for their respective industries. These diverse stakeholders collaborate to build a blockchain-based platform that allows to store all relevant data, during the life-cycle of a car, in order to better serve the car ecosystem in a variety of use-cases. Thus, these stakeholders will interact with each other on the basis of blockchain, in order to store and process data (Zavolokina, Ziolkowski, et al., 2020). In the following, we will use the term 'the consortium', when we refer to collaborative activities including all of the above-mentioned stakeholders. When taking the specific lens of one of the stakeholders, we will use the following abbreviations: insurer, car retailer, road-traffic authority (RTA), Car Sharing Company (CSC).

To reach our research objective, we conducted semi-structured expert interviews, held workshops with all stakeholders individually and jointly, and used conceptual modelling of business processes and data-flows. Overall, we conducted three iterative exploration steps which resulted in: (1) a deeper understanding of the problem- and solution-space, (2) a thorough literature review and the adaption of scholarly concepts to explain observed phenomena and answer our RQ, and finally (3) derive guidelines from the results and discuss the learnings from our case to other application domains of blockchain. Additionally, a year later we conducted a fourth interview round in order to reevaluate the results, refine our concepts and to analyze how the blockchain value disciplines need to be approached during the development of the blockchain platform to enable early value creation for all stakeholders while at the same time allowing to reap individual benefits later.

The paper is structured as follows: in section 2 we depart from digital technologies and digital innovation, we introduce blockchain, and describe the three value disciplines that served as our theoretical lens to analyze the business potential in the Cardossier project. Section 3 describes the applied methods, and section 4 presents the results. In section 5 we derive guidelines from our case and discuss learnings for other practitioners. Finally, section 6 presents limitations, future outlook and conclusions.

2 Related Work

2.1 Digital Technology and Innovation

Many determinants need to be evaluated to define how a firm achieves and sustains competitive advantage. While the business model and the environment have been characterized as key determinants that directly influence a company's success, change is claimed to impact both, the business model and the environment in which businesses compete (Teece, 2007, 2010). Hence, change, that can arise from many sources (e.g. competitors, suppliers, customers, or technology) indirectly affects a company's performance (Teece, 2007). Today, digital technologies account for one of the greatest sources of change due to the continuously accelerating rate of innovation that again result in novel technologies (Chesbrough, 2002; Fichman et al., 2014; Tidd & Bessant, 2011). If companies miss out these opportunities, just as the formation of the internet economy has shown, digital technologies can very quickly change how business is being done and render existing business models obsolete (Hagler & Singer, 1999). This, makes of the key determinant of successful firms, namely the business model, not static but rather dynamic that requires constant innovation (Teece, 2010). Narrowing the concept of innovation, Fichman et al., (2014) defined digital innovation as *"a product, process, or business model that is perceived as new, requires some significant changes on the part of adaptors, and is embodied in or enabled by IT".* This definition incorporates both product (Yoo et al., 2010) and process innovation (Chesbrough, 2002; Desouza, 2011; Tidd & Bessant, 2011) but also business model innovation (Teece, 2010), a more recent class of innovation in IS research. Hence, following this definition, every new digital technology that requires significant change calls for digital innovation. Blockchain, a technology that comes with many new properties, is often claimed as being such a disruptive game changer with the potential to transform existing businesses or even create entirely new industries (Avital et al., 2016; Beck et al., 2017; Lindman et al., 2017). One prominent example, that has gained major attention from both academia and practice is its application of blockchain in the used-car market (Notheisen, Cholewa, et al., 2017; Zavolokina, Miscione, et al., 2018). By enabling multiple stakeholders to at the same time collaborate and share the power, it promised to disrupt not only the used-car market but also other car-related industries (Zavolokina, Ziolkowski, et al., 2020). Thus, requires further in-depth analysis to understand how to harness its full potential (Morabito, 2017).

2.2 Blockchain Technology

In its essence, blockchain is a distributed ledger maintained and shared between nodes in a decentralized peer-to-peer network (Beck et al., 2016; Sharples & Domingue, 2016; Tschorsch & Scheuermann, 2016). All nodes share the same copy of the ledger, and changes are reflected immediately to all participants of the network. To ensure a single version of truth, all transactions are agreed upon through consensus. More specifically, entries in a blockchain are only accepted if they build on honest pervious entries and adhere to predefined protocols, ensuring tamper-proofness and validity (Naerland et al., 2017; Rückeshäuser, 2017). Despite various systematizations of the key characteristics of blockchain, delimiting it from mere distributed databases (Naerland et al., 2017), analyzing the interrelations of its key characteristics (Seebacher & Schüritz, 2017), or applying a layered perspective (Glaser, 2017), currently there is no unified definition of blockchain in literature and no common agreement whether or not all these different instantiations can be called blockchain (Wüst & Gervais, 2017). Yet, there are a few first approaches, that provide for example definitions for the bitcoin blockchain (Meiklejohn et al., 2016), blockchain applications (Lacity, 2018), or definitions of blockchain through different lenses: technical, business and legal view of blockchain (Mougayar, 2016). A more generic and comprehensive definition is provided by Treiblmaier, (2018) (p.547) who say, *"A Blockchain is "a digital, decentralized and distributed ledger in which transactions are logged and added in chronological order with the goal of creating permanent and tamper-proof records."*. The reason for the varying definitions of blockchain might be due to the fact that there is no 'one and only' blockchain, but rather different instantiations of its key constructs. Specifically, variations in the properties regulating access rights to transactions have created grounds for classification. Dependent on the instantiation of the two dimensions (a) read and write access, and (b) validation rights to transactions, the authors classified blockchain in: public-permissionless, public-permissioned and private-permissioned blockchains. While, in a public-permissionless blockchain unknown nodes are free to join the network, and read, write, and validate transactions, in a private-permissioned blockchain, only registered nodes have specific rights to perform transactions. Furthermore, a private-permissioned blockchain allows to differentiate between validating and non-validating peers, which regulates the validation of transactions and ledger maintenance. Compared to public-permissioned blockchain, this enables increased network security and increased scalability performance of the blockchain network (Li et al., 2017; Xu et al., 2017). Besides this classification, the concept of enterprise blockchain starts emerging in literature, which refer to blockchain systems that are adapted in a way to fit specific business needs (de Kruijff & Weigand, 2017; Morabito, 2017). There are many reasons for the necessity of business adaption of the technology. For example, businesses have to consider privacy concerns of their customers, their own business secrets, and not least legal restrictions to data protection (Hamm, 2016; Lacity et al., 2018; Morabito, 2017). This also applies for the Cardossier project, the case that serves as unit of analysis for this research paper. Evaluating the trade-offs of transparency vs. anonymity with respect to read-, write-, and validation- access, considering latest data protection regulations, as well as the trade-offs with respect to performance of transaction processing, the consortium decided to use a private-permissioned blockchain. Comparing the chosen blockchain to centralized technologies, these were legally and organizationally not acceptable for the stakeholders (Zavolokina, Ziolkowski, et al., 2020). Finally, other distributed technologies might be available, but at that point of time those were not sufficiently mature to be accepted for this project. Besides the Cardossier project, there are several other projects that have started to work on the idea of a digital blockchain-based dossier. Examples are cartifcar, Car eWallet, or Mobi. From a more academic perspective the solution approach of using blockchain to address issues in the market for lemons has been first described by Notheisen, Cholewa, et al., (2017). Yet, a thorough investigation of the business potential of blockchain technology and especially its application in the car ecosystem is missing. Thus, we follow the calls for further research in this area (Avital et al., 2016; Rückeshäuser, 2017; Seebacher & Schüritz, 2017).

2.3 Value Disciplines

To explicate potential business value of blockchain we utilized the value disciplines initially described by (Treacy & Wiersema, (1993). They suggest that businesses must select and excel in one of the three value disciplines: Product Leadership, Customer Intimacy or Operational Excellence, while remaining competitive at the other two. According to the authors, product leadership "means offering customers leading-edge products and services that consistently enhance the customer's use or application of the product, thereby making rivals' goods obsolete" (Treacy & Wiersema, 1993). Excellence in customer intimacy refers to a company's superior ability to match exactly the individual customer needs by segmenting and targeting specifically, compared to its competitors. Finally, according to Treacy & Wiersema, (1993), companies excelling in operational efficiency serve the customers' needs through providing products and services with minimal inconvenience and at the lowest costs possible. Thus, the goal of each company should be to align and focus the operating model on one of these three value disciplines (Hagler & Singer, 1999; Osterwalder & Pigneur, 2010). As the computer business exemplified, the sudden drastic reduction in interaction costs changed the way companies exchanged goods and services and opened access to unexploited value that was quickly grasped by specialists rather than generalists (Hagler & Singer, 1999). Blockchain provides similar potential to reduce transaction costs even further (Beck et al., 2016; Davidson et al., 2016; Iansiti & Lakhani, 2017), and especially on the application layer provides greater possibility to specialize and focus on business operations (Glaser, 2017). Furthermore, researchers argue that in order to prepare for the blockchain future, companies will need to identify their distinct use-cases, which require varying approaches (Lacity, 2018). Hence, exploring value creation through the value disciplines (Treacy & Wiersema, 1993) provides a good tool to analyze the business potential in the Cardossier project. Furthermore, given the novelty of the technology and the wide-reaching concept of digital innovation, spanning product, process and business model, through the value disciplines lens we can address all three. This is because on the one hand the value disciplines are broad in the sense that they incorporate the view on a company's culture, business processes, management and IT systems (Treacy & Wiersema, 1993) and support key IT design decisions (Eichen, 2006). On the other hand, they give the necessary focus to exploit specific customer values and help to explicate these for our stakeholders on a more operational level. To be comprehensive, Treacy & Wiersema, (1993) also discuss 'Masters of Two', companies that successfully manage and excel in two value disciplines. In order to achieve this, companies need to resolve the inherent tension of each value disciplines' distinct operating model. Yet, they argue that while currently mastering at least one value discipline is a minimum to be successful on the market, *"chances are that the big winners of the future will have mastered two"*(Treacy & Wiersema, 1993) (p.86). In the internet economy this resulted again in novel business models (Osterwalder & Pigneur, 2010). However, how this evolves with the blockchain revolution is yet unknown.

3 Methods

The lack of knowledge of how business value can be created from blockchain is a common problem of current blockchain projects. Thus, informed by a problem with practical relevance (Hevner et al., 2004) we explored this general problem in the course of a larger Design Science Research project, the Cardossier. However, in this paper we solely focus on explicating the value potential from the technology through qualitative data analysis. Drawing on the findings from our case, it is our goal to derive guidelines for the design of a blockchain systems that will allow business value creation for practitioners through a better understanding of the specific value potentials of blockchain (Gregor, 2006; Gregor et al., 2013; Hevner et al., 2004).

Despite the focus on one project, the multitude and diversity of project partners in this project greatly represent the car ecosystem and hence serve as an excellent subject for examination. Overall, this exploratory analysis is grounded on the following data sources: (1) in total 16 stakeholder interviews (between 50 – 70 min. each) conducted in four rounds over a time period of two years, (2) four consortium workshops (between 40 – 60 min. each), (3) conceptual models, in the form of business process flows or data-models and, (4) further company information that were provided by the stakeholders individually and jointly. The interviews and workshops served the purpose of eliciting information and evaluating results. All interviewees were either subject matter experts or C-Level managers from the partner companies and active participants in the Cardossier project, who participate in regular design and development sessions. Hence, all interview participants shared a common understanding of the blockchain technology they were questioned about. Throughout these iterative exploration and evaluation loops conceptual models were developed and refined. All interviews were conducted as semi-structured interviews (Myers & Newman, 2007) and later transcribed and analyzed with qualitative data analysis software. For the coding, an open coding process was used (Saldaña, 2009) and the coded units were phrases, sentences and paragraphs (Weber 1990). To increase internal validity and ensure a shared conception of reflection, the codebook was crosschecked between the authors (Weston et al., 2001). The goals, applied methods, and conceptual models that we used during the four iterative data collection steps followed both, the guidelines for theory-generating design science research (Beck et al., 2013), and the guidelines for applying the Value Disciplines as a tool to understand and shape IT decisions (Eichen, 2006), and can be summarized as follows:

(1) First we aimed for a clear understanding of the problem and solution space (Beck et al., 2013; Eichen, 2006) and therefore performed two semi-structured interview (Myers & Newman, 2007) rounds. (1a) the first interviews were conducted between May and July 2017. Each partner company was interviewed individually to create a general understanding of the specific problem domain (Eichen, 2006) of each partner. The questions addressed the overall business model of each company, the specific business areas that are related to the Cardossier project, and finally the goals of each stakeholder with respect to the joint project. This resulted in several process diagrams, documenting current business processes. The resulting business processes diagrams, as well as the data and system architecture models were then evaluated with the project partners individually.

(1b) a second interview round was conducted between September and October 2017 and served to further narrow the problem area (Eichen, 2006) of each stakeholder, as well as the consortium. Thus, we asked each partner company to describe their problem in their own words and outline potential ways for data and information sharing through the joint blockchain infrastructure. This enabled to model future data and process flows (Chen, 1976) for the ecosystem via the planned blockchain architecture which were then evaluated in a joint consortium workshop. To exemplify this, we have added in the supplementary material one process diagram that shows results of interview-round 1a, the current process flows, in this case of a car import process (Supplementary Figure 9), as well as process diagram that resulted from the second interview rounds (Figure 10) that show the envisioned process flows via the Cardossier system.

(2) Next, on the basis of these thorough insights, coupled with knowledge from scholarly theories introduced earlier, we derived ideas for future value creation mechanisms. This resulted in 15 high-level business concepts (Beck et al., 2013) each centering around one of the previously introduced value disciplines (Eichen, 2006) targeting the car ecosystem. The idea behind this was to provide each stakeholder and the consortium with three options, focusing on a choice between the value disciplines.

(3) These business concepts were evaluated again through interviews with stakeholders individually and the consortium (Beck et al., 2013) which took place in March and April 2018. During this third interview round, always two stakeholders from each company participated in the interviews. Here we specifically focused on the interrelation of the business concepts with the technology (Eichen, 2006). Finally, when analyzing these interviews, we used the value discipline lenses to guide the coding process, these formed our high-level categories. However, within these categories we used a bottom-up open coding process, meaning we moved from codes that emerged to categories and then to theory (Saldaña, 2009). This was done to refine each value discipline and allowed us to explicate the value potential that is specific about blockchain and abstract knowledge for value creating blockchain design decisions (Beck et al., 2013; Eichen, 2006).

(4) Almost a year later, between February and April 2019, we again conducted interviews with the Cardossier project. One specific focus of the interviews were again the business model and the value potential for each partner company as well as the consortium. The goal was to reevaluate our results, gain a deeper understanding of the blockchain value potentials through targeted questions, and to capture any changes that might have occurred over time. These interviews were conducted by an independent person, who has a good understanding of the value

potential concept, however is not biased as being an author. These interviews were coded through the previously identified blockchain value discipline lenses, but again with an open-coding towards refinement as well as a time-perspective (Saldaña, 2009).

Table 2 gives an overview of all workshops and interviews that were conducted for data collection and evaluation. Furthermore, the roles and affiliation of the interviewees are stated to clarify belonging of the quotes presented in the results section. Next to the stakeholders mentioned earlier, the project also involves a Software Company which also participated in the interviews. The Software Company is responsible for system development and project management activities. Thus, they share the same understanding of the technology that they were questioned about, as the other interviewees. Besides that, during the reevaluation phase also the project manager from the research institute was interviewed who was engaged since the very beginning with the project and has had mainly the consortium's perspective.

Table 2. Summary of Data Collection and Evaluation

Interview Round & Timing	**Purpose and Goal of the Interviews**	**Affiliation**	**Role and short name used in to present the quotes in the results section)**	**Results**
1st Interview Round May – July 2017	Understand the problem and solution space	Software Company	Cardossier Project Management	Process diagrams documenting current business processes flows
		Importer & Retailer	C-Level Management	
			Project Manager	
		Insurance Company	C-Level Management	
		Road Traffic Authority	B-Level Management	
2nd Interview Round October / November 2017	Narrowing the problem-space	Software Company	Cardossier Project Management	Data model and Process-flows for the planned blockchain architecture of the ecosystem 15 high-level business concepts each centering around one of the value disciplines
		Research Institute	Project Management	
		Insurance Company	C-Level Management	
		Road Traffic Authority	C-Level Management	
		Consortium Workshop	Representatives from all stakeholder groups	

3rd Interview Round March / April 2018	Evaluation of the results from the prior phase (Business Model Concepts) In-depth analysis of the interrelation of the business concepts with blockchain technology	Software Company	Cardossier Project Management	3_SC_PM_1	Model that depicts how blockchain enables value creation Blockchain value potentials & guidelines for businesses
			Cardossier Project Management	3_SC_PM_2	
		Importer & Retailer	Project Manager	3_IR_M	
			Subject Matter Expert	3_IR_E	
		Insurance Company	C-Level Management	3_IC_M	
			Subject Matter Expert	3_IC_E	
		Road Traffic Authority	C-Level Management	3_RTA_M	
			Subject Matter Expert	3_RTA_E	
		Car Sharing Company	C-Level Management	3_CSC_M	
			Subject Matter Expert	3_CSC_E	
		Consortium Workshop	Representatives from all stakeholder groups		
4th Interview Round Feb – April 2019	Reevaluation of prior results, refinement of concepts and addition of the time-perspective	Software Company	Cardossier Project Management	4_SC_PM_1	Refined value potentials Time-reflected view on blockchain value creation
		Research Institute	Project Management	4_RI_M	
		Insurance Company	C-Level Management	4_IC_M	
		Road Traffic Authority	C-Level Management	4_RTA_M	

4 Results

In this section we present our results from the qualitative analysis of the third step, the evaluation of the value discipline centered business concepts. We do so by giving specific examples from the Cardossier project for each of the value disciplines and underpin these with code units. Besides that, we show the validity of our results by providing additional quotes from our fourth interview round. For each value discipline, we will focus on one business concept and explain on the horizontal level the pervasive character of blockchain enabled value creation. Figure 8 illustrates the blockchain characteristics that emerged as code units from the interview analysis and which were categorized into blockchain capabilities. Finally, enabled by the blockchain characteristics, the blockchain capabilities enable the manifestations of the blockchain value disciplines: Distributed Product Innovation, Shared Operational Efficiency and Controlled Customer Intimacy. The resulting blockchain characteristics and capabilities will be explained in detail in section 4.1. In section 4.2 and 4.3 will only shortly exemplify these but rather keep the focus on our main contribution, the specificities of value creation through blockchain. At the end of each subsection a table will summarize the result.

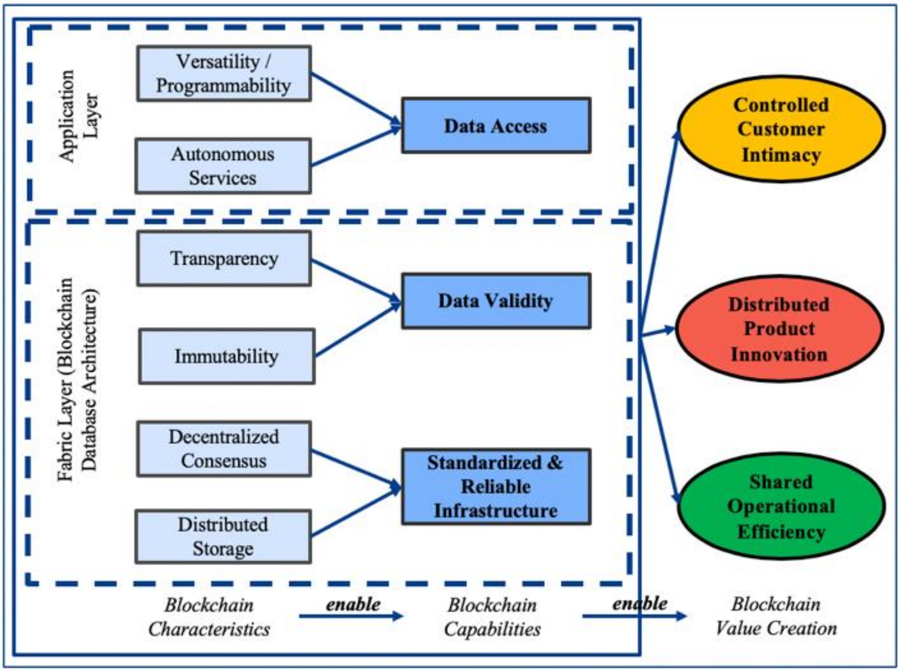

Figure 8. Blockchain Enabled Value Creation

4.1 Distributed Product Innovation

From the first two interview rounds we learned that one key problem the consortium aims to solve through blockchain is the information asymmetry between buyers and sellers during the sale of a used car (market for lemons problem in academic literature; (Akerlof, 1970)). This also marks the initial case that brought together the consortium, namely addressing this information asymmetry through a blockchain-based digital dossier for cars, a *cardossier*[4], that stores all relevant events during the life-cycle of a car. Thus, the stakeholders aim to store

[4] Please note, a lower-case spelling of *cardossier* stands for the application. A capitalized spelling, *Cardossier*, refers to the project itself.

and process all car-related data and information, and jointly create a dossier for all cars on the market, aiming to reduce asymmetries and increase market transparency (Bauer, Zavolokina, & Schwabe, 2019). Similar solutions like an Eurotax or a Carfax report might exist today, yet given their shortcomings (e.g. the lack of trust towards one single provider and the lack of trust in data quality; or inconsistency and incompleteness of a central registry of one provider; and high costs that do not justify the benefits) they only showed limited impact on the market so far. Thus, the consortium decided to address the issues prevailing the used car market today with a novel approach. This novel approach foresees a joint infrastructure, where the participating firms will be able to process data in a secure manner. The justification for blockchain to solve this problem in general was evaluated thoroughly by the stakeholders and also in academia (Notheisen, Cholewa, et al., 2017). Still a variety of alternatives exist in how specifically IT might approach this problem. Thus, by questioning through the value discipline lens, we were able to understand the strategic focus of the consortium and the pervasive blockchain characteristics they rely on to create customer value through a joint blockchain-based infrastructure.

The consortium showed agreement that they aim for product leadership through providing an innovative solution to a yet unserved market. Besides little disagreement whether to classify it as a product or service, the interviewees mentioned: *"With the consortium glasses cardossier clearly is a service innovation which solves a clear need, that customer have, but which they might not necessarily be aware of today, (...) I would say there is great unserved potential to leverage through providing this transparency with cardossier."* (3_IC_E). Another said, *"It is for sure a quite complex product, however also a very innovative one for our customers"* (3_CSC_M). Once the value for the users was clearly delineated, during the discussions with the consortium, we further asked about the novelty of the solution and the necessity of blockchain for creating such a digital dossier for cars. In its essence, the two rationales that emphasized the need for blockchain are the need for collaboration and the sharing of power. The responses were pretty clear, *"Blockchain is the only technology, as of today, that allows all of us to work together."* (3_RTA_M). To overcome the shortcomings of currently existing solutions, in particular the lack of comprehensive and trusted data, the stakeholders realized that they needed to join forces and work together with other firms in their industry but also with firms from other (car-related) industries. While the project today only involves one representative from the major car related industries, the vision of the consortium is to build an architecture that will allow also direct competitors to join at a later stage. Or as mentioned by the project manager, *"(...) all our partners support this, the platform only makes sense if all competitors will also be on it (...)"* (4_SC_PM_1), only then they would be able to create a complete and consistent car history for all cars in their target market. Another framed this in a paradoxon, *"Of course we could solve these collaboration challenges we previously had differently but if we would do so, and evaluate the resulting technology neutrally, we would end up with exactly a solution as blockchain"* (3_SC_PM_1). When we dug deeper and asked what specifically about blockchain it was that enabled them to collaborate and jointly build a novel architecture that will eventually allow to provide a digital dossier for cars, we managed to ascertain the key blockchain characteristics they rely on. Namely on the one hand, *decentralized consensus* and *distributed storage* of data. As these two blockchain characteristics were always used jointly or interchangeably to explain the key blockchain capabilities that they relied on, during the coding process we categorized these as the blockchain capabilities enabling: *standardized and reliable infrastructure.* For example, one manager explained: *"So many changes occur during the life-cycle of a car, sometimes even on a daily basis. Thus, it would not be enough to get a snapshot every now and then, (...) but being able to dynamically have insights to all changes and being sure about these entries is what blockchain-consensus enables us (...)."* (3_IR_M). More specifically it enables collaboration but at the same time sharing of power. Sharing of power enabled through decentralization, turned out as being essential given the lack of trust that exists between firms but also the trust towards the solution otherwise. If the solution was not a decentralized data-base system, who should then be in charge of such a central data collator? This would rather create a threat than an opportunity to businesses in the car ecosystem. On the other hand, the blockchain characteristics, *transparency* and *immutability* of transactions were mentioned by the consortium as key characteristics that allow increased *data validity*. E.g.: *„The security aspect of blockchain is something of very high priority for us. Data must be safe, immutable and not manipulable by anybody.* (…) *Being sure about the validity of the data is the alpha and omega for our business, which blockchain provides us now."*

(3_RTA_M). Another mentioned, *"one key differentiator it brings for us, is that we can clearly say that we respect data security and that we are even pioneers here (...) that is a quality label of Cardossier"* (4_IC_M). Again, these two characteristics were mentioned not only once, however when the partners, for example referred to transparency, they always also emphasized again the reliability of the data entry that they aim to achieve. E.g. *"Through mutual verification we can now trust the data entry of others, and even use what they added to the database to further process it."* (3_RTA_E).

Finally, a third blockchain capability emerged from the characteristics, *programmability/versatility* and *autonomous services*, namely the ability to create a decentralized *data access*. However, when talking about these blockchain characteristics the interviewees mainly referred to the adaptable application logic and the possibilities for implementing smart services, that build on the underlying key data structure and infrastructure logic. One C-Level Manager described this nicely, *"So the business idea is to provide a platform (...) that allows to extract data and work up individual business cases. Since we have created an ecosystem where each partner might have different interests. In fact, the Cardossier infrastructure is the base or the core from which one can extract some elements to work of certain use cases."* (4_RTA_M). Thus, also in accordance with the literature introduced earlier (Glaser 2017), we grouped the first two capabilities to the *fabric layer* and the third capability to the *application layer*. For the Cardossier platform that is created jointly from multiple independent stakeholders, especially the adaptability to their own infrastructure was mentioned as the most important factor. For instance, one manager explained: *"We are building a really innovative product with many original owners, thus, allowing individual integration but also aligning different things from different owners is really essential here."* (3_SC_PM_1).

In sum, from our case we learned that blockchain enables *product innovation*, through enabling companies to create data access and data validity and a reliable and standardized infrastructure which in turn draws on key blockchain characteristics (shown in Figure 8). However, as the above delineated results show, the cardossier application is not an innovation of one company alone but arises from the distributed efforts of multiple stakeholders. Or as one manager framed it, in this project *"all help each other to get better, and this is only possible together."*

(3_SC_PM_1). The stakeholders are all experienced in the car market, and also pursue the same interests, which is to serve the needs of buyers and sellers of used cars through providing a novel information infrastructure which eventually allows to extract a novel information product, a cardossier. Yet especially, *"the network of partners in this consortium is essential to achieve early market entry and leadership."* (3_SC_PM_2). All stakeholders mentioned that they were aware of this customer need before, yet they lacked the necessary capabilities that enables them provide a trusted comprehensive solution. Thus, the key difference blockchain makes, is that it goes beyond simply product innovation but enables companies to collaborate and innovate in a *distributed* manner. Hence, through the creation of a new product, the cardossier that has multiple owners, allows the stakeholders to create value and excel through *distributed product innovation.* A summary description and a key code are presented below in Table 3.

Table 3. Summary Distributed Product Innovation

Blockchain Value Creation	**Description of identified concept supported by a key code**
Distributed Product Innovation	Blockchain enables to collaborate and innovate new products and services across organizations in a distributed manner. *"Through mutual verification we can now trust the data entry of others, and even use what they added to the database to further process it."* (3_RTA_E). *"*

4.2 Shared Operational Efficiency

Removing mistrust between industry players, blockchain further promises each company to improve operations through sharing processes and leveraging cross-organizational efficiencies. *"All around the ecosystem of the car partners can enhance and automate their processes, thus achieve efficiency gains"* (4_SC_PM_1). Hence, those companies that focus on the possibilities of reducing transaction costs through sharing processes via blockchain, can achieve *shared* *operational excellence*. In the Cardossier project this is yet another important business case for most stakeholders. *"The collaboration with regards to business processes is where I see the great value lever."* (3_IR_M). Another stakeholder mentioned: *"Blockchain finally allows us to achieve agreement with regards to business processes and resolve inefficiencies."* (3_RTA_E).

To give a specific example, todays information flows between customers, car importer, customs and the RTA are characterized by manual processes relying on physical documentation. This physical document handling is not only prone to error for the individual companies like authorities and the importer, but also inconvenient and leads to doubled work for both, the customers and the stakeholders. *"I think one problem that is being solved is the friction we have in the currently partially poor data quality (...) another aspect is the trust of customer in our business"* (4_RTA_M). Today, customers have to provide similar details, to multiple stakeholders, in physical forms, and time-consuming ways. One example for this is the import form, a central document during the import process of a car that changes hands multiple times, not only between a customer and stakeholders, but also between businesses directly. *"The importer records the document, customs do, the insurers take similar notes, you see there are a lot of points for failure "(4_RTA_M).* Thus, providing great potential for reducing transactions costs through a single point of truth. Adding to that, blockchain particularly enables cost reduction across organizations. One interviewee stated: *"Yes I am pretty sure that, as of today, blockchain is the only technology that allows us to resolve these inefficiencies and jointly digitize these things."* (3_RTA_E). When we further asked 'why blockchain', they again most importantly referred to the security aspects of blockchain. *"Being sure about data validity and knowing where it comes from, and having the possibility to trace things, is key for authorities like us"* (3_RTA_M). Also, the importer agreed to the necessity of blockchain to digitize these important, and often shared documents in a tamper-proof manner. When we asked conversely, they also mentioned the lack of trust in data validity and the lack of possibilities to share these documents in a secure and reliable way as the key reason for not being able to resolve these inefficiencies so far. Additionally, one manager emphasized *"almost all business cases which target cross-firm operational processes, depend on the penetration, meaning how many cars we have in the Cardossier system."* (4_IC_M), which on the one hand relates back to the overall vision of the project, namely to include as many firms from the car related industries as possible, on the other hand highlights the necessity of an infrastructural basis like blockchain, that allows for collaboration but also competition, as explained earlier.

With respect to the beneficiaries, the stakeholders agreed that this would lead to increased customer convenience and minimize points of failure at both ends, authorities like RTA and end users (e.g. owners of a car), but also businesses, for example operating as car importer. Next to user convenience (both private and business users), they further stressed the potential for cost reduction that can be leveraged from both standardization and integration of todays fragmented systems*: "The data in general we could also get from customers, that is not the biggest issue today, where I see the biggest value is in the integration of the systems, that leads to cost reductions. This integration aspect, combined with reliable digital data exchange will also allow us to further optimize other processes, for example our fleet management."* (3_IR_M). Finally, on the application layer this also allows to automate cross-organizational business processes, *"these two aspects go hand*-in-*hand, namely that all firms have the same view on the data which cannot diverge, and that they can automate the overarching processes nicely."* (4_SC_M_1)

Along these lines we exemplified that blockchain also has the potential to enable sharing of critical processes and documents across organizations, and leverage value through cross-organizational sharing. Nonetheless, the technology still allows each stakeholder to set their individual foci, e.g. on customer convenience like the RTA, or on reducing operational costs like the importer. In other words, *"so we have the joint platform (...) and on top of that each company can realize its own efficiency cases" (4_IC_M)*. Hence, all in all blockchain enables both players to excel through *shared operational efficiency* (Table 4).

Table 4. Summary Shared Operational Efficiency

Blockchain Value Creation	**Description of identified concept supported by a key code**
Shared Operational Efficiency	Blockchain enables companies to minimize overhead costs through sharing processes. *"These two aspects go hand-in-hand, namely that all firms have the same view on the data which cannot diverge, and that the one can automate the overarching processes nicely."*

4.3 Controlled Customer Intimacy

Through collaboration over a shared and transparent ledger, the stakeholders discovered that the technology also creates opportunities to even further customize their existing products and services according to niche customer preferences. Or to put it in their words, *"for sure, they (the project partners) are also interested in having this data to make more personalized offerings for their clients."* (4_RI_M). Hence, allowing the stakeholders to create additional value. This is yet again possible only through increased access to valid data and, just as importantly, through a reliable and standardized infrastructure. However, access to customer data over the blockchain requires the consent of that customer, *"It (the data) is not public. So, to think about the technical implementation, we're using Corda, which is not a public blockchain itself, in the way it gives us benefit for privacy because we have the personal data of car owners. In general, the concept is that you can share your data and you have control over your data. So you know who you share the data with and you can revoke the access that you have given to somebody at any time."* (4_RI_M). Thus, blockchain enables value creation through customization, however in a *controlled* manner.

One example from our Cardossier project is the possibility to customize insurance services. Or as one partner summarized it: *"Today our insurance premiums and services are packaged the way they are because we lack knowledge. For example, about the quality of a car. Thus, simply said, we have to put all* *customers in the same pot. Now, through blockchain and the Cardossier project we would be able to tailor our services better to our customers' needs because we can be sure that we are talking about that specific car with that specificities."* (3_IC_E). Or as another put it more succinctly *"blockchain enables us to customize our products better, one example could be object pricing"* (3_IC_M). With respect to the blockchain capabilities they also further elaborated and explained, for instance, increased data access and data validity as follows: *"We could also give discounts dynamically because through the blockchain system we can query information, for example about mileage, regularly and hence give you a plus or minus on a quarterly-basis (...). The data might have been collected through one of our partners, or even through dongles automatically, and we need not to bother the customer for that, since we can be sure about the correctness of the data. (...) Plus, we can get access to more data, for example from the importer or the manufacturer, and make more precise evaluations."* (3_IC_M). When we asked why they did not leverage this potential before, we could again elicit that it is specifically the interplay of all three blockchain capabilities that enables them now to create value through increased customer intimacy. One expert framed it simply: *"It is a matter of trust. Ok, maybe we could trust the importer we collaborate in this project with, however, thinking further we also want to integrate other car importer and retailer which we maybe cannot trust."* (3_IC_E). Yet, blockchain adds a specificity to the customization of products and services: *"We have to be careful here. I think intimacy is an unstable balance with blockchain. It is much more a give and take then before. (...) You'll have to build up the trust from the customers to the insurance companies first, so that they will allow you access into their data."* (3_SC_PM_1). What the manager refers to in this specific case also emerged in other examples and hence, we classified it as *control* by the customer. Since all development efforts of the project build on the principle, "*we make the customer, the owner of the data, responsible for his or her data him-/herself."* (3_SC_PM_2), customers will no longer have to acquiesce everything. In turn, for our partners this means, *"only the ones that play fairly get a chance to better customer intimacy. That is something new for businesses we all have to get used to."* (3_SC_PM_1). Finally, as the project matured, it also emerged that advantages through increased customization require the partners also to consider multi-party access rights to data. Some data in the system might be provided by one user but belong to another user, for example an insurance company might store the insurance certificate for their customers in the blockchain, however also the owner (from whom the insurance certificate was provided) has rights over this data event. Thus, as mentioned by the manager from the insurance company, *"We have to get into the ecosystem thinking and learn how it works. So that if we need data we need authorized access sometimes not only by one-to-one connections."* (4_IC_M).

All in all, this clearly exemplifies that blockchain allows companies to create value through *controlled customer intimacy*. On the one hand, the increased access to valid data allows companies to better understand their customers and tailor their services accordingly. On the other hand, standardization of infrastructure and data formats create low friction for access and inhibit high costs. Yet, the relationships to customers experiences a twist, in a way that they gain increased control over their customization. Furthermore, to achieve even better customization they will need to consider not only 1:1 relationship but ask for access from multiple parties. Thus, value creation through controlled customization, over blockchain will only function for stakeholders *"that rule this game through fair give and take"* (3_SC_PM_1) (Table 5).

Table 5. Summary Controlled Customer Intimacy

Blockchain Value Creation	**Description of identified concept supported by a key code**
Controlled Customer Intimacy	Blockchain enables companies to achieve excellence in customer intimacy, however, in a customer-controlled manner. *"We have to be careful here. I think intimacy is an unstable balance with blockchain. It is much more a give and take then before. (...) You'll have to build up the trust from the customers to the insurance companies first, so that they will allow you access into their data."*

5 Discussion

From our conceptualization and evaluation steps with the Cardossier project, we collected first evidence for how blockchain can enable companies to create value in the car ecosystem. Drawing on the blockchain characteristics, which enable the capabilities, our findings suggest blockchain value creation through: *Distributed Product Innovation, Shared Operational Efficiencies and Controlled Customer Intimacy*. These insights are valuable for both researchers and practitioners as they help to understand the potential business value that lies within blockchain platforms. Further, on the basis of these results we derive guidelines that help to guide design decisions in a way to enable business value realization from the technology. In the sections below, we will first discuss what our learnings can mean for other businesses aiming to create value from blockchain. Table 6 summarizes the guidelines for each of the blockchain value disciplines. Subsequently, based on our observations over a time span of two-and-a half years, we further discuss how other consortium blockchain projects should approach the development of the blockchain platform to enable early value creation for all stakeholders while at the same time allowing to reap individual benefits later. These insights will help other projects, aiming to create value from blockchain technology, to move from use case prototpying to implemention phase.

All in all, we provide first evidence for the academic question raised above and the problems managers currently face. Further, previous research has claimed that blockchain has the potential for disrupting businesses (Beck et al., 2017; Lindman et al., 2017), we add to this by demonstrating *how* this can be realized in the car ecosystem. More precisely we reveal the blockchain traits on a vertical level, that penetrate business practices. During our qualitative analysis it emerged that in accordance with previous research (Glaser, 2017), also in this project a two-level perspective of blockchain (fabric and application layer) might help to understand the implications of the technology. Yet, focused on the business implications of the technology, we further uncover along that path. Finally, as we have seen that blockchain affects products (cardossier), business models (customization) and processes (sharing of processes) this supports our choice of the value disciplines (Treacy & Wiersema, 1993) as an academic lens.

5.1 Guidelines for Excelling a Blockchain Value Disciplines

In the following we summarize our results and discuss the specificities of each blockchain value discipline. Additionally, we derive guidelines for other businesses aiming to excel in one of the three blockchain value disciplines.

Distributed Product Innovation

Distributed Product Innovation means that blockchain enables co-creating new products and services across organizations in a distributed manner. We have refined the value discipline lens of Treacy & Wiersema, (1993), and characterize product innovation when blockchain technology is used as *Distributed* Product Innovation. This is because the technology now enables companies to collaborate but still share power and thus create innovative artifacts, that serve unserved customer needs. However, being able to do so, companies need to put on their consortium glasses and focus on the customer needs that might exceed their current industries boundaries. As we have seen from the Cardossier case, blockchain is a technology that allows to collaborate across industries and jointly create a product like the cardossier to previously unserved customer needs by drawing on distributed resources. Prior, a single company was not able to serve customers' needs sufficiently, because they lacked the competences or resources. For example, in the case of the used car market one single company does not possess all data about the car. Thus, to achieve a comprehensive view multiple stakeholder are needed to meet customers' needs accordingly. These customer needs however are not inherent to one company's current primary business focus but rather lay at intersections. Thus, for other companies experimenting with the technology and aiming to create business value through novel products or services, we suggest to join efforts with other players in the same ecosystem. By adapting a holistic view on the ecosystem and collaborating with other experts from related industries they will be able to uncover unsolved potential and innovate products and services for a novel joint market.

Shared Operational Efficiency

Operational Efficiency when blockchain technology is used, means that it enables companies to minimize overhead costs through sharing processes. As the key value lever lies at the intersection of organizational processes, we have characterized the value discipline with respect to blockchain as *shared operational excellence*. In our case project there were plenty of examples for resolving inefficiency and eliminating intermediary steps. One example elaborated above was the case of a car import, where authorities like road traffic authority and customs can digitize and share processes with importer businesses. This allows on the one hand authorities to increase customer convenience. On the other hand, it facilitates opportunities for cost reduction for importers. Both resulting in individually optimized business processes from cross-organizational collaboration.

Based on these insights from the Cardossier case, our suggestions for other companies aiming to create value from the technology through better infrastructure management, is to apply a balanced perspective. On the one hand, jointly target cross-organizational inefficiencies with your partners. On the other hand, focus on the specificities of your own business to leverage the full potential from arising unresolved inefficiencies. Hence, mastering this value discipline requires on the one hand a lot of skills in business to business collaboration, on the other hand it also requires an expert knowledge in current business processes to identify and target the greatest inter-organizational inefficiencies that will quickly show great payoffs.

Controlled Customer Intimacy

Controlled Customer Intimacy refers to the ability of companies to achieve excellence in customer intimacy through blockchain, however, in a customer-controlled manner. We exemplified this through the possibilities of customized insurance, yet, while respecting customers' voice. Thus, as some of our stakeholders have already learned from the project, companies that aim to leverage this potential need to build trust with their customers first. This is because a platform like the one of the Cardossier project allows increased access to customer data. However, inherent to the characteristics of blockchain it also inhibits unpermitted control. On the one hand, this is necessary to allow companies to trust the data they get from other players in the system. On the other hand, this also introduces greater control over data access for customers. Finally, we also learned that sometimes in the case of a blockchain-based data market like the one the Cardossier project is building, even multi-party-ownership is possible. Hence, access to data that eventually enables businesses to create value through increased customization of products and / or processes, might require the consent of multiple parties. Thus, the guideline we derive for other companies that rely on a customer relationship business and aim to create value through blockchain, is to focus on building even greater trust relationships with their customers. More specifically they should interpret the term intimacy in a more bilateral sense and build an intimate bilateral relationship, in order to create value through blockchain with the customer. Furthermore, this also requires a better understanding of the data ownership and data structure (especially with respect to multi-party data ownership). An early participation and co-creation of such a complex system might help business to gain a competitive advantage through learnings on how to deal with such new rules as well as through building early relationships with customers as well as data co-creators.

Table 6. Guidelines for Blockchain Value Creation

Blockchain Value Creation	**Guidelines for other businesses**
Distributed Product Innovation	Put on your consortium glasses and focus on unserved potential in the ecosystem rather than your industry segment.
Shared Operational Efficiency	Resolve cross-organizational inefficiencies but set your own focus to leverage the full potential for your business.
Controlled Customer Intimacy	Be aware of the changing (power) relationships and focus on understanding the data-structure and building trusted-relationship to your customers and data co-creators.

Besides these promising potentials we would also like to acknowledge some boundaries of the value potentials that should not be forgotten. These are on the one hand the boundaries of customer intimacy which need to be respected. Societal questions like reinforcement of a two-class society through too much individualization need to be evaluated carefully. On the other hand, changing operational processes that incorporate authorities are not as simple. Sometimes even legal groundings are needed for that. Yet, the novelty and constant evolution the technology itself makes it hard for practitioners to initiate legal changes. Thus, despite discovered value potential, leveraging it is yet another hurdle.

5.2 Approaching Multiple Blockchain Value Disciplines

While the results and the above-mentioned guidelines show great potential for how individual businesses can realize the value potential from blockchain, there are also certain hurdles we encountered during our exploration. First, in such a big project multiple interest groups need to be managed. As this analysis exemplifies, there is great potential for all stakeholder, however in different ways, or in other words through different value disciplines. Thus, managing these different interests accordingly, to allow all stakeholders to leverage the potential they are after, is a key activity affecting all companies involved in the project. Second, all companies collaborating on the same project for one ecosystem will all have the same potential, independent the industry they are in now. This can induce competition over business potential. Thus, given the multitude of value potential combined with the paradoxon of collaboration and coopetition in such a blockchain project, from our longitudinal observation we can that derive mastering multiple value potentials is certainly a key to success. This is especially the case for platform blockchain projects, that are deployed by multiple stakeholders. As Treacy & Wiersema, (1993) already indicated, while excelling in one value discipline is the minimum and mastering two is the future, we agree with that view and take it a step further. Specifically, we argue that while entanglement of the value potentials at the individual business level is still a solid approach, in order to create value from blockchain in an ecosystem, the consortium of stakeholders that deploy the blockchain, need to master multiple value disciplines. In our case project, the cardossier application, the initial case that brought together the Cardossier consortium was the drive to innovate and create a novel product for the used-car market by enabling distributed access to resources and capabilities. However, along the prototyping phase, the stakeholders quickly realized that even great value can be achieved through Shared Operational Efficiency. Thus, while bearing in mind the initial business case as well as the other value potentials, the focus of development quickly shifted to enable early value creation through reduced cost and increased efficiency by sharing operational processes. This is of interest for all stakeholders as it enables all involved equally to create value from the platform's data and the shared infrastructure through increasing efficiency. Thus, based on these insights for other projects that aim to create value from blockchain, we recommend to:

- *design for all three blockchain value disciplines, but*
- *implement and execute shared operational efficiency first.*

By addressing first the shared operational efficiency potential from blockchain technology this will allow the consortium to achieve a common ground for all involved stakeholders and enable the necessary collaboration. At the same time, in order to allow for competition later, the other blockchain value disciplines should be kept in mind during the development of blockchain architecture. This means that the ability to jointly create novel products and services by drawing on distributed resources and capabilities as well as to leverage potential through controlled customer intimacy need to be embedded early in the system architecture and governance of the platform. For example, distributed product innovation in the case of the car ecosystem requires to incorporate and consider a fair data market mechanism that will incentivize and reward all relevant stakeholders adequality. Controlled customer intimacy requires an architecture that incorporates adequate privacy protection. Thus, designing for three value potentials but focusing on shared operational efficiency first, can be a successful approach to manage multiple value disciplines in a blockchain project where multiple stakeholders are involved.

6 Conclusion

In this paper we address the little attention that was given to blockchain from a business perspective by explicating how businesses can create value from a decentralized car ledger. Thus, we answer our research question, by showing how blockchain enables distributed product innovation, shared operational efficiency, and controlled customer intimacy.

Furthermore, based on the results from the Cardossier project, we derive guidelines for other businesses aiming to create value from blockchain. More specifically, we propose how other businesses should approach each blockchain value discipline and give recommendations on why and how blockchain projects in ecosystems should master multiple blockchain value potentials.

These insights are valuable not least for (1) academia, as we add to the limited discourse on business potential from blockchain by applying a scientific lens to the value creation and hence providing first answers to open research questions; (2) businesses, through disclosing insights in an advanced blockchain project in a highly-competitive market and providing guidelines for other businesses; (3) society as we emphasize both, the necessity of legislators for adapting and loosening legislation to allow leveraging efficiencies, but also keeping an eye on regulations with respect to customer protection. Yet, our paper has a few limitations. First, our analysis is based solely on the findings of one blockchain project. Thus, we recognize future research will be needed to test the generalizability and the applicability of our findings in the selected, and in other domains. Second, even though our project moved beyond the mere prototyping phase, it is still in an early market entry phase, thus the proposed value potential will require testing in practice. Third, we acknowledge the generality of the approach to define the business value of blockchain projects and the need for more fine-grained analysis. For example, through an instantiation and testing of one of the value potentials in a specific market context. We aim to address this deficit through future research, as part of our ongoing collaboration with the Cardossier consortium. Finally, it has to be noted that blockchain itself is still a recent innovation that might experience further developments which could impact the value creation logic. Thus, our findings should be viewed as an initial step towards a more holistic understanding of the business potential from blockchain.

7 Appendix

Data Availability Statement

The datasets generated for this study are available on request to the corresponding author.

Ethics Statement

All interviews and workshops were conducted in the course of this Innosuisse project and under the written consent of our project partner provided in a cooperation agreement.

Author Contributions

Ingrid Bauer (IB), Liudmila Zavolokina (LZ), Fabian Leisibach (FL) and Gerhard Schwabe (GS) contributed to the conception and design of the study. FL and IB conducted and coded the interviews. The codebook was crosschecked by FL, LZ and IB. IB wrote the whole manuscript. All authors contributed to manuscript revision, read and approved the submitted version.

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AdNovum, AMAG, Mobility. The road traffic authority did not provide any financial or non-financial compensation. The project was funded for the duration of the project (24 months), from October 2017 until October 2019.

Acknowledgement

We thank all partners for their involvement and feedback, and all reviewers for critical comments that enhanced the research. All interviews and workshops were conducted in the course of this Innosuisse project and under the written consent of our project partners provided in a cooperation agreement. The manuscript is based on the conference publication[5] from the 52nd Hawaii International Conference on System Sciences (HICSS). The authors confirm the right to reuse the material and confirm that a major part of this work is new.

Supplementary Material

The first supplementary Figure 9 below shows the current simplified process flow of a car import. It depicts the duplicated documentation process and the manual exchange of information between importer and customs.

[55] Bauer, I., Zavolokina, L., Leisibach, F., & Schwabe, G. (2018). Exploring Blockchain Value Creation: The Case of the Car Ecosystem. In Proceedings of the 52nd Hawaii International Conference on System Sciences.

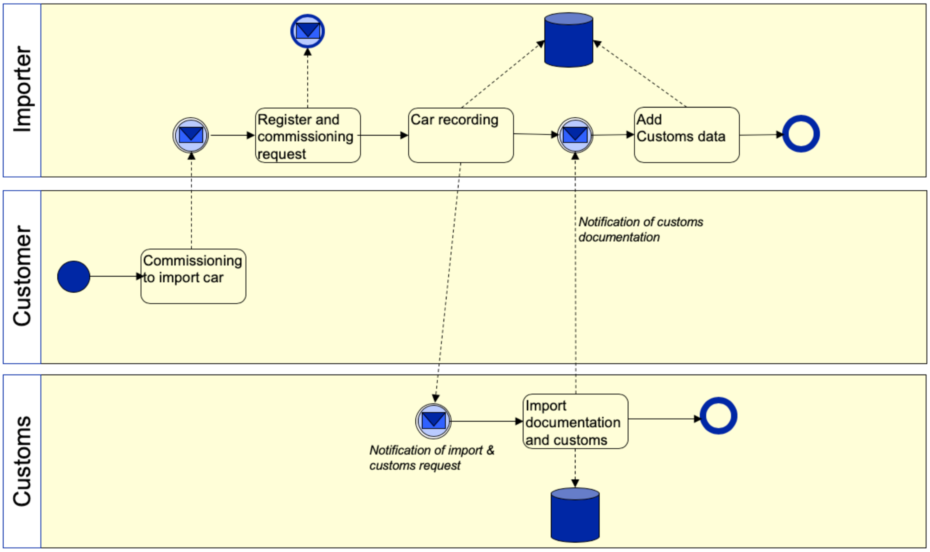

Figure 9. Current Process Flow of a Car Importer

The Supplementary Figure 10 below shows the envisioned process flow where the importer and the customs authority can share the process of car documentation during import.

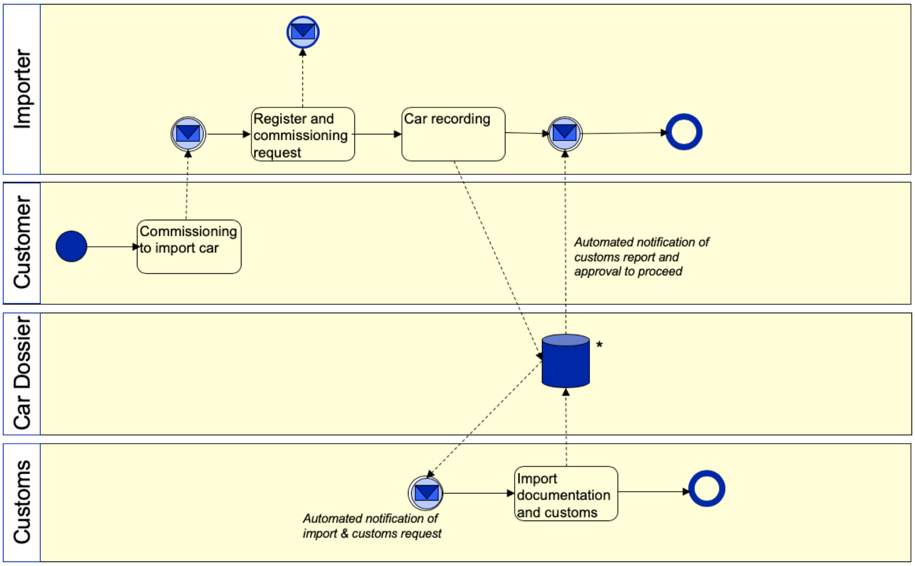

Figure 10. Envisioned Import Process Flow

**For simplicity reasons the blockchain infrastructure is represented via a single database.*

ESSAY II – IS THERE A MARKET FOR TRUSTED CAR DATA?

The content of this essay is based on the following publication:
Bauer, I., Zavolokina, L., & Schwabe, G., *"Is There a Market for Trusted Car Data?",* Electronic Markets Journal, September 13, 2019, https://doi.org/10.1007/s12525-019-00368-5.

Abstract

Based on a thorough understanding of the value potentials of blockchain for businesses in the car ecosystem, this essay delves deeper into the distributed product innovation potential. More specifically, essay I has shown that the most promising distributed product innovation that businesses in the car ecosystem foresee is offering a car history certificate to address information asymmetry problems in the used car market. Thus, this essay digs deeper into the narrowed environmental context of applying a decentralized car ledger to mitigate the problems of information asymmetry (i.e., input/output) and develops a first general understanding of the socio-technical interaction from which value will be generated and leveraged. Further it proves its market acceptance and value.

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 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, this essay explored the effects of trusted car data on the sales price of the cars and the relative revenue of buyers and sellers. Additionally, based on interviews conducted with the participants of the market game, the perceived customer values are elicited.

1 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 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 €2,000 - €5,000 on average and overall fraud costs for customers and businesses of €5.6 - €9.6 billion a year (European Parliament, 2018b). 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, 2008). 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 coffee-shop payment solutions (Beck et al., 2016). Finally, the technology's key characteristics of decentralization and trust (Seebacher & Schüritz, 2017) have also shown to reduce information asymmetries and mitigate adverse selection effects in the market for lemons (Notheisen, Cholewa, et al., 2017). Notheisen, Cholewa, et al., (2017), 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, Cholewa, et al., 2017; Notheisen, Hawlitschek, et al., 2017). 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 & Strausz, 2017). More specifically, according to (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, Hawlitschek, et al., 2017). 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.

2 Related Work

2.1 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 & 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 & 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).

2.2 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 & Pavlou, 2006; Huston & Spencer, 2002; Lewis, 2011; Pavlou & 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 & 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 € 2,800 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, Cholewa, et al., 2017; Zavolokina, Miscione, et al., 2018). 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, Cholewa, et al., 2017) 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, Miscione, et al., (2018) 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, Tessone, et al., (2018) 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, Zavolokina, Leisibach, et al., 2019). 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, Hawlitschek, et al., 2017).

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.

2.3 Blockchain and Trusted Car Data

Taking a deeper view at the infrastructure layer, blockchain, in simple terms, is defined 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 & 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 & Schüritz, 2017). Finally, such a trusted social network (Y. 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.

3 Methods

3.1 DSR using Eexperimental 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 & 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 & 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

3.2 Market Game Setting

Game Design

Our market game is a web-based application 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 (Figure 11).

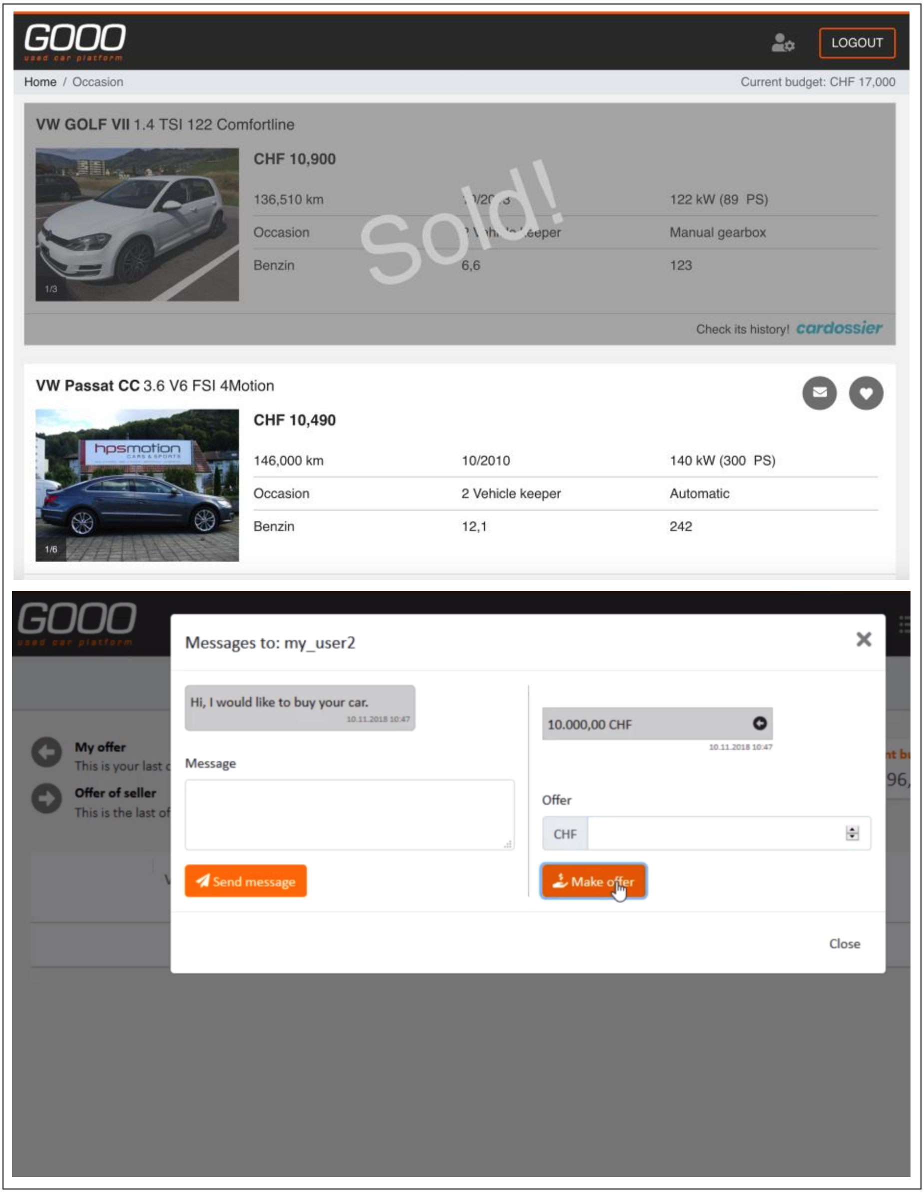

Figure 11. Overview-page for the Online Marketplace Gooo and Communication Space for Users

Into this web-based market platfrom Gooo, the IT artifact cardossier is embedded into. Within the bigger picture of the Cardossier's architecture (depicted in Figure 12) the cardossier IT aritfact is one of many foreseen applications. 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. Thus, for the purpose of the market game 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.

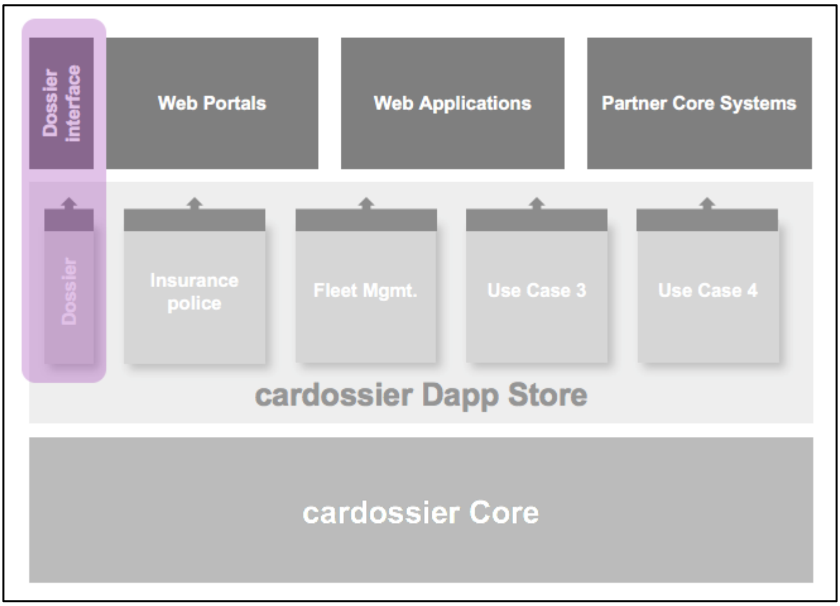

Figure 12. The Cardossier Architecture

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 minutes 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[6] 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 Figure 11), 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

[6] 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).

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 7 gives an overview of key terms used in the market game, their meaning and explains the source of the information and calculation methods.

Table 7. 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.[7]
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: $RR_{Buyer} = \frac{(AV-SP-IC)}{AV}$; $RR_{Seller} = \frac{((SP+IR)-(AV+IC))}{AV}$

[7] 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

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 Figure 13, 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.

consistently. The assessment table considers different variables and relatively accounts their effect on the actual value of the car.

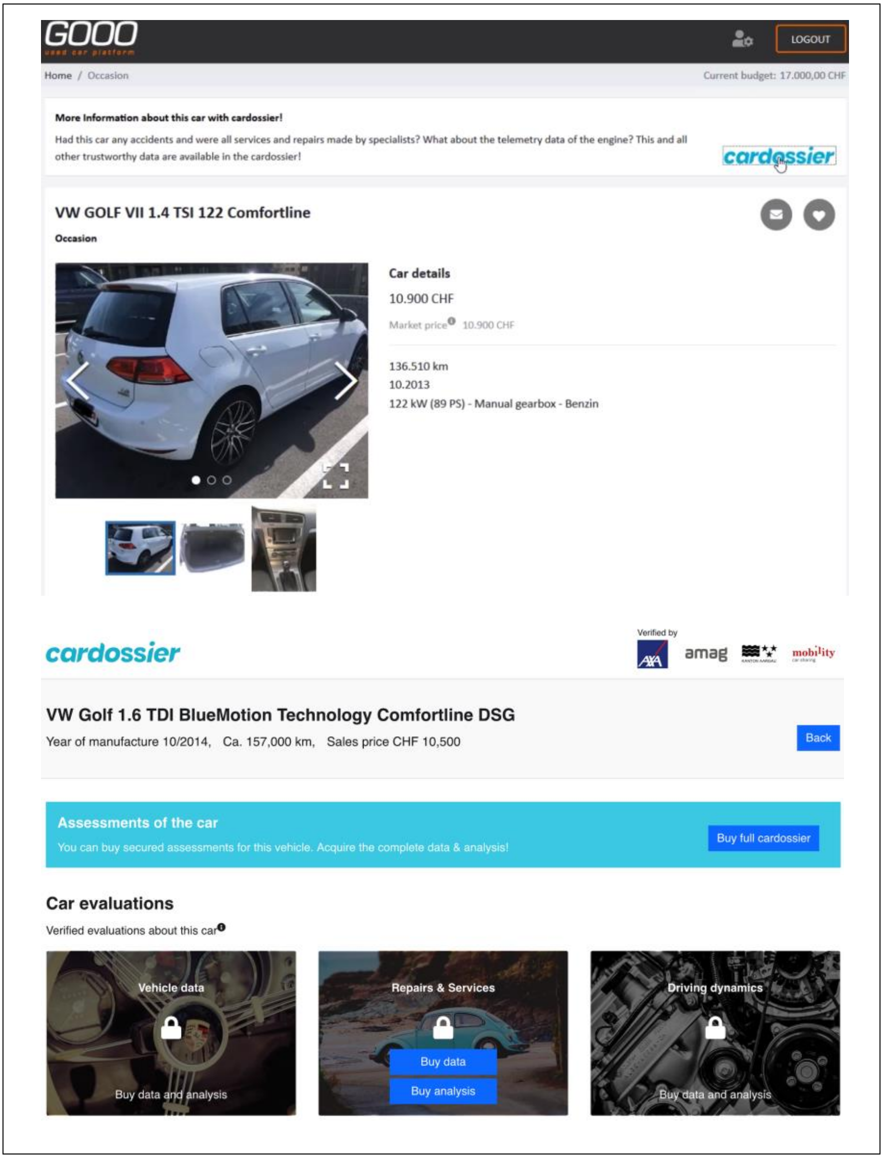

Figure 13. View of the IT Artifact in the Cardossier Market Game

3.3 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 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 & 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. 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.

4 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.

4.1 Effects of Trusted Car Data

<u>Market view</u>

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 8 summarizes the results, which are explained in detail below.

Table 8. Results of Market View Analysis

Game Round	(a) Total Actual Value (all Cars)[8] 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	-1,325	-0.55	5,130.00	-2.66
Deviation of market value of cars sold between the games		**21,974**		**+9.05**	**+5,130**	**+6.93**

As shown in Table 8, 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 9,000 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 -1,325 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.=9,150, S.D.=1,958) and

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

cardossier (M.=10,065, S.D.=1,448) 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 products to purchase. In the cardossier round, the total information costs were USD 5,130. 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 3,000 to USD 11,900, on the cardossier market the sales prices only ranged from USD 7,900 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 9 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).

Table 9. Results of the Agent View Analysis

	Seller				**Buyer**		
Game Round	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	1,050	780	-1,595	-0.09	3,990	3,990	-0.07

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 3,990, 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 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 14 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 Figure 14 indicates that the average number of purchases of trusted car data was three.

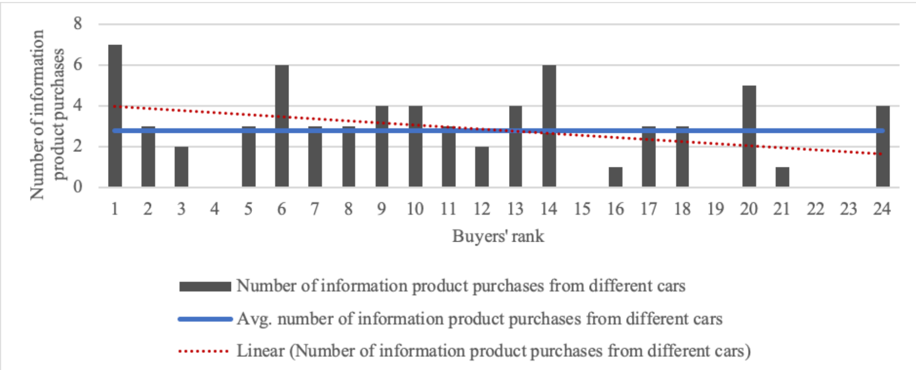

Figure 14. Number of Information Product Purchases by each Buyer Ordered According to their Rank

4.2 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 10 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.

Table 10. 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."*

5 Discussion

5.1 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 todays 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, Cholewa, et al., 2017). 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.

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.

5.2 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 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 & Dimoka, 2008). This changed on the cardossier supported 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 5,130 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.

5.3 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 10). 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 (Figure 14) 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 supported 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, Cholewa, et al., 2017; Zavolokina, Miscione, et al., 2018) 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.

6 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, Tessone, et al., 2018), 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. Further, 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. Finally, for future work, it would also be worthwhile to investigate the identified experienced values by users (e.g., improved signaling ability, informed bargaining) more in-depth.

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.

7 Appendix

Additionally, for the interested reader, we are disclosing below the detailed raw results, that each user group (Seller: Table 11 / Buyer: Table 12) has achieved during broth game rounds (Traditional Round / Cardossier Round).

SELLER

	Traditional Round						Cardossier Round							
username	car_id	Actual Value	Sales Price	Abs. Revenue (AV - SP)	Relative Rev. (AV - SP) /AV	Rank	car_id	Actual Value	Sales Price	IC	Revenue	Abs. Revenue (SP - AV)	Relative Revenue (SP-AV)/AV	Rank
user18	37	12099	10000	-2099	-17.35%	20	3	9471.75	11100	15	47.5	1660.75	17.53%	1
user46	47	10212.5	3000	-7212.5	-70.62%	24	48	8694	10000	50	27.5	1283.5	14.76%	2
user27	6	8848	8300	-548	-6.19%	11	40	8900	10000	0	15	1115	12.53%	3
user13	35	9075	7745	-1330	-14.66%	17	34	7735	8750	50	0	965	12.48%	4
user40	45	11959.5	10000	-1959.5	-16.38%	18	46	8365.5	9200	50	115	899.5	10.75%	5
user5	1	12198.78	10100	-2098.78	-17.20%	5	32	9917	10500	50	0	533	5.37%	13
user15	36	8073	8300	227	2.81%	6	37	12099	12500	55	42.5	388.5	3.21%	7
user55	51	12376	11900	-476	-3.85%	23	50	9954	10250	50	0	246	2.47%	11
user12	34	7735	8500	765	9.89%	3	35	9075	9300	50	25	200	2.20%	9
user16	3	9471.75	11600	2128.25	22.47%	1	36	8073	8169	50	80	126	1.56%	10
user54	50	9954	6700	-3254	-32.69%	4	49	9599.04	9700	50	20	70.96	0.74%	20
user33	42	8848	8000	-848	-9.58%	15	10	9355.5	9200	50	62.5	-143	-1.53%	12
user9	33	9345	10000	655	7.01%	9	1	12198.78	12000	50	60	-188.78	-1.55%	24
user48	48	8694	8750	56	0.64%	8	47	10212.5	10000	50	20	-242.5	-2.37%	14
user26	40	8900	10000	1100	12.36%	2	41	12017.5	11550	50	15	-502.5	-4.18%	15

user44	46	8365.5	6500	-1865.5	-22.30%	21	45	11959.5	11500	50	0	-509.5	-4.26%	16
user36	43	12911.5	11800	-1111.5	-8.61%	13	44	9156	8600	50	7.5	-598.5	-6.54%	17
user21	38	10692	9900	-792	-7.41%	12	39	13090	12200	20	15	-895	-6.84%	18
user39	44	9156	8000	-1156	-12.63%	16	43	12911.5	12000	50	40	-921.5	-7.14%	19
user53	49	9599.04	10400	800.96	8.34%	19	51	12376	11500	50	35	-891	-7.20%	6
user29	41	12017.5	10900	-1117.5	-9.30%	14	6	8848	8150	70	20	-748	-8.45%	21
user34	10	9355.5	9600	244.5	2.61%	7	42	8848	7900	0	62.5	-885.5	-10.01%	22
user24	39	13090	10000	-3090	-23.61%	22	38	10692	9500	40	62.5	-1169.5	-10.94%	23
user7	32	9917	9600	-317	-3.20%	10	33	9345	8000	50	7.5	-1387.5	-14.85%	8

Table 11 Detailed Performance Results for Sellers

BUYER

User ID	Traditional Round						Cardossier Round						
	Car ID	Actual Value	Sales Price	Abs. Revenue (AV -SP)	Relative Rev. (AV - SP) /AV	Rank	Car ID	Actual Value	Sales Price	IC	Abs. Revenue (AV - SP)	Relative Revenue (AV-SP)/AV	Rank
user8	38	10692	9900	792.00	7.41%	13	33	9345	8000	125	1220	13.06%	1
user35	34	7735	8500	-765.00	-9.89%	22	42	8848	7900	150	798	9.02%	2
user32	43	12911.5	11800	1’111.50	8.61%	12	38	10692	9500	325	867	8.11%	3
user11	6	8848	8300	548.00	6.19%	14	51	12376	11500	0	876	7.08%	4
user22	45	11959.5	10000	1’959.50	16.38%	7	52	10900	10000	170	730	6.70%	5
user30	51	12376	11900	476.00	3.85%	15	39	13090	12200	210	680	5.19%	6
user41	44	9156	8000	1’156.00	12.63%	9	44	9156	8600	100	456	4.98%	7
user28	1	12198.78	10100	2’098.78	17.20%	6	43	12911.5	12000	300	611.5	4.74%	8
user37	41	12017.5	10900	1’117.50	9.30%	11	6	8848	8150	300	398	4.50%	9
user4	32	9917	9600	317.00	3.20%	16	45	11959.5	11500	160	299.5	2.50%	10
user20	37	12099	10000	2’099.00	17.35%	5	41	12017.5	11550	175	292.5	2.43%	11
user1	10	9355.5	9600	-244.50	-2.61%	18	10	9355.5	9200	100	55.5	0.59%	12
user19	46	8365.5	6500	1’865.50	22.30%	4	1	12198.78	12000	165	33.78	0.28%	13
user31	36	8073	8300	-227.00	-2.81%	19	47	10212.5	10000	400	-187.5	-1.84%	14
user43	47	10212.5	3000	7’212.50	70.62%	1	50	9954	10250	0	-296	-2.97%	15

user10	33	9345	10000	-655.00	-7.01%	20	37	12099	12500	15	-416	-3.44%	16
user45	35	9075	7745	1’330.00	14.66%	8	36	8073	8169	185	-281	-3.48%	17
user42	40	8900	10000	-1’100.00	-12.36%	23	49	9599.04	9700	300	-400.96	-4.18%	18
user49	48	8694	8750	-56.00	-0.64%	17	32	9917	10500	0	-583	-5.88%	19
user47	42	8848	8000	848.00	9.58%	10	35	9075	9300	515	-740	-8.15%	20
user14	49	9599.04	10400	-800.96	-8.34%	21	46	8365.5	9200	30	-864.5	-10.33%	21
user23	50	9954	6700	3’254.00	32.69%	2	40	8900	10000	0	-1100	-12.36%	22
user17	39	13090	10000	3’090.00	23.61%	3	34	7735	8750	0	-1015	-13.12%	23
user2	3	9471.75	11600	-2’128.25	-22.47%	24	3	9471.75	11100	265	-1893.25	-19.99%	24

Table 12 Detailed Performance Results for Buyers

ESSAY III – MULTI-PARTY CERTIFICATION ON BLOCKCHAIN AND ITS IMPACT IN THE MARKET FOR LEMONS

The content of this essay is based on the following publication:
Bauer I, Parra-Moyano, J., Schmedders, K., & Schwabe, G., *"Multi-party Certification and its Impact in the Market for Lemons."* Journal of Management Information Systems, 39 (2) Spring 2022.

Abstract

Building on the promising results of essay II, essay III deepens the proposed value experience of blockchain-based car history certification (i.e., trusted car data) for sellers to signal product quality by analyzing in-depth the socio-technical interaction that affords this action potential. While the prior essay identified multiple value experiences for buyers and sellers of used cars, this essay III specifically deepens signaling, as a review of prior works – presented in this study – indicates that signaling is the most commonly used and most effective method to mitigate information asymmetries today. While there are multiple ways to signal product quality, the dealer's use of quality signals takes up the greatest share of the market today. The signals sent by intermediating dealers indeed help to mitigate information asymmetries in used-car markets today. However, these markets still function well below their optimum: a large share of goods sold are overpriced, and most of the benefits are reaped by intermediaries. Thus, this essay III delves deeper into the signaling potential of blockchain-based car history certificates to understand how it impacts the used-car market and what consequences this comes with.

Applying the socio-technical lens of Chatterjee et al. (2020), this essay describes how blockchain-enabled multi-party certification affords dealers the action potential to send signals that are more closely correlated to the unobservable quality of the underlying good (i.e., signals with a higher fit) than the signals they send today. We then both theorize and experimentally explore the

market effects of the two types of signals. Using data from a laboratory market experiment with 210 participants, we confirm and concretize earlier evidence that multi-party certification, as we will term the car-history certificates in this paper, affords dealers the action potential to send signals of significantly higher fit than those sent by intermediaries alone. Further, this essay also shows that his leads to a reduction in information asymmetries, a more efficient allocation of goods, and increased market fairness.

1 Introduction

Information asymmetries emerge in markets in which one party has more information about the quality of the offered goods (Stahl & Strausz, 2017). The party with this information advantage is able to discern the quality of the goods; the party with the information disadvantage is not (Levin, 2001). Classical examples of markets that suffer from information asymmetry include the insurance market, the employee-recruitment market, and the used-car market. The last of these is perhaps the best-known illustrative example of this issue. In such markets, signaling methods have emerged as one of the most effective mechanisms for mitigating the effects of information asymmetry (Spence, 1973). Signals are pieces of information sent by one party—the better-informed party—to the less-informed party (Dawson et al., 2010). To be trustworthy and effective, signals need to be difficult to fake (Spence, 1973). The extent to which a signal correlates with the unobservable quality of the underlying element it refers to is called the signal's *fit* (Clemons & Thatcher, 1997). In the case of the used-car market, the most common type of signal is that sent by intermediating dealers. Dealers have the skills necessary to better identify product quality and to profit from buying peaches (goods of relatively high quality) at—or slightly above—the average price. And to then sell them back to buyers at higher prices, using their established brand name or guarantees as signals (Blundell et al., 2019).

Yet despite the positive effects of intermediary signaling sent by dealers—the fact that it forestalls market collapse and enables a large share of market transactions—the used-car market still functions well below its optimum (The Economist, 2019). Overall, according to the European Parliament (2018a), odometer fraud alone entails losses for European Union citizens of 8.9 billion euros each year. Further, the overpayment made by buyers for used lemons (cars of relatively low quality) sold by dealers after their first year of ownership constitutes on average 18 percent of the price of such cars (Blundell et al., 2019). Finally, while dealer signaling allows more transactions to take place, most of the additional revenue generated is reaped by the intermediary dealers themselves (Lee et al., 1999). Consequently, many sellers of peaches refrain from entering the market and a large number of potential trades do not even take place.

The digitalization of the automotive ecosystem is about to change all this: Car manufacturers aim to monetize their access to clients by offering clients services and generating value from the very data that clients, and their vehicles, collect. Such data can much better describe and predict the value of a used car, and thus resolve the market-for-lemons problem. Centralized control of car usage data (by vehicle manufacturers, or technology firms such as Google) may, however, result in digital platforms of ever greater power reaping the lion's share of the benefits of any efficiency gains these changes lead to. This would not be in the interests of other players in this market, including insurers, or national and supranational regulators (Rieger et al., 2019; Schallbruch et al., 2021).

Lately, blockchain information systems have been proposed as an enabler of a novel approach to allowing real-world assets, such as used cars, to be digitized in a trusted and decentralized manner (Gomber et al., 2018; Notheisen, Cholewa, et al., 2017). Using blockchain technology, it is possible to ensure data integrity and compatibilities that foster data sharing (Sarker et al., 2021) while keeping transaction costs under control (Zhang et al., 2021). This enables multiple parties to collaborate and create trusted, decentralized product history certificates that draw on the data sources of many agents (Ostern et al., 2020; Ziolkowski et al., 2020). Such blockchain-based multi-party product history certificates—as we will argue in this paper—afford dealers the action potential to send signals of a higher fit than those they send today. However, given that blockchain-enabled multi-party certificates are only a resource in the context of information asymmetries and not a solution per se, it remains to be seen whether this will indeed lead to significantly different market outcomes. Contrary to the hype surrounding the technology, it has yet to prove itself to several challenges and open questions. Building on the behavioral assumptions and theories that govern the market for lemons, we therefore formulate the following research question (RQ):

RQ: *How does multi-party certification impact the market for lemons?*

This question responds to widespread calls for in-depth analytical and empirical analysis of the affordances of blockchain applications for their users and how these affect market outcomes (Fridgen et al., 2018; Rossi et al., 2019; Sun Yin et al., 2019). The IS discipline is methodologically the best suited to the study of the capabilities of blockchain and its economic impacts, an endeavor that essentially can help to avoid unnecessary costs and at the same time foster the advancement of blockchain-based systems by guiding better-founded and targeted development (Zwass, 2021). We will apply a socio-technical artifact perspective (Chatterjee et al., 2020) to structure the benefits of blockchain more precisely and to theorize and explicate “the axis of cohesion” of blockchain-enabled multi-party certification in the market for lemons (Sarker et al., 2019).

The remainder of this paper is organized as follows. First, we review the economics that govern the market for lemons today and the shortcomings of current mitigants. Next, we introduce the socio-technical artifact framework of Chatterjee et al., (2020), which enables us to work out, on the one hand, how blockchain affords multiple businesses the action potential to generate multi-party certificates and, on the other, blockchain’s affordance for the users of its application in the used-car market. In the subsequent section we theorize the impact of dealers’ use of multi-party certification in the market for lemons in a formal model and derive a set of hypotheses. We then empirically test these hypotheses using data from an experiment. Next, we present the results of that experiment, which indicate that buyers and dealers react to multi-party certification as theoretically proposed in the assertions derived from the model. In light of prior work, we continue discussing the observed effects of blockchain-enabled multi-party certification in the market for lemons and its practical implications. Finally, we conclude, pointing out the limitations of this paper and possible lines of future work.

2 Related Work

2.1 The Market for Lemons and Current Mitigants

The market for lemons is usually modelled as though only two types of goods—peaches and lemons—are available to trade. While peaches have no observable defects, lemons do. Since the characteristics that differentiate the two types of goods, in our case used cars, are mostly hidden or hard to ascertain, buyers cannot tell the difference between a peach and a lemon, so, between a good and a bad car. As a result, both types of car will sell at a market price (resulting from an equilibrium of supply and demand) that reflects the average quality of the cars on the market (Wilson, 1980). This market outcome is caused by buyers' inability to evaluate product quality as well as by sellers' inability to prove the quality of their cars (Pavlou & Dimoka, 2008). This market equilibrium leaves the sellers of good cars with no choice but to sell their peaches for less than their actual value—obtaining negative rents—or to leave the market (Wilson, 1980). Consequently, the classical adverse-selection phenomenon comes into effect: lemons tend to drive out peaches, which theoretically might even lead to a market collapse (Akerlof, 1970). Hence, markets with such an asymmetric distribution of information suffer from losses in social welfare (Clemons & Thatcher, 1997). These losses include overpayments by buyers for lesser quality goods (in our case, poorer quality used cars), the negative rents of the sellers of peaches, and the losses of both buyers and sellers due to a reduced number of trades (Akerlof, 1970).

A collapse of this market is, however, unknown. One main reason for this in the case of the used-car market is the existence of used-car dealers (Akerlof, 1970; Lee, 1997). Dealers have the skills to identify product quality and consequently profit from buying peaches at, or slightly above, the average price and selling them at a higher price by using signaling methods such as warranties or licensing models, or simply thanks to buyers' greater trust in their established brand names (Blundell et al., 2019). Such methods intermediate the market by providing a signal to the buyer, and hence reduce product uncertainty (Wolinsky, 1983). From a seller's perspective, such measures lead to more high-quality cars entering the market thanks to the promise of higher prices (Rosenman & Wilson, 1991) for peaches. Signals can be understood by the less-informed party, and help that party to mitigate information asymmetry (Dawson et al., 2010). While signals can reduce information asymmetry, their effectiveness is affected by their fit (i.e., the extent to which a signal is correlated with unobservable quality), their frequency (the number of times a receiver receives a signal), and their observability (the extent to which outsiders are able to notice them) (Connelly et al., 2011; Hoang & Kauffman, 2018). Signals provided by intermediaries, such as dealers, have been shown to somewhat ameliorate the lemons problem. Yet the great share of the benefits in such markets are reaped by these very intermediaries (Biglaiser, 1993). Due to their information advantage and the market setting, they apply negotiation tactics such as working with the anchoring effect (Adomavicius et al., 2013; Allen & Parsons, 2010). The anchoring effect is a well-known cognitive bias in negotiation. It is the tendency to assign too much weight to the first number put on the table and then to inadequately adjust from that starting point (Beggs & Graddy, 2009).

Product history certification provides an alternative to signaling by intermediating agents. Product history certification can be provided either by individual sellers who create individual documentation of their products' quality or by independent certifiers. Product history certification provided by individual sellers has thus far been inefficient and costly from a seller's perspective. Moreover, this type of signal also fails to create the necessary trust on the buyers' side: document falsification is easy, which makes the faking of the signal easy too (Pavlou & Dimoka, 2008). Product history certification generated by single independent certifiers is more established than that provided by individual sellers. Carfax and Eurotax are examples of this type of third-party certification in the car market, and each also enables signaling (Stahl & Strausz, 2017). But despite their established role, they have shortcomings. First, single providers often lack the ability to obtain extensive information that is dispersed among different actors (Notheisen, Cholewa, et al., 2017). Second, even if an intermediary certifier collects data from multiple parties, it is often not known where this data comes from and whether it is correct or can be trusted (Zavolokina et al., 2019). There is, therefore, no traceability and no data provenance, both of which have been deemed crucial for the efficient transmission of valuable information (Koutroumpis et al., 2020; H. G. Lee, 1997). This lack of traceability and data provenance negatively affects signal fit (Clemons & Thatcher, 1997).Third, single third-party intermediary certifiers have no incentive to provide more information than the minimum required. According to prior studies (Lizzeri, 1999), in a monopolistic market the best strategic choice for such intermediaries is to maximize profits by designing certificates that reveal only minimal information. Thus, in today's markets we often observe such single third-party certifiers employing monopolistic strategies, including providing a quality label concerning specific vehicle characteristics inspected. These shortcomings—the lack of access to relevant information dispersed among multiple parties, the lack of trust in data quality, and the lack of incentives for single third-party certifiers to provide extensive information—all limit signals' fit, and hence their effectiveness (Connelly et al., 2011).

From prior work it emerges that the signals provided by used-car dealers have thus far been the most effective mechanism for mitigating the negative consequences of information asymmetry in this particular instance of the market for lemons. Yet such intermediaries also reap a large share of the benefits that they themselves generate in the market. Markets with information asymmetry thus continue to function below a socially optimal level, and there is clear evidence that the classical market-for-lemons problem still persists today (European Parliament, 2018a; The Economist, 2019).

2.2 Blockchain-Based Product History Certification

"Blockchain" is regularly used as an umbrella term for a combination of technologies. The key characteristics of blockchains (Beck et al., 2017; Glaser, 2017; Glaser & Bezzenberger, 2015; Lacity, 2018; Lindman et al., 2017; Mougayar, 2016) are *their distributed database architecture*, which enables them to store and access transactions dispersed among multiple parties; *their network-based consensus mechanism*, which allows agreement to be reached regarding transaction validity, based upon predefined rules in a decentralized manner without the need for a central authority; and *their inherent cryptographic logic*, which defines their immutable and transparent nature. Blockchain-based systems make it possible to manage unique digital assets in a distributed and decentralized setting (Parra-Moyano et al., 2020; Sarker et al., 2021). Bitcoin strove to create and distribute digital money without a central bank (Nakamoto, 2008). Thus, decentralization is not just a feature of blockchains; rather it is their defining element, and one that has been eagerly adopted by practitioners. The Cardossier consortium, for example, strives to collect all data from a car's life cycle, creating unique and definitive records describing the history and the state of each car on its platform. The consortium chose to go with a distributed ledger to avoid the concentration of economic power that comes with a central platform (Zavolokina, Ziolkowski, et al., 2020). In recent years more sophisticated architectures have become popular (e.g., Ethereum, Corda). They encapsulate the traditional blockchain components in hardware and protocol layers. On top, they establish platform mechanisms to allow for distributed apps (DApps). They share typical features of app stores (such as secure and authenticated access and quality control) but in addition can access data shared via a blockchain (Glaser, 2017; Hawlitschek et al., 2018) and ensure its integrity (Cho et al., 2021).

For the purposes of this paper, a blockchain is best regarded as a socio-technical system (Sarker et al., 2019). As the information stored in the system is key to an understanding of the potential and impact of blockchain systems, the recently published conception of an IS artifact (Chatterjee et al., 2020) is well suited to structuring prior work. It also serves as a theoretical basis that helps us to deduce the affordances of the technology for a variety of social actors working with it or using an application of it. Finally, we will use, in particular, insights about the affordance of the technology for sellers of used cars to dive deeper, and to model the effects of the use of the technology's application in the market for lemons. The relationship between the framework derived by Chatterjee et al. (2020) and our model emerges through incorporating their language, and some of their assertions and meta-principles.

The core of the reference IS artifact consists of the technical and the social subsystems, which are in an affording/constraining relationship. While the technical subsystem describes the techniques and mechanisms that enable organizational transformation, the social subsystem describes the individual actors and their knowledge and skills, as well as incentives and these actors' relationships. The notion of *affordances–constraints* connects these two subsystems. Another essential part of the reference IS artifact is the information element, which determines how the social and technical subsystems interact (Chatterjee et al., 2020). The subsystems are open and interact with the surrounding environment. The dynamic nature of the IS artifact is highlighted by a feedback loop, which feeds information from the output of the system back into the system, leading to changes in the interactions between the subsystems promoting a dynamic equilibrium. The feedback loop also helps to manage the system's information entropy (or *entropy* as we will hereafter refer to it), which is the average level of uncertainty inherent in a variable's possible outcomes (Shannon, 2001). As such, the entropy describes the degree to which a system is *disorganized*, with higher entropy implying a higher level of uncertainty in a (sub)system (Chatterjee et al., 2020).

An analysis of prior research reveals three distinct but interrelated socio-technical subsystems working with or using blockchain in the automotive ecosystem (Figure 15): the infrastructure provider subsystem, the car-related business subsystem, and the used-car buyer and seller subsystem. We will now briefly introduce the first two subsystems in the context of our research, and clarify the role of blockchain technology in the development of multi-party certificates. We will also detail the used-car seller (i.e., dealers) and buyer subsystem, which allows us to derive the affordance of multi-party certificates provided by blockchain for the participants of the used-car market.

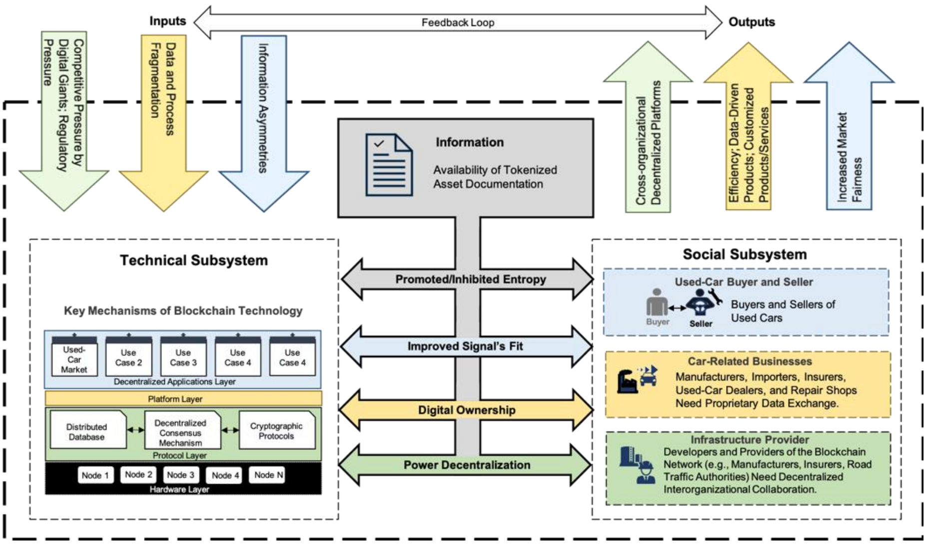

Figure 15. The IS Artifact Framework of Chatterjee et al. (2020), Enriched by a Summary of Prior Work on Blockchain-Enabled Certification in the Car Ecosystem

The *Infrastructure Provider Subsystem (marked in green in Figure 15)*: Participants in automotive ecosystems, including car manufacturers, importers, used-car dealers, car insurers, and mobility service providers, are experiencing rising competitive pressures from "digital giants" (*input*). At the same time regulatory pressure (for example, from the European Union) (Zavolokina, Ziolkowski, et al., 2020) is forcing car manufacturers to explore new ways of collecting, managing, and using their ever increasing amounts of car-related data (*input*). While digital giants try to establish monopolistic platforms for collecting and maintaining the increasing amounts of data generated by car usage, the goal of blockchain infrastructure providers is to build cross-organizational decentralized platforms (Avital et al., 2016; Sun Yin et al., 2019) (*output*). Thus, the distributed, decentralized, and immutable system architecture of blockchain (*technical subsystem*) becomes a necessary enabler to addressing the social needs (i.e., decentralized interorganizational collaboration (Ziolkowski et al., 2020)) of the developers and providers of a blockchain infrastructure (*social subsystem*). Put differently, through the *affordance* of decentralizing systems' power, blockchain enables the developers and providers of a decentralized car ledger to collaborate in a decentralized manner (W. (Derek) Du et al., 2018). As a result of the distribution of "information", and consequentially a reduction of extreme outcomes, the system experiences a reduction in entropy. While other technologies (e.g., distributed databases) could in principle provide similar solutions, they tend to be either too centralized or less technologically mature. The chief architect of Cardossier project summarizes, *"Of course we could solve these collaboration challenges we previously had differently but if we would do so, and evaluate the resulting technology neutrally, we would end up with exactly a solution as blockchain"* (Bauer et al., 2020) (p. 7).

Car-Related Businesses (marked in yellow in Figure 15): The individual business actors of the automotive ecosystem see opportunities to exchange data and increase efficiencies, create novel, data-driven products, and better customize their products and services to suit users' needs (Bauer et al., 2020; Parra-Moyano et al., 2020) (*output*). Today, however, they fear losing control over advantageous resources if they engage in exchanging data (Bauer, Zavolokina, Leisibach, et al., 2019; Koutroumpis et al., 2020) (*input*). Building on its decentralized infrastructure and utilizing blockchain's property of tokenization *(technical subsystem)* (Beck et al., 2017; Sarker et al., 2021), businesses can create novel data exchanges that address their need to leverage but at the same time protect their resources (Zhang et al., 2021) *(social subsystem).* More specifically, besides the decentralization of system power for infrastructure providers, blockchain *affords* providers of car data the action potential to create ownership over digital resources (Miscione et al., 2020; Ostern et al., 2020). By enabling the explicit assignment of property rights over digital goods such as data (Ziolkowski et al., 2020), it incentivizes car-related businesses to provide and trade their proprietary data, as they can now control its use and, consequently, monetize it fairly (Zavolokina, Tessone, et al., 2018). This consequently enables car-related businesses to create joint product innovations such as multi-party car history certificates (Bauer et al., 2020; Bauer, Zavolokina, Leisibach, et al., 2019). While research in this area is, to date, rather limited, it is fair to say that by integrating previously fragmented data, such joint data products enable a reduction in uncertainty (e.g., concerning the characteristics of a car being registered, insured, or sold)—and so, a decrease in information entropy.

While the idea of providing certification of a car's history is not new, based on the above insights we can conclude that blockchain-based approaches to product history certification (e.g., the initial prototype proposed by Notheisen et al. 2017) differ from previous approaches—such as a Carfax or Eurotax reports, both provided by a single third party—in that they are joint, multi-party efforts via which tokenized, digital representations of real-world assets are created. Building on these insights, we coin the term "*multi-party certification,*" defining it as follows: *"Multi-party certification is the documentation of the history of an asset by multiple independent parties in a trusted manner."* We acknowledge that multi-party certification could be delivered by any (existing or future) technology similar to blockchain that would address the needs of its providers in terms of power decentralization and unique digital ownership.

While the first two subsystems concern *the development of* multi-party certificates, the last subsystem, the *Buyers and Sellers of Used Cars Subsystem (marked in blue in Figure 15)* concerns *the use of* multi-party certificates: The *social actors* that are intended to use multi-party certificates are the sellers and buyers of used cars (Baumann et al., 2021; Zavolokina et al., 2019; Zavolokina, Schlegel, et al., 2020). These are confronted with problems of information asymmetry during used-car sales (*input*) (Akerlof, 1970). The desired outputs of the use of blockchain applications are a reduction of information asymmetries and a consequent increase in market fairness (Bauer, Zavolokina, & Schwabe, 2019; Notheisen, Cholewa, et al., 2017) (*output*). The use of multi-party certificates—which are provided by blockchain DApps that draw on the resources of many and consequently provide more comprehensive information, and come with the ability to provide proof-of provenance of the record history *(technical subsystem)*—affords sellers the action potential to better signal the quality of their cars (Bauer, Zavolokina, & Schwabe, 2019). This ability of sellers to better signal product quality is due to both the increased amount of data collected and combined from multiple sources and the increased trust in data quality due to the difficulty of faking data. Thus, we posit that blockchain-enabled multi-party certificates afford dealers (i.e., sellers) the action potential to *send signals of higher fit* than they would without such certificates.

While the present review of prior work in this field has allowed us to coin the term multi-party certification and to suggest how it affords dealers the action potential to send signals of higher fit, multi-party certification's impact on agent behavior and on market outcomes (including the dynamic equilibrium of the system and of the subsystems, induced by changes in information entropy) remains an unknown. A first approach to addressing this gap has been proposed by Notheisen et al. (2019), for the credit market (Notheisen & Weinhardt, 2019). Using modelling techniques, the authors show that disclosed blockchain-based information allows participants in the credit market to learn about quality differences between peaches and lemons, to deceive their counterparties, and to move to a new equilibrium with increased utility. The researchers forecast a market collapse despite a welfare gain (Notheisen & Weinhardt, 2019). While this research provides important insights into the credit market, its findings cannot simply be transferred to the used-car market, as market dynamics might differ due to the presence of different participants and interrelationships. Besides, it lacks an empirical analysis of the proposed market dynamics and the changes in entropy. This lack, and uncertainty regarding market outcomes, motivates our research study. In the following we derive a model to theorize the market effects of dealers' use of multi-party certificates.

3 Model

This paper strives to understand *how (blockchain-enabled) multi-party certification impacts the market for lemons*. This goal requires a more explicit modelling of the buyers and sellers subsystem to understand its current dynamics and how these may be affected by the availability of multi-party certificates.

In this subsystem potential sellers (i.e., dealers) and buyers meet and negotiate potential trades for used cars. They may use information provided by the blockchain application. This results in lower entropy due to the higher fit of the signals afforded by the dealers' use of multi-party certification. We now present a simple economic model that describes this particular social subsystem in more detail. The objective of this model is to analyze how the existence of multi-party certification might affect agent behavior and market outcomes. The model is a slightly altered version of that introduced by Levin (2001). To represent a signal's fit, we use different parameterizations for signals sent by dealers where multi-party certification is available and for those signals sent by dealers where multi-party certification is not available. Further, the model formalizes the concept of a good's quality over a continuum of possible values. This differs from the traditional, dichotomous approach, which only accounts for high- and low-quality goods (Connelly et al., 2011).

3.1 Market Definition

Following Levin (2001) (Levin, 2001), we consider an indivisible good, which can be traded between a used-car dealer and a buyer. The exact quality of the good, and the resulting value, v, are unknown to both agents. Each agent receives a signal about the good. After receiving their respective signals, dealer and buyer attempt to negotiate a price, p, for the good. If they agree on a price, they trade the good at that price. Thus, the respective relative revenues for dealer and buyer are $(p-v)/v$ and $(v-p)/v$. If no trade occurs, each agent receives a zero payoff. We employ relative revenues (both in the model and in the experiment) to account for the fact that cars of different prices are sold. In order to demonstrate the generalizability of our findings, we also develop a model using absolute price differences for risk-averse dealers and buyers, and a standard CARA utility function. This function changes neither the resulting propositions nor the outcomes of their testing. The results are available upon request. In the setup where multi-party certification is not available, both buyer and dealer receive a general description of the good. As a result, both dealer and buyer believe that the good's value, v, lies in some compact interval $[L,U] \subset \mathbb{R}$.

In addition, the buyer believes that a distribution of possible values is given by the density function f_B: $[L,U] \rightarrow \mathbb{R}$ with $L > 0$. In line with the instructions provided to participants in the experiment, the buyer wants to maximize the expected value of his relative revenue, $(v-p)/v$, if he pays the price, p. This allows us to model the quality of the cars to be traded over a continuum space, and not only in a dichotomous manner. Since he receives a payoff of zero in the absence of a trade, the buyer will only buy at price p if his expected relative revenue at that price is nonnegative,

$$\int_L^U \frac{v-p}{v} f_B(v)dv.$$

In addition to the general description of the good, the dealer also receives the average value, *m*, of the good, satisfying the general description that dealers have more information than buyers about any particular car's quality. The used-car dealer now believes that a distribution of possible values is given by the density function $f_S : [L,U] \rightarrow \mathbb{R}$. The dealer wants to maximize her relative revenue, $(p-v)/v$, if she receives the price, p. Since she receives a payoff of zero in the absence of a trade, she will only accept price p if the expected relative revenue at p is nonnegative. This conditional expected value is

$$\int_{L}^{U} \frac{p-v}{v} f_S(v)dv,$$

with the density satisfying

$$m = \int_{L}^{U} v\, f_S(v)dv.$$

In the setup with multi-party certification, both dealer and buyer not only receive the general information about the car (and the dealer also the mean price, m) but also verified and detailed information about the specific instance of the car. Both used-car dealers and buyers need, however, to derive their own price expectation with regard to the car based on this information. To simplify the analysis, we assume that the two agents form their expectations independently of one another. Thus, we avoid the analysis of a common value problem, and instead assume independent values. As before, the buyer forms his beliefs about the support of a density function of values of the good. However, due to the additional detailed information, $f_{B,M} : [L_M,U_M] \rightarrow \mathbb{R}$ with $L \leq L_M < U_M \leq U$, the buyer's conditional expected surplus at a trade of price p is now

$$\int_{L_M}^{U_M} \frac{v-p}{v} f_{B,M}(v)dv.$$

Similarly, the dealer's conditional expected surplus at a trade of price p is now

$$\int_{L_M}^{U_M} \frac{p-v}{v} f_{S,M}(v)dv,$$

with her density being $f_{S,M}$: $[L_M,U_M] \to \mathbb{R}$. Depending on the detailed information, the dealer's density may or may not satisfy the mean condition. The detailed information on the specific instance of the good may convince the dealer that the average price of such an instance cannot be m.

3.2 Parametrizations

To obtain more specific predictions, we make further assumptions. Without loss of generality, we impose the normalization $L = 1$. Further, we assume that f_B is the uniform density, and so

$$\int_{L}^{U} \frac{v-p}{v} f_B(v)dv = \int_{1}^{U} \left(1-\frac{p}{v}\right)\frac{1}{U-1}dv = 1 - \frac{p\ln(U)}{U-1}.$$

Hence, in the setting where multi-party certification is not available the buyer will only accept a price of at most $(U-1)/ln(U)$. In this setup, the dealer only receives the additional information that the mean value of this type of good is m. The value of m now affects her beliefs. For Case Single-Low (SL), she believes that $1 < m < (U+1)/2$, in a uniform distribution on $[1, 2m-1]$, and for Case Single-High (SH) that $U > m > (U+1)/2$, in a uniform distribution on $[2m-U,U]$. In Case SL, the dealer's expected payoff, conditional on a trade at price p, is

$$\int_{L}^{U} \frac{p-v}{v} f_S(v)dv = \int_{1}^{2m-1} \left(\frac{p}{v}-1\right)\frac{1}{2(m-1)}dv = -1 + \frac{p\ln(2m-1)}{2(m-1)},$$

and in Case SH the payoff is given by

$$\int_{L}^{U} \frac{p-v}{v} f_S(v)dv = \int_{2m-U}^{U} \left(\frac{p}{v}-1\right)\frac{1}{2(U-m)}dv = -1 + \frac{p\ln\left(\frac{U}{2m-U}\right)}{2(U-m)}.$$

This simple model reproduces the classical result of Akerlof (1970). In Case SL, when the dealer receives a signal indicating a low value for *m* she will trade and agree on a price within

$$\frac{2(m-1)}{\ln(2m-1)} \leq p \leq \frac{U-1}{\ln(U)}.$$

On the contrary, in Case SH, when the dealer receives a signal of higher fit the agents will not trade. For *m > (U+1)/2*, the dealer will demand a price of at least *2(U-m)/ln(U/(2m-U)),* which exceeds the upper bound on the price, *(U-1)/ln(U),* that the buyer is willing to pay. We summarize the results in the following proposition.

Proposition 1: In the parameterized model where multi-party certification is not available, a trade is impossible if and only if the dealer receives a signal, *m,* larger than *(U+1)/2*. If a trade occurs, then the price satisfies

$$p \in \left[1, \frac{U-1}{ln(U)}\right].$$

Next, we consider the parameterized setup where dealers are expected to send signals of higher fit through the use of multi-party certificates. In this case, the buyer's conditional expected surplus at a price *p* is

$$\int_{L_M}^{U_M} \frac{v-p}{v} f_{B,M}(v)dv = \int_{L_M}^{U_M} \left(1-\frac{p}{v}\right)\frac{1}{U_M-L_M}dv = 1 - \frac{p\ln\left(\frac{U_M}{L_M}\right)}{U_M-L_M},$$

assuming again a uniform distribution. Hence, with signals of higher fit the buyer will only accept a price of at most $(U_M - L_M)/\ln\left(\frac{U_M}{L_M}\right)$.

Recall that in the parametrized model where multi-party certification is not available—and hence only signals sent by dealers based on their own knowledge advantage and reputation are available—the buyer has a uniform distribution on *[1,U]*. This probability distribution has the maximal entropy of all continuous distributions with the support *[1,U]*. Therefore, whenever $1 < L_M$ or $U_M < U$, the entropy for the buyer's belief distribution is smaller in the parametrized model with signals of higher fit, which dealers send by means of multi-party certification. Put differently, the difference in belief distributions between the parametrized models reflects how the technical subsystems in Figure 15 affect the level of entropy of information in the social subsystem of dealer and buyer. The signals sent when multi-party certification is available provide more information and thus lower entropy than those sent when multi-party certification is not available.

The dealer now has access to the more detailed multi-party information (in addition to the mean price, m). In order to combine this detailed multi-party information on the specific good with the average m of typical instances of the good, we need to distinguish three cases.

Case Multi-Low (ML): The signal sent when multi-party certification is available indicates a very-low-quality car, such that $U_M \leq m$. While the dealer realizes that the value of the good cannot be m, she believes that the density is increasing in $[L_M, U_M]$. Specifically, she believes that the density is linear with

$$f_{S,M}(v) = \frac{2(v - L_M)}{(U_M - L_M)^2}$$

for $v \in [L_M, U_M]$ and 0 otherwise. The dealer's conditional expected surplus at price p is then

$$\int_{L_M}^{U_M} \frac{p-v}{v} f_{S,M}(v)dv$$
$$= \int_{L_M}^{U_M} \left(\frac{p}{v}-1\right)\frac{2(v-L_M)}{(U_M-L_M)^2}dv$$
$$= \frac{(U_M-L_M)(L_M+2p-U_M)-\ 2\,L_M\,p\ln\left(\frac{U_M}{L_M}\right)}{(U_M-L_M)^2}.$$

There will be no trade, since the dealer's and buyer's surpluses are never both nonnegative for a price $p \in\ [L_M, U_M]$. (Aside: here, the signals sent thanks to the dealer's use of multi-party certification and the signal on the average, *m*, are so diffuse that the resulting beliefs of the dealer prohibit a trade.) The entropy of the information from the signal afforded by the dealer's use of multi-party certification is smaller than that for the signal sent by the dealer alone where multi-party certification is not available since $U_M \leq m$ and so $[L_M, U_M] \subset [1, 2m-1]$. Recall that the uniform distribution on $[1, 2m-1]$ in Case SL is the distribution with maximal entropy on $[1, 2m-1]$.

Case Multi-High (MH): The signal sent when multi-party certification is available indicates a very-high-quality car, such that $L_M \geq m$. While the dealer realizes that the value of the good cannot be *m*, she believes that the density is decreasing in $[L_M, U_M]$. Specifically, she believes that the density is linear with

$$f_{S,M}(v) = \frac{2(U_M-v)}{(U_M-L_M)^2}$$

for $v \in\ [L_M, U_M]$ and 0 otherwise. The dealer's conditional expected surplus at a price *p* is then

$$\int_{L_M}^{U_M} \frac{p-v}{v} f_{S,M}(v)dv$$

$$= \int_{L_M}^{U_M} \left(\frac{p}{v} - 1\right) \frac{2(U_M - v)}{(U_M - L_M)^2} dv$$

$$= \frac{(U_M - L_M)(L_M - 2p - U_M) + \; 2\, U_M\, p \ln\left(\frac{U_M}{L_M}\right)}{(U_M - L_M)^2}.$$

There will always be a trade, since now the dealer's and buyer's surpluses are both nonnegative for all prices in a nonempty, compact subinterval of $[L_M, U_M]$. In particular, contrary to the intermediary signaling only setup, there will now be a trade even for high-value cars, when $L_M > \frac{U+1}{2}$. Comparing Case SH with Case MH, we notice that once again the signal sent when multi-party certification is available leads to a lower entropy distribution for the dealer than does the signal sent without the availability of multi-party certification. Since $L_M \geq m$, $[L_M, U_M] \subset [2m - U, U]$, with the latter interval being the support of the uniform distribution in Case SH.

Case Multi-Middle (MM): The signal sent when multi-party certification is available satisfies $[L_M, U_M] \ni m$. If $3m > L_M + 2U_M$—so that the signal indicates a rather-low-quality car—then no triangular distribution on $[L_M, U_M]$ has the mean m. In this case the dealer chooses the same distribution as in Case ML. There is no trade. Moreover, $[L_M, U_M] \subset [1, 2m - 1]$, and so the entropy is lower than in the system with the signal of the dealer only.

If $3m < 2\, L_M + U_M$—so, the signal sent when multi-party certification is available indicates a rather-high-quality car—then no triangular distribution on $[L_M, U_M]$ has the mean m. In this case the dealer chooses the same distribution as in Case MH. There is a trade. Moreover, $[L_M, U_M] \subset [2m - U, U]$ and so the entropy is again smaller with the signal sent when multi-party certification is available.

Finally, for

$$\frac{2\,L_M + \,U_M}{3} \leq \, m \, \leq \, \frac{L_M + \,2\,U_M}{3}$$

the dealer assumes a triangular density on [L_M,U_M] with mean m. The mode, $D \in \, [L_M, U_M]$, of the distribution satisfies (L_M + D + U_M)/3 = m. The resulting density is

$$f_{S,M}(v) = \frac{2(v - L_M)}{(D - L_M)(U_M - L_M)} \text{ for } L_M \, \leq \, v \, \leq D,$$

and

$$f_{S,M}(v) = \frac{2(U_M - v)}{(U_M - D)(U_M - L_M)} \text{ for } D \leq \, v \, \leq \, U_M,$$

and 0 otherwise. The dealer's conditional expected value given a trade at price p is then

$$\int_{L_M}^{U_M} \frac{p - v}{v} f_{S,M}(v) dv$$

$$= \frac{(D - L_M)(L_M + 2p - D) - 2pL_M \ln\left(\frac{D}{L_M}\right)}{(D - L_M)(U_M - L_M)}$$
$$+ \frac{(U_M - D)(-U_M - 2p + D) + 2pU_M \ln\left(\frac{U_M}{D}\right)}{(U_M - D)(U_M - L_M)}.$$

For a sufficiently small D near L_M there is a trade. For larger values of D (and m) there is no trade. We summarize the results in the following proposition.

Proposition 2: In the parameterized model with signals sent where multi-party certification is available, there is a threshold $T \in (2\,L_M + U_M, L_M + 2\,U_M)$ such that there is no trade if the dealer's signal, m, satisfies $3m > T$. On the contrary, for $3m \leq T$ there is always a trade. If a trade occurs, then the price satisfies

$$p \in \left[L_M, (U_M - L_M)/\ln\left(\frac{U_M}{L_M}\right)\right].$$

Based on these two propositions, we can draw additional conclusions for an important special case—namely, when the signals sent when multi-party certification is available lead to identical relative changes of the lower and upper bounds of possible values.

Corollary 1: Suppose $L_M = \frac{L_M}{L} = \frac{U}{U_M} = 1 + \Delta$ for some $\Delta > 0$ such that $L_M \leq U_M$; that is, the signal afforded by the dealer's use of multi-party certification increases the lower bound and decreases the upper bound of the good's value by the factor $1 + \Delta$. Then,

$$L < L_M \leq \frac{U_M - L_M}{\ln\left(\frac{U_M}{L_M}\right)} < \frac{U - 1}{\ln(U)};$$

that is, the model with signals afforded by the dealer's use of multi-party certification predicts trades occurring within a smaller price range than the model with signals sent by the dealer only.

Alternatively, suppose $L_M = \frac{L_M}{L} = 1 + \Delta$ and $U_M = U * (1 - \Delta)$ for $0 < \Delta < 1$ such that $L_M \leq U_M$; that is, the signal sent when multi-party certification is available increases the lower bound and decreases the upper bound of the good's value by the portion Δ. Then, again,

$$L < L_M \leq \frac{U_M - L_M}{\ln\left(\frac{U_M}{L_M}\right)} < \frac{U - 1}{\ln(U)}.$$

Figure 16 positions the models with dealer-only signaling and with signaling through the dealers' use of multi-party certification, respectively, in the context of the social subsystem of the used-car buyer and seller system. The left (right) diagram in the center right of the figure shows the knowledge of the individual agents (buyer/seller) under dealer-only (with the use of multi-party certification) signals. Based on the available knowledge, the buyer derives a maximal price he is willing to pay and the dealer derives a minimal price at which she is willing to sell. If the dealer's minimal price exceeds the buyer's maximal price, then there will be no trade. On the contrary, if the order of the two price limits is reversed, then the two agents can find a trade price in the arrangement zone. As a consequence of changes in the availability of knowledge, we expect to see changes in the asking price, sale price, the revenues for buyer and seller, and the allocation of goods in the market, which we will formulate as hypotheses in the following. And, all in all, *as Figure 16. Economic Model of the Used-Car Buyer and Seller Subsystem* indicates we expect an increase in market fairness at the overall output.

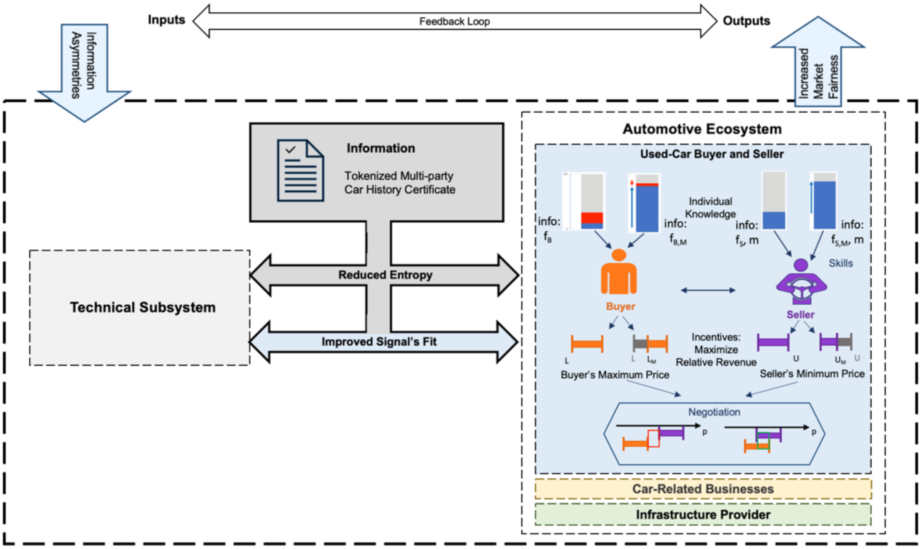

Figure 16. Economic Model of the Used-Car Buyer and Seller Subsystem

3.3 Hypotheses Development

A comparison between the model with signals sent by the dealer alone and the model with additional signals sent by the dealer where multi-party certification is available—in conjunction with insights from the academic literature—leads us to several testable hypotheses regarding the effects of the introduction of multi-party certification. First, due to the fact that dealers—by their very nature—have an information advantage in the market today, and in line with Akerlof (1970) (Akerlof, 1970), we expect our experiment to mirror the natural behavior of dealers. So, dealers will utilize their information advantage and anchor buyers by demanding well-above-average prices (Adomavicius et al., 2013; Allen & Parsons, 2010). However, since we expect the signals afforded by the dealer's use of multi-party certification—enabled by blockchain technology (Notheisen, Cholewa, et al., 2017)—to have greater fit and therefore to be more effective, we also expect the dealer's initial asking price to decrease. Thus, we derive hypothesis H1 regarding the dealer's initial asking price:

H1 (Dealer's Initial Asking Price): *Where multi-party certification is available, the dealer realizes that her relative information advantage will be reduced by the ability to send signals of higher fit. Consequently, the dealer will open negotiations with lower initial asking prices compared to those in the setup where multi-party certification is not available.*

While our model does not consider the agents' negotiation strategies, it does predict—under the assumptions of Corollary 1—that the set of possible prices for trades in the model with signaling afforded by the dealer's use of multi-party certification will be a subset of the corresponding set for the model with signaling stemming from dealers alone; see also the price ranges in Figure 16. We therefore expect lower average sale prices with signals sent when multi-party certification is available than with signals sent by intermediary dealers only. We would expect the same outcome as a consequence of the reduction in opportunities for dealers to take advantage of the anchoring effect. The confluence of the model's implications and our knowledge, from the behavioral literature, of the workings of the anchoring effect suggests the following outcome for sale prices (H2):

H2 (Sale Prices): *Given the reduced anchoring effect with signals where multi-party certification is available, the lower opening asking prices of the dealer lead to lower average sale prices than is the case with signals sent by the dealer only.*

Consequently, as the dealer's use of multi-party certification provides the buyer with signals of higher fit, reducing the relative information disadvantage if not eliminating it, hypothesis 2 appears to suggest that the dealer's (buyer's) relative revenue is lower (higher) when multi-party certification is available than when it is not. Thus, to specify H2, we test two additional hypotheses, specifically concerning the agents' relative revenues (H2.1 and H2.2):

H2.1 (Impact for the Dealer): *The dealer's average relative revenue is lower with signaling afforded by her use of multi-party certification than with dealer signaling alone.*

H2.2 (Impact for the Buyer): *The buyer's average relative revenue is higher with signals afforded by the dealer's use of multi-party certification than with dealer signaling alone.*

The model predicts, somewhat starkly, that in the setup where only dealer signaling is available no peaches will be sold (see also Proposition 1). In the model (see Cases ML and MH in the derivation of Proposition 2) with signals of higher fit meanwhile, both lemons and peaches will be sold. This leads to a hypothesis with respect to the quality of the cars sold (H3):

H3 (Market Impact): *The proportion of lemons sold decreases with signaling afforded by the dealer's use of multi-party certification, whereas the proportion of peaches sold increases.*

4 Experimental Design

In the following, we first explain how our laboratory market game was designed and then detail the experiment setup for the data collection processes.

4.1 Market Game Design

With the ultimate aim of testing our hypotheses regarding the effects of multi-party certification on market outcomes, we developed the experimental market game CarMarket. An experimental approach is beneficial in studies that, like the present one, aim to understand market dynamics under changing conditions (Bolton et al., 2008). The laboratory environment provides a suitable vessel within which to study how the introduction of a novel application—in this case, multi-party certification—affects the market and its participants (Adomavicius et al., 2012; Hashim et al., 2014; Roth, 2002; Tung & Marsden, 2000).

Our CarMarket game involves a web-based application designed in the form of an online car marketplace in which the participants have the task of buying and, respectively, selling a used car. The overall design was drawn from, and discussed with experts from, an existing, widely used online used-car market platform in Europe, AutoScout24. As is the case for today's used-car market platforms, participants in our experiment had the opportunity to sign up to the platform and view or advertise cars. Unlike in much of today's market, they were additionally able to negotiate and engage in binding sales transactions and to close deals online. A used-car deal is considered closed once both buyer and dealer agree and confirm the transaction. In order to resemble the real-world market setting, in which dealers have an information advantage, as mentioned in the model description dealers also receive the average market price of their car.

Further, CarMarket was designed to allow the installation of two different information structures. In the first setup, Instance A, participants receive no more information than that we describe in Section 3 (general information about the car, provided by the dealer), such that buyers have to form their beliefs based solely on the advertisement and the negotiation process with dealers. In the second setup, Instance B, ceteris paribus, both buyers and dealers have access to information that emerges from a blockchain-based IS artifact—CarFile. CarFile simulates a blockchain-based information system that enables a variety of stakeholders to collect and maintain all relevant events that occur during the life cycle of a car. The IT-artifact CarFile therefore offers trusted car history certificates created jointly by multiple parties. It was designed and developed in collaboration with representatives of the real-world blockchain project Cardossier that actually builds such car history certificates using Corda technology. As mentioned in the model description, CarFile was used to verify the general information about the cars (e.g., mileage wear, model, year of manufacture, engine type etc.) and to provide additional detailed information about the specific instance of each car, which helps users to narrow the expected value range. The two additional information categories provided were: repair and service history (e.g., accidents, maintenance, service recalls etc.), and driver dynamics (e.g., previous handling, driving characteristics and distances). The information provided by CarFile was visually highlighted Figure 17 illustrates how this was experienced by experiment participants.

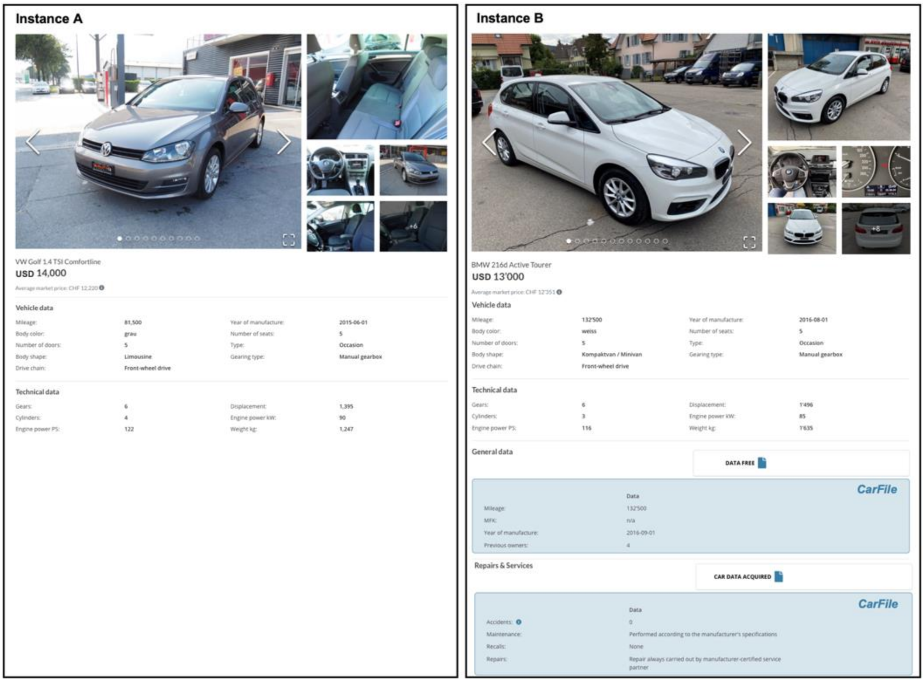

Figure 17. Information Representation with and without CarFile (Left: Instance A; Right: Instance B)

To ensure external validity, the design of the marketplace was iteratively discussed and developed in collaboration with experts from the field. Further, the cars used in CarMarket were real cars that were available on the real-world used-car market at the time the experiment was conducted. To reduce complexity and ease comparability, the value of the cars that were available on CarMarket varied within a fixed range of USD 8,000–12,000. Similarly, the number of models and brands were kept to a minimum. We received all our information about the cars thanks to our collaboration with the aforementioned online used-car market platform. Further, in order to evaluate the cars and approximate their true values, we used a standard-assessment table provided to us by a leading Swiss used-car retailer. We acknowledge that no universal true actual value exists; thus, additionally, two expert valuations were conducted, each by a project partner who are also major players in Switzerland. The mean of these valuations constituted the actual value of the cars for the purposes of our analysis. This value is the value $v > 0$ in the model from Section 3. As is the case with today's used-car market, a certain proportion of the cars on CarMarket were of below average quality, just as a certain proportion of the cars were of above average quality. Over the course of a year, we conducted several small-scale tests of our market game to validate its design.

4.2 Experimental Design

In order to test our hypotheses, a larger test group was selected and a between-subjects design was applied (Qureshi & Compeau, 2009). Overall, 105 participants played both roles (buyer and dealer), giving us 210 users. The participants in the market game were students from a Master's program in Business Administration at the University of Zurich, who were strongly incentivized to act realistically by the opportunity to earn bonus points for their final assessment. The bonus points that they received at the end of the game were dependent on the results they achieved during the game. The objective of each player was to maximize his or her relative revenue from both roles. We choose relative revenue as a measurement of success in order to account for the fact that the cars involved had values that differed slightly from one another. In other words, it did not matter whether a participant bought a rather expensive or a rather cheap car. This approach also validates our choice of having a continuum of qualities rather than a dichotomous view that merely differentiates peaches from lemons. All relevant information (i.e., regarding the game's objective and the criteria governing the apportioning of bonus points, the quality of the cars on the market, and CarFile, as well as blockchain technology) was clearly communicated and explained to the participants in advance, in written form and through a screencast. Additionally, at the beginning of the experiment, the game, the objectives, and the application's key features, as well as CarFile and the concept of blockchain technology, were again explained, this time verbally.

Approximately 70 of the 130 students enrolled in this class normally attend sessions. For this particular session, 105 students signed up and participated, thus indicating that the incentive of earning bonus points for the final assessment did indeed work. The results achieved (i.e., bonus points) were automatically calculated and communicated to the students either after they finished playing both roles or once the allotted time was up. If a participant did not conclude a deal within the given time, the final relative revenue was zero. From prior studies, we know that using students as study objects can yield just as reliable results as using actual customers if the students have sufficient requisite knowledge, and we tested for this before the game using a questionnaire (Höst et al., 2000). Further, implementing an economic experiment in the context of IS can bridge the gap between rational economic models like the one in Section 3 and the actual process of human decision-making (Gupta et al., 2018).

To allocate the participants between the two instances (Instance A and Instance B) and apply a between-subjects design, we randomly divided the participants into two groups and only controlled for an equal distribution of study subjects between the groups (List et al., 2010). Also, in order to account for internal validity, we randomized the allocation of cars to the participants. We ensured, however, that in both instances the same cars were put on sale. Since all participants had the same objective, the budget each received was also the same. Finally, all participants started the CarMarket game at the same time and in both instances the duration was set equally for all participants, at one hour.

5 Results

In the following we present the results of our experimental market game in relation to the hypotheses formulated in Section 4.

Starting with the impact of the availability of multi-party certification on dealers' initial asking prices, Table 13 presents descriptive statistics with regard to the average initial asking price proposed by dealers in each instance. We analyzed the very first offer prices set by dealers for the cars that had been randomly allocated to them on the platform.

Table 13. Dealers' Initial Asking Prices

	A: Single-party	**B: Multi-party**
Average initial asking price (USD)	13.742	11.910
Standard deviation	3.162	2.568
Pooled SE mean	447	353
Number of cars	52	53
P-value	0.00174***	

While we distributed the participants equally between the instances, we deleted one transaction in Instance A due to a participant having sold a car at an unrealistic price.[9] Thus, we report on 52 transactions for Instance A and 53 transactions for Instance B. The results show that the average initial asking price proposed by dealers in the instance with dealer signaling only, Instance A, is USD 1.832 higher than that in the instance with signaling afforded by the use of multi-party certification, Instance B. In order to test if the average initial asking price is significantly different between the instances, we conduct a two-population t-test for the difference between the two means. The resulting t-statistics show a standard deviation of 3.162 for the average initial asking price under dealer signaling only and one of 2.568 for the average initial asking price under signals sent when multi-party certification was available, which leads to a two-sided p-value of 0.00174. Hence, there is support for **H1**.

Next, we analyzed how the anchoring effect of the initial asking price influenced the final average sale price of the cars sold in each instance (Table 14).

[9] *The car was sold for USD 10 when the participant wrongly placed a decimal separator.*

Table 14. Sale Prices

	A: Single-party	B: Multi-party
Average sale price (USD)	11.567	10.011
Standard deviation	1904	2.152
Pooled SE mean	331	369
Number of cars	52	53
Number of cars sold	33	34
P-value	0.00256***	

We find that the average sale price for cars decreased between the instances, from USD 11.567 in the instance with no multi-party certification, Instance A, to USD 10.011 in the instance where multi-party certification was available, Instance B. In other words, we observe a USD 1.556 reduction in the average sale price between the instances. The difference between the two means is strongly significant, with a p-value for the two-population t-test of 0.00256. Therefore, we find support for **H2**.

Next, we examined more closely the impact of signaling afforded by the dealers' use of multi-party certification on dealers' relative revenues (Table 15). Recall that dealers' relative revenues are given by the relative difference between the car's selling price and the car's actual value: *(p-v)/v*.

Table 15. Dealers' Relative Revenues

	A: Single-party	B: Multi-party
Average relative revenue	0.1866	0.0429
Standard deviation	0.1709	0.19634472
Pooled SE mean	0.02974	0.0337
Number of cars	52	53
Number of cars sold	33	34
P-value	0.00000***	0.204085

The results show an average relative revenue of 0.1866 in the instance with dealer signaling only and a lower average relative revenue of only 0.0429 in the instance with multi-party certification. In other words, the large positive average relative revenue achieved by dealers under dealer signaling only was reduced by

0.1437 under signaling with multi-party certification. The results of the single-population t-test yield a p-value of 0. Hence, we accept **H2.1**.

The buyers' relative revenue, meanwhile, significantly increases in the instance where multi-party certification was available, as shown in Table 16. Recall that the buyers' relative revenue is given by *(v-p)/v*.

Table 16. Buyers' Relative Revenues

	A: Single-party	**B: Multi-party**
Average relative revenue	-0.1866	-0.04290
Standard deviation	0.1709	0.1963
Pooled SE mean	0.02974	0.03367
Number of cars	52	53
Number of cars sold	33	34
P-value	0.00213 ***	

While under dealer signaling only, buyers' average relative revenue is -0.1866, under signals sent when multi-party certification was available these negative rents are reduced to -0.04290. The results of the two-population t-test yield a p-value of 0.00213. Thus, we cannot reject **H2.2**.

Finally, we compare the proportion of peaches sold under dealer signaling only and under signaling where multi-party certification was available, and make the equivalent comparison for lemons. The results are presented in Table 17.

Table 17. The Proportions of Peaches and Lemons Sold

	A: Single-party	**B: Multi-party**
Number of cars	52	53
Number of cars sold	33	34
Number of peaches sold	4	18
Number of lemons sold	29	16
Number of unsold cars	19	19
Fraction of cars sold as peaches	0.08	0.34
Fraction of cars sold as lemons	0.56	0.30
Fraction of cars unsold	0.36	0.36
P-value (difference in peaches sold)	0.0011	
P-value (difference in lemons sold)	0.0071	

In Instance A, only 4 of the 52 cars offered on the market were purchased at a price below or equivalent to their real value, which classifies these cars as peaches. Moreover, 29 cars were sold at a price above their actual value, which classifies these cars as lemons. The remaining 17 cars were not sold at all, meaning no deal was reached. In Instance B, meanwhile, out of the 53 cars on offer 18 were sold as peaches whereas only 16 were sold as lemons. Regarding the proportion of lemons sold in each instance, there was a significant decrease in the proportion of lemons sold in Instance B compared to Instance A. Finally, the p-values (0.0011 for peaches and 0.0071 for lemons) that result from testing whether the proportions of cars sold are different between the instances are strongly significant. This leads us to accept **H3**.

6 Discussion

Many scholars have begun to investigate the use of blockchain technology as a way of collecting and maintaining data throughout a car's life cycle (Notheisen, Cholewa, et al., 2017; Zavolokina, Ziolkowski, et al., 2020) in order to provide trusted car history certificates to buyers and sellers (Bauer et al., 2020; Bauer, Zavolokina, & Schwabe, 2019).That research provides us with valuable insights into the technical foundations of how blockchain can be applied to the used-car market. While it is essential to have an in-depth understanding of the opportunities of the technical subsystem, it is just as important to understand *how it unfolds in and impacts the users in the social subsystem and how this interaction shapes and is shaped by information* (Sarker et al., 2019). Viewing the central artifact as an interconnected system with its elements and subsystems allowed us to investigate what is at the core of IS research. Namely, how technology unfolds in a specific application context, and how it affects that context (Chatterjee et al., 2020). This is also the crux of our research question, "*How does multi-party certification impact the market for lemons?*" Thus, within the framework of blockchain research (Kohli & Liang, 2021) our study can be positioned as follows: the *research theme* that we analyze is how a blockchain application unfolds in an application domain and how it impacts market outcomes; our *specific application domain* is that of the used-car market but is generalizable to other markets that suffer from asymmetric distribution of information; the *key construct* we analyze is the effectiveness of blockchain-enabled asset documentation for signaling; the *outcome* we are interested in is changes in market dynamics and social welfare; for this we use and add to the *underlying theories* of signaling, information asymmetry, and socio-technical information systems; the applied *research methods* are economic modelling and experimental techniques.

In the following we first discuss whether, and if so why, blockchain-based certification is required if dealers are to send signals of higher fit. Then we discuss what the availability of multi-party certificates means for the market's agents and for market outcomes. Based on these insights, at the end of each sub-section, we also present recommendations for practitioners working on the development of systems of this kind.

6.1 Blockchain-Based Multi-party Certification for Signals of Higher Fit

Our analysis shows us that, all else being equal, *signaling afforded by a dealer's use of multi-party certification is more informative and consequently provides a greater fit than signals sent by dealers only.* The reason why signals sent when multi-party certification is available are more informative is threefold.

First, due to the way in which multi-party certification systems are built, they are able to collect extensive, dispersed information from several stakeholders—information that is difficult for dealers to obtain today (Notheisen, Cholewa, et al., 2017). Second, the use of blockchain's tokenization feature ensures that the data collected from dispersed stakeholders can be trusted and traced, which ensures the provenance of this data without disclosing business-relevant specifics (Zhang et al., 2021), a feature deemed crucial for the efficient transmission of valuable information (Koutroumpis et al., 2020; H. G. Lee, 1997). Third, multi-party certification counteracts the problem of single-party intermediary certifiers having no incentive to provide more information than the minimum required, which is the case in monopolistic market structures (H. G. Lee, 1997). The necessary incentives are generated by giving the different participants in the system control over their original tokenized data, which consequently allows them to monetize that data accordingly. While data could potentially be copied and resold outside the blockchain-based system, it would not hold the same value for users. In sum, these effects can be attributed to blockchain's distributed database architecture, decentralized consensus mechanism, and immutable cryptographic logic, all of which allows multiple stakeholders to collect and maintain data from multiple sources and to create a novel, shared certification offering (Avital et al., 2016; Sun Yin et al., 2019). These stakeholders can include car-related businesses such as importers, road-traffic authorities, and insurers, but also private owners of vehicles that generate data during their use (Zavolokina, Tessone, et al., 2018; Zavolokina, Ziolkowski, et al., 2020).

The three described effects illustrate how blockchain is a technology that enables the development of multi-party certification. It is important to note that the technology (blockchain in this particular case) can be used to generate incentives that trigger behaviors in the social system that reduce entropy and therefore increase the harmony of the system as a whole. The extent to which individual stakeholders will contribute to a shared car ledger—and consequently the level of the signal's informativeness vis-à-vis the market—largely depends on the incentives set for them (Zavolokina, Ziolkowski, et al., 2020). But even a minimal number of stakeholders providing only minimal information would result in dealers being able to send signals of higher fit.

Another reason why multi-party certification affords dealers the action potential to send signals of higher fit; is the difficulty of faking the information provided by multi-party certification. Since signals need to be difficult to fake in order to be effective (Spence, 1973), information provided by multi-party certification is more trustworthy than that provided by a single dealer alone, who could also—potentially—lie. This increase in trustworthiness is, again, due to the technical design of blockchain-based certification (and therefore to an element of the technical subsystem), which makes it almost impossible to corrupt transactions (Sarker et al., 2021) and consequently to corrupt multi-party certificates. While false entries could—potentially—harm trust in such certificates, the adoption of mechanisms that incentivize truthful event reporting (Zavolokina, Tessone, et al., 2018) has been shown to counteract this risk. Further, blockchain's transparency paradigm (Notheisen & Weinhardt, 2019) makes each piece of information that is part of the signal traceable, and therefore objectively verifiable (Koutroumpis et al., 2020), a quality that is crucial for the efficient transmission of valuable information. This is yet another example of an interaction between subsystems: only those systems that provide adequate incentives for agents in the social subsystem to record their available information accurately will be able to generate useful signals.

To harness the promised benefits of blockchain-based systems at a large scale, signals need to be effective. Hence, it is fundamental that the agents recording the information to be stored in the blockchain (car owners, merchants, etc.) only record correct information. Thus, designers of multi-party certification need to apply proper incentive schemes to mitigate the risk of false event reporting, and offer traceability options to those receiving the signal.

In this study, and in line with (Zavolokina, Ziolkowski, et al., 2020), we argue that blockchain is an enabler if applications are to achieve the goals of multiple stakeholders in the generation multi-party certificates. At this stage, one could, however, ask *whether other technologies could do the same*. The answer to that question is that blockchain is currently the only technology that—by its nature—makes possible decentralized collaboration between parties that do not trust each other (Ziolkowski et al., 2020), and creates unique ownership over digital goods for data providers (Miscione et al., 2020), by doing so countering the current information strategies of intermediaries, who maximize their profits by providing minimal information (Lizzeri, 1999). Any technology or mechanism that achieves the same goals would also be adequate for the generation of multi-party certificates.

6.2 The Economic Impacts of Multi-party Certification in the Market for Lemons

In order to analyze the market effects of multi-party certification we developed a simple economic model and tested the derived propositions by using a laboratory market game. Overall, our results show that the availability of multi-party certification and consequently the ability of dealers to send signals of higher fit leads to a significant reduction in information asymmetries and an increase in market fairness.

In our empirical analysis we observed the changing behavior of dealers, who demand lower initial asking prices when multi-party certification is available than those they demand in a market where multi-party certification is not available (H1). This behavior reduces the anchoring effect, which, today, leads to overpayment for cars purchased (Adomavicius et al., 2012). Therefore, as theoretically proposed and empirically proven, the resulting sale prices are significantly lower in the market where multi-party certification is available compared to in the market where it is not (H2). From a market perspective, we can confirm the proposed benefit of trusted car data (Bauer, Zavolokina, & Schwabe, 2019)—that it results in average sale prices that are much closer to the actual values of the used cars concerned, also in the wholesale market. Further, we advance these insights by pointing out *how* this is achieved—namely, through decreasing the information gap (entropy) between buyers and sellers. As shown and calculated by our analytical model, a reduction of the entropy in the buyers and sellers subsystem occurs as a consequence of the increase in information availability. Sellers are thus prohibited from taking advantage of the anchoring effect. In our study, we observed an average deviation of sale prices from actual values of more than 18 percent where multi-party certification is not available; a figure that was reduced to only around 4 percent when multi-party certification was available. While our results indicate a slightly higher lemons penalty than that proposed by Blundell et al. (2019) (Blundell et al., 2019), one should note that we did not differentiate between the age of the cars available, and that for our experiment only a certain class of car was used.

Furthermore, analyzing in particular the situational changes for buyers and dealers we observe an increase in market fairness. This is explained, on the one hand, by a significant reduction in the profits that better-informed dealers make today (H2.1) and, on the other, by a significant reduction in buyers' losses (H2.2). If we disregard information costs, this is a simple zero-sum game: the losses of one group of actors being the profits of the other. Additionally, we observe that significantly more peaches and significantly fewer lemons are sold in the market where multi-party certification is available. This, the outcome described by H3, can be explained by increased incentives for dealers of peaches to strike a deal given the promise of higher returns for their good-quality cars. In line with prior research (Akerlof, 1970; Bauer, Zavolokina, & Schwabe, 2019), we argue that this observed result can be explained by an increased ability to signal a product's quality.

One implication that we can derive from these market changes is that as information advantage is reduced, dealers will no longer have the incentive to intermediate the market, given reduced transaction prices and the consequently smaller profits that they can achieve. This reduction in information asymmetry reflects how the relationship between the technical and the social subsystems reaches a new equilibrium, which is induced by a new level of entropy. In a world where multi-party certification is not available, dealers are valuable for private sellers of rather good quality cars as they mediate the market (Akerlof, 1970). They enable sellers of good quality cars to achieve slightly larger margins than they would alone. If, however, we assume that multi-party certification is accessible also to private car sellers, following Bauer et al.(2019) we argue that the incentive for private sellers of good quality cars to work through intermediating dealers will be reduced. Thus, it is only a matter of time before dealers raise for themselves the question of whether their current business model is still worthwhile.[10]

Another implication of the higher fit of signals afforded by the dealers' use of multi-party certification is a reduction in the system's entropy (explicitly modelled in Section 3). This reduction in entropy occurs due to a reduction of the probability of extreme outcomes. Recall that *when entropy is high, subsystems find innovative ways to reduce entropy such that creative outcomes happen* (Chatterjee et al., 2020) p. 11). Which explains the currently observable surge in innovative proposals for mitigating the information asymmetries inherent in this type of market. Our analytical results show how the entropy of the system is reduced by the dealers' use of multi-party certification. Our empirical results, meanwhile, depict how the technical subsystem affects the behavior of the agents in the social subsystem. Ultimately, the interaction of the technical subsystem and the social subsystem increases the harmony in the entire system due to the reduction in entropy induced by the ability of dealers to send signals of higher fit. Note that when social and technical subsystems are jointly optimized and in harmony, the entropy level is low (Chatterjee et al., 2020). This higher degree of harmony (i.e. lower level of entropy) is reflected in the empirical results of this paper, which show why the (actually desirable) outcomes stated in our hypotheses cannot be rejected.

Finally, practitioners should note that signals of higher fit increase the social welfare of the economy and reduce the number of transactions resulting in highly unprofitable outcomes for some agents. As a result, agents who are concerned about significant (downside) risks from unprofitable outcomes (e.g., sellers of peaches, buyers, etc.) will benefit from the availability of such signals and enjoy higher relative revenue. The increased relative revenue leaves space for requiring a fee in exchange for accessing the signal. Such fees can help finance the initial development cost of new peer-to-peer systems that reduce information asymmetries inherent to certain markets. Put differently, the increased relative

[10] We acknowledge that there might be other reasons for private sellers to work through intermediating dealers, including market liquidity, or efficiency. In the current study, however, we only focus on relative revenues.

revenues generated by the signals of higher fit offer new opportunities for forward-looking practitioners who want to use information technology to establish and finance (decentralized) solutions that help solve problems associated with information asymmetries.

7 Conclusion

While the concepts of information asymmetries (Akerlof, 1970) and signaling (Levin, 2001; Spence, 1973) have been widely discussed, their intrinsic problems remain. The latest developments in the field of information systems include a novel, potentially revolutionary solution mitigant based on blockchain. In this paper, we take prior work a step further and show how the use of blockchain-based asset certification unfolds in practice, and empirically evaluate its impact on the market and its agents. Our results confirm that blockchain-based certificates enable dealers to send signals of higher fit than the signals they send today, leading to a reduction in information asymmetries by reducing the entropy of the overall system. This leads to a more efficient allocation of goods and to an increased market fairness. These results are relevant for scholars, practitioners, and policymakers.

For scholars, we advance the growing body of research into the economics of blockchain by shedding light on the phenomena that blockchain technology induces at the market and the agent level, all in the context of well-established IS and economics theories. This allows blockchain research to advance further, and to go beyond a mere technology or application potential standpoint. Further, our results establish the initial ground for studying blockchain in markets with asymmetric information. This may result in fruitful discussions that help scholars to broaden the theoretical basis of blockchain-based systems. Moreover, we show how to apply the analytical computation of a system’s entropy, something that might ease the path toward the broader use of this concept in IS research.

For practitioners, our results provide valuable insights and guidance concerning their blockchain development work. These can be especially relevant for designers of blockchain-based systems, as they allow them to consider and anticipate market participants' strategic behavior and consequently sharpen future business models.

For policymakers, our results show how novel technology might provide solutions to some of the problems they are called to tackle. Fostering innovation, research, and regulation in the realm of blockchain technology (e.g., by providing subsidies (Cho et al., 2021)) might help policymakers acquire new tools to better achieve their objectives of market fairness and transparency. And more broadly, as researchers and practitioners alike move beyond mere blockchain prototyping, society itself might benefit from the adoption of the technology.

Our research is not without its limitations, but these limitations themselves open avenues for further research. First, the economic model is fairly simple. We deliberately choose a parameterization of the model that allows for closed-form solutions. We represent the idea of a signal's fit simply, by using different parameterizations for signals sent by dealers when multi-party certification is available and signals sent by dealers alone. Also, we make deliberately elementary choices for the utility and density functions. Yet to counteract these shortcomings and demonstrate generalizability, we additionally develop a different model, using a CARA utility function, which yields the same hypotheses. Further research could advance our work by adopting more complex modelling approaches.

Second, the sample size of our experiment, while not small by the standards of experimental economics, is not large enough to enable more in-depth analysis. In further research it would be interesting to study further the changes in the behavioral patterns of different agents caused by the adoption and use of the technology and by the phenomena it induces in the market. We also acknowledge that an experimental negotiation in a classroom setting is not the same as a real-life negotiation with (tens of) thousands of dollars at stake. However, the use of experiments in economics has been proven useful by many scholars before us (Gupta et al., 2018; Höst et al., 2000; Roth, 2002). Our close relationship with industry experts ensured a design and setup that were as close as possible to reality.

Third, in future research it would be worthwhile exploring end users' perceptions of the role of blockchain in product history certification.

Finally, since the realization of systems of this kind largely depends on whether or not enough money is available to finance their development and maintenance, we emphasize the need for future research that investigates how multi-party certification could be funded. Also, since the cost for the infrastructure would ultimately translate into transaction costs, a careful investigation of pricing options and their effects is vital.

Summarizing, we consider that our study can help design and implement multi-party certification that will enable sellers to send signals of higher fit. Eventually, such signals could result in a reduction of information asymmetry in a manner that would end up solving the market for lemons problem. The fact that this might be the case justifies the current study, and future studies of this type of certification.

ESSAY IV – VALUE CAPTURING FROM TOKENIZED ASSET HISTORIES

The content of this essay is based on the following working paper:
Bauer, I., & Schwabe, G., *“Value Capturing from Tokenized Asset Histories,”*.

Abstract

While a thorough understanding of how value can be created from a decentralized car ledger applied in the used-car market context has been established through essays II and III, this subsequently presented essay IV follows up on these insights and studies *how the value of increase signaling ability can best be captured*. It builds on the insights from essay III that specifies that value is generated by affording sellers the action potential to better signal product quality and incorporates it into the application design (technical subsystem). A user-controlled offering and pricing concept for the offering of car history certificates (technical subsystem) is thus proposed and evaluated. Specifically, this study delves into the key changes in the information element (tokenization) that bring this new opportunity about.

Due to the ability to tokenize data (i.e., creating unique ownership and ensuring the prove of provenance of the data), sellers can be granted control over the offering and pricing of the data contained in the multi-party car history certificates without sacrificing trust in the reliability of the data. Today, product history certificates are offered as intermediary products due to a need for a trusted intermediary to ensure reliability and trust in the data. However, with blockchain, this need for trust is replaced through traceability and transparency in the record history. Hence, while technically this new design opportunity arises (both for blockchain-based systems, potentially also for other systems that utilize tokenization mechanisms), it remains the question of whether it would be worthwhile from a business perspective. Thus, this essay presents how this proposed novel approach was implemented and tests it against established modes of intermediary pricing and offering of car history

certificates through the means of another experimental market game. The results of the experiment, conducted with 102 participants, prove that users can be granted control over the offering and pricing of tokenized asset histories without sacrificing its value but significantly increasing its trade and revenue.

1 Introduction

Tokenization sparks the interests of the art business (Franceschet et al., 2021), the music business (Chalmers et al., 2021), tourism (Treiblmaier, 2020), and many other areas. Digital tokens are defined as the unique, digital representation of something (Oliveira et al., 2018). They allow attributing value to digital objects that were difficult to evaluate before (Sunyaev et al., 2021) and to handle these objects in ways not possible before (Miscione et al., 2020). One important sub-area is the tokenization of data. Tokenized data is special in that it may have a higher trading value than data that can be copied without costs (Drasch et al., 2020; Mazzei et al., 2020). But how should the trade of tokenized data be organized? This is the question that was raised in the Cardossier consortium. The Cardossier consortium strives to create a comprehensive digital history of a car using the Cardossier blockchain platform. This 'car history certificate', then has significant value if the car is traded: Car buyers can use it to verify the state of the car. As creating and running this Cardossier platform is expensive, the Cardossier consortium searched for a way to capture the value of the stored data. The interesting trait of this stored car history certificate is that it loses its value if moved outside the platform: Only the Cardossier platform assures that the data is correct, complete, and up-to-date. Outside the Cardossier platform, it is just an unsubstantiated and largely worthless claim. So a car history certificate is a unique representation of a car's history, i.e., a tokenized car history.

Like in the case of the Cardossier consortium, the interest in tokens has been triggered by the rise of blockchain technologies in many areas. However, increasingly practitioners have become aware that tokens can also be realized using centralized platforms. For example, the European Central Bank plans to issue the digital Euro using a centralized platform (European Central Bank, 2021). The choice between a centralized and a decentralized approach depends on economic criteria, such as the feasibility and the desirability of a central platform (Zavolokina, Ziolkowski, et al., 2020) and process management (Fridgen et al., 2017). In the case of the Cardossier, the members were afraid that a centralized platform provider might become too powerful, and they did not trust any consortium member to take over this role. So they opted for a decentralized approach using a distributed ledger. However, it is conceivable that car manufacturers use their economic power and their direct access to the car to provide a car history certificate. Or that digital giants like Google gain access to car histories. Either way, any of them will face the issue of how to best capture the value of a tokenized car history certificates. While value creation is vital for satisfying customer needs, creating adequate revenue streams to turn the newly created value into profits (i.e., capture the value) are just as critical to businesses (Chesbrough, 2002; Osterwalder et al., 2005). And this issue is faced not only by the car ecosystem aiming to tokenize car histories (Bauer et al., 2020) but also by many other projects aiming to tokenize histories of buildings (Gupta et al., 2020) or precious stones (Mohanty, 2019) for example.

The key issue in any offer is the pricing. Most prior research on pricing information (e.g., digital newspapers) looked at prizing only from the perspective of central information providers to information consumers (Varian, 1995). Here the production cost of the producer and the utility of the consumer determine pricing models. However, more recent research (Parra-Moyano et al., 2020) indicates that pricing a tokenized asset history (such as the one provided by the Cardossier) could follow more sophisticated rules by granting users more control of their own data resources. But how can a platform make use of this insight to increase its revenues? And how can this be implemented? So we use the 'instance problem' (J. S. Lee et al., 2011) of the Cardossier project to study the abstract problem of value capture from tokenized asset histories (in the following referred to as TAHs) and ask the following research question:

RQ: *How can tokenized asset histories be offered and prized to advance trade and revenue for its providers?*

Applying Design Science Research (DSR) methods, in this study, we substantiate prior suggestions for the pricing and offering of TAHs and evaluate its effectiveness through an experimental market game. We suggest that users can be granted control over the offering and pricing of TAHs. Thus they could be offered as tools for sellers to further support their ability to signal product quality (Stahl & Strausz, 2017). To evaluate and contrast the impact of this approach against established modes of pricing and offering of TAHs on business success, we conducted an experimental market game with 102 users. Applying a between-subject design, the market game simulated the used-car market and employed one of the two modes of TAH pricing and offering (i.e., intermediary- vs. user-controlled). The results show that by applying a user-controlled pricing and offering mode, both trade with TAHs and revenue from TAH purchases for its providers significantly increases.

2 Related Work

Tokenized information can be used for documenting and managing real-world assets to increase transparency in markets that struggle with information asymmetries (Notheisen, Cholewa, et al., 2017). The used-car market is probably the predominant example of a market struggling with information asymmetries between buyers and sellers and has been termed as the "market for lemons" by Akerlof, (1970). The lack of information about product quality on the buyer's side and the inability of sellers to prove product quality leads to enormous inefficiencies and a loss of social welfare (Clemons & Thatcher, 1997), even today (European Parliament, 2018b; The Economist, 2019). Businesses in the car ecosystem (e.g., car manufacturers, car insurers, or used-car dealers) aim to address these problems of information asymmetry through the use of blockchain technology. Zavolokina et al., (2020) argued that in the car ecosystem, blockchain technology enables multiple businesses to develop an inter-organizational information system that decentralizes market power and avoids yet another Google or Facebook for car data. Thus, following regulatory demands for decentralizing the power of platforms (Schallbruch et al., 2021), car businesses see an opportunity to finally monetize the increasing availability of car-related data by building on blockchain technology and offering novel data-driven products and services (Bauer et al., 2020; Bauer, Zavolokina, & Schwabe, 2019). Drawing on the data sources of many different stakeholders will allow them to document the whole life cycle of a car and offer tokenized car histories (i.e., unique digital representations of a car) to buyers and sellers in the used car market (Zavolokina et al., 2019).

Initial exploratory studies indicate that TAHs, could indeed offer valuable information products in the form of verified data entries or analysis and increase the value of used cars by approximately 7% (Bauer, Zavolokina, & Schwabe, 2019). While the results are promising, open questions remain regarding how the platform providers should offer such TAHs to increase trade among users and revenue for its providers that will finance its operation.

While car history certification, in general, is not novel, TAHs provide immutable proof of the origin of the record history (Koutroumpis et al., 2020) and allow to establish uniqueness and scarcity in terms of ownership (Miscione et al., 2020) and use (Sunyaev et al., 2021) of it. Consequently, providers of TAHs have the potential to provide more control over the use (e.g. in terms of offering and pricing) to the actual owners of the physical cars and thus their digital twins (Parra-Moyano et al., 2020; Subramanian, 2018). Such power shifts from data cooperatives to individuals are increasingly demanded from a legal point of view (Rieger et al., 2019; Schallbruch et al., 2021). While this sounds promising, empirical analysis of how this can be applied and what its effects on its provider's business success would be does not yet exist.

Analyzing prior work on existing designs for the offering and pricing of certification in opaque markets in similar context (i.e. without building on DLT), Stahl and Strausz (2017) propose two essential business models for providers of certificates that differ in their effect on the market. "Buyer certification" and "seller certification," as they term them, differ regarding whom certification is offered to and who eventually pays for it. In the "buyer certification" model, the buyer can buy certification from a third-party certifier and use it for inspection. In the "seller certification" model, certification is offered to sellers who pay for it and use it to signal product quality. The researchers argue that seller certification, by its nature, is more informative than buyer certification. While in the case of buyer certification, a lack of certification reveals nothing about a product's quality, in the case of seller certification, no disclosure of certification indicates that the seller has something to hide (Stahl & Strausz, 2017). While seller certification serves both buyers and sellers in opaque markets, buyer certification is only useful to buyers; it does not enable sellers to signal product quality (Stahl & Strausz, 2017). Apart from this theoretical analysis by Stahl & Strausz (2017), literature that investigates different modes of offering and pricing certification is rare. A paper proposed by Durbin (1999), for example, compares the sale of guidebooks to buyers privately to selling certificates to sellers that publicly certify the quality of their goods. Research proposed by Fasten & Hofmann (2010) examines two-sided certification for rating agencies. However, neither of these proposals analyzes empirically the effects as well as their impact on the certifier's revenue.

3 Methods

Originating from computer and engineering science, DSR is aimed at solving practical problems with the design of new IT artifacts that extend the current capabilities of individuals and organizations (Hevner et al., 2004; March & Smith, 1995). The problem at hand that we aim to address with this research is the lack of design knowledge concerning the pricing and offering of TAHs and their effects on its provider's success. We observed these problems in a real-world blockchain project called Cardossier, which we will introduce in the following section. Thus, the rationale for a design science approach is the design and development-centered initiation aimed at designing and evaluating instantiations of pricing and offering schemes of TAHs (Peffers et al., 2007). As part of the design cycle (Beck et al., 2013), the goal is to address the lack of both academic and practical knowledge of how different pricing and offering modes affect the artifact use and profits. Following the three cycles of relevance, design, and rigor proposed by Hevner (2007), we first identified the problems both in related works and in the application domain (rigor and relevance). Next, we built on the concepts introduced in the related work section and designed instantiations of the artifact (design). We then applied experimental techniques, through the use of a market game, in order the evaluate the two designs (evaluate). Finally, through the means of this paper, we report on our findings, position them in the context of prior work, and provide important design insights for practitioners (rigor and relevance).

In the following sections, we first elaborate on the problem field from a practical perspective by introducing the Cardossier project. We then explain the artifact design. Thereafter, we introduce how the experiment was set up and conducted and how the resulting data was analyzed.

3.1 The Cardossier Project

Cardossier is a real-world blockchain project where multiple businesses from car-related businesses have formed a consortium to develop a decentralized car ledger to monetize their data resources. The consortium utilizes the technical mechanisms of blockchain as they allow the involved businesses to decentralize system governance. It also allows them to tokenize data events, thus ensuring transparency and traceability over data provenance. Offering TAHs – in the form of verified car data entries and analysis services in different information categories – to buyers and sellers in the used car market that are currently suffering from information asymmetries, businesses hope for novel business potential. Initial innovation funding and the current membership fees were sufficient for the first prototyping phase, but now the consortium is questioning how tokenized car histories could be offered and priced to achieve long-term sustainable revenue for their use. Estimates provided by car retailers that are members of the consortium indicate that each car history certificate may be worth approximately US$100. As around 800,000 used cars are sold each year in the regional market that Cardossier is targeting, the potential market volume of TAHs in the region – if, on average, one certification is sold per traded used car – is about US$80 Million. If we assume that buyers investigate more than one car, this number is even higher. Yet, these are only estimates based on comparisons with current existing solutions (such as Carfax or Eurotax). However, the consortium is questioning whether novel user-controlled approaches, that TAHs enable are a successful alternative from a business perspective.

3.2 Artifact Design

For the design of the offering and pricing functions of TAHs, we drew on the earlier works introduced above, as well as insights gained from the Cardossier project. Based on these insights, for two years, two dominant modes of offering and pricing TAH were designed and implemented: intermediary- and user-controlled offering and pricing. While offering refers to what information is offered in a car history certificate, pricing builds on the offering and describes who sets the prices for the offerings.

In intermediary-controlled (IC) design, all information included in a car history certificate is offered and priced by the platform. The offering is available to all interested parties if they paid for it the set price. The platform sets all prices, and the seller receives a fixed share of the revenue. This revenue share rewards the seller's "data ownership" and incentives to share data. In the user-controlled (UC) design, the seller decides which information is offered to the buyer by setting prices respectively. He can, in fact, refuse any request for information by charging an astronomical price for it. In the user-controlled design, the platform decides only its own price for the data sale. The seller has the opportunity to determine its own return on data trading via a markup or markdown on the platform price. This yield can also be negative (i.e., he can subsidize the data purchase by the buyer). In this way, building on Stahl & Strausz, (2017), he can potentially signal the high quality of the car. All in all, as mentioned, the intermediary-controlled mode represents the “as is” situation, where an intermediary (i.e., a third-party certifier like Carfax or Eurotax) offers tokenized car histories to both buyers and sellers of used cars. Whereas the user-controlled mode emerged as a further development and instantiation of the proposals of prior works (Parra-Moyano et al., 2020; Stahl & Strausz, 2017)), and ideas from the collaboration with Cardossier.

The designs were iteratively developed and constantly evaluated through workshops with partners from Cardossier. Initially, the researchers developed conceptual models and sequence flows of potential pricing and offering functions. Building on the feedback of partners from the Cardossier project, these were refined and presented as mock-ups. After another workshop iteration with project partners, the designs were again refined and finally implemented. The final artifact design was then tested with managers and employees of the businesses involved in the Cardossier project before the final experimental evaluation.

Following prior research, the offered TAH types included both data and analysis (Bauer, Zavolokina, & Schwabe, 2019; Zavolokina et al., 2019). While data is produced by the individual stakeholder in the consortium (e.g., road-traffic authorities, insurers, importers and, potentially, private users), analysis is considered as an extra service provided by Cardossier and assumed to incur additional costs. Table 18 below summarizes the different TAH types, explains how they are generated, and gives an example for each.

Table 18. TAH Types

TAH Types	**Explanation and Example**
Data	Data is provided by the individual stakeholders and shows a verified data entry. Example: *Mileage wear: "250,000 km"*
Analysis	Analysis for each car is a service additionally provided by industry experts. It represented an evaluation and a recommendation of the verified data entry. Example: *Mileage wear: "250,000 km indicates a high mileage wear, leading to a 10% deduction of the market prices"*

Besides that, TAHs provided in the form of data and analysis are offered in three information categories: (1) general car usage, (2) repair and service, and (3) driver dynamics. The information categories were discussed and designed in collaboration with industry experts who are part of the Cardossier consortium. As mentioned, in the intermediary-controlled instance, Cardossier controlled and preset the prices of the TAH types in all information categories and offered these equally to both buyers and sellers, with one exemption, namely that sellers were granted free access to the data about their own car. This was done to account for their information advantage, as it was their task to put themselves in the role of truly selling "their own" car. However, the sellers could not release this information to their counterparties in a secure manner supported by the TAH decentralized application. Only in the user-controlled instance were they able to do so. In case they decided not to make any changes, by default, the same prices as in the IC instance were displayed. These ranged between US$15 and US$20 for data and between US$20 and US$25 for analysis, dependent on the information category. For revenue distribution, both the IC and UC pricing and offering modes follow the same basic idea of dividing the achieved revenue generated from TAH purchases fairly according to where costs are incurred. In collaboration with Cardossier, the following rules were applied: Data sale: A 70:30 distribution is applied, where used-car sellers receive 70% of the revenue from the data sales and its providers receive 30% of the revenue. In the case of UC pricing, if sellers decide to publish their data freely, no revenue is generated. Hence, nobody receives any revenue. Analysis Sale: 100% of the revenue goes to the platform operators since this is a service provided jointly by the experts from the Cardossier consortium. Table 19 summarizes the two modes and describes the sellers' level of control for each TAH type. Additionally, Figure 18 shows how sellers in the UC instance could study their data, purchase analysis, and manage prices per information category.

Table 19. Modes of Pricing and Offering TAHs Types

Instance	Description
IC: Intermediary-Controlled	**Cardossier has central control over pricing and offering TAH types.** **Data:** Sellers are granted free access to their data in all categories to account for their information advantage. Buyers have to pay a fixed fee per data category that is the same for all cars on the market. Sellers have no option to release the data to buyers in a secure TAH DApp-supported manner. **Analysis:** Both buyers and sellers have to pay the same fixed fee for analysis that is the same for all cars on the market and only slightly varies per information category.
UC: User-controlled	**Sellers have individual control over pricing and offering TAH types.** **Data:** Sellers are granted free access to their data to account for their information advantage. Further, sellers of used cars can set the prices for their data themselves. They can set a price between US$0 and US$100,000. If they choose to set the price to US$0, they offer their data free of charge to all interested buyers on their car advertisement page. If they set a price, buyers have to pay this price to view the respective data. **Analysis:** Sellers can buy the analysis themselves for a fixed price. Additionally, they have three options to manage the release of analysis to potential buyers (per information category): (1) they can opt to not take over any costs for potential buyers interested in their analysis; (2) they can opt to split costs with potential buyers and take over a certain percentage (1%-99%); and (3) they can opt to take over 100% of the costs.

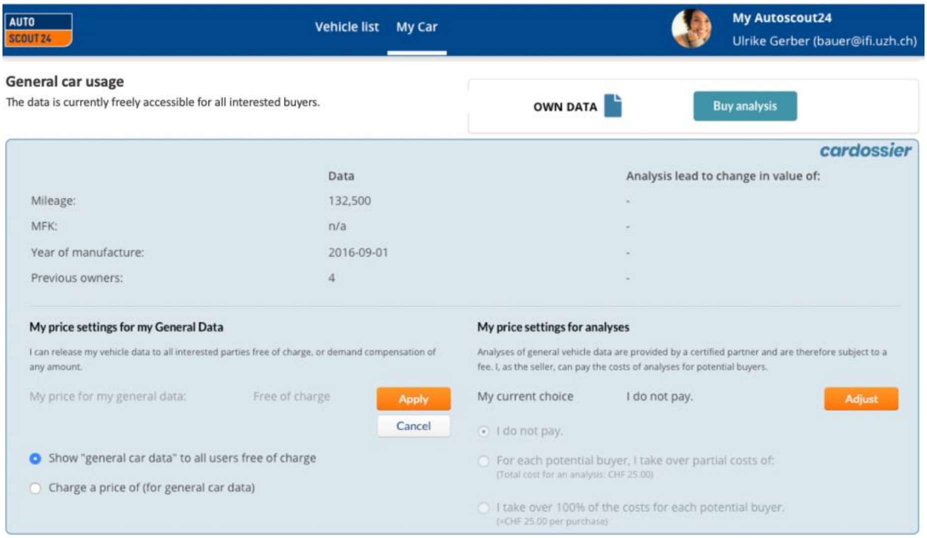

Figure 18. UC Instance: Sellers' Options for Offering and Pricing TAHs

3.3 Evaluation

To evaluate the two designs for offering and pricing TAH, we applied experimental techniques through the use of a market game. This market game (called CarMarket) simulated the used-car market and allowed us to embed TAHs. According to Stebbins (2001), besides serving the validation of theoretical models, experimental techniques are a well-suited method to discover and describe phenomena and their correlations in the course of exploratory research. Further, experimental techniques within DSR enable the designer to measure whether the outcome that they want to achieve with the IT artifact has been achieved (Briggs & Schwabe, 2011). Finally, they enable the designer to explore market dynamics and agents' behavior, and hence, inform early the design of novel systems (Roth, 2002).

CarMarket was designed and implemented as a rebuilt of the currently existing and well-established used-car market platform AutoScout24. For this, we were granted access to all relevant information by AutoScout24. While AutoScout24 offers a variety of additional services, next to buying and selling used cars, for our study we minimized the rebuilt platform to the core functionalities relevant for testing the IT artifact TAH. These included the registration of users and cars, and the core marketplace functions of offering and searching for used cars. In addition to AutoScout's functions, we included the possibility for users to negotiate via a simple chat function and the possibility to close a deal online via CarMarket. Besides that, the ability to offer and buy TAHs was embedded into the CarMarket rebuild, and the administrator of the system could switch between the two modes of offering and pricing TAHs (i.e., intermediary- vs. user-controlled). For the experiment, CarMarket was installed on two different servers and made accessible for users via two different URLs (installing one of two different pricing and offering modes). To account for external validity, we discussed and developed CarMarket iteratively in collaboration with AutoScout24 for the online used-car market setting, and with experts from the Cardossier consortium to integrate TAHs. For the experiment, AutoScout24 also granted access to real used cars currently available on the used-car market. We ensured that a certain portion of cars that had below-average quality and a certain portion of cars that had above-average quality were included in the sample, following current research (Blundell et al., 2019; European Parliament, 2018b; The Economist, 2019). The additional novel data used for simulating TAHs was created in collaboration with Cardossier based on their expertise and expectations of future data availabilities.

Prior to the main experiment, we conducted multiple smaller tests of the experiment with both experts from Cardossier and with students. Drawing on the experts' views, we ensured the validity and accuracy of the experimental market game setting in relation to reality. The test performed with a smaller student group enabled us to test the understandability and internal validity of the experiment with non-experts.

After smaller pretests, we conducted the large-scale experiment with 102 students from a master's program in Business Administration at the local university. The students were strongly incentivized to act in a realistic manner by the opportunity to earn bonus points for their final exam. The number of bonus points they received depended on the results achieved from the used car sale, including their information costs spent on and earned from trades with TAHs. Approximately 70 of the 130 students enrolled in this class normally attend. For this experiment session, 105 students signed up and participated, thus indicating that the incentives of earning bonus points for the final exam indeed worked. The objective of all players was to maximize their relative revenues. We chose the relative revenue as a measure of success, to account for the fact that the values of the cars slightly differed from each other. In other words, it did not matter whether a student bought a rather expensive or a rather cheap car. The relative revenue was calculated based on the actual value[11] of the car compared to the sales price, plus accounting for the participants' expenditures and revenues from TAH sales and purchases. Using students as study objects can yield results that are just as reliable as using actual customers if they have sufficient knowledge about the study environment (Höst et al., 2000). Hence, to account for sufficient background knowledge, we purposefully selected an economics class where the students have just learned about the market for lemons problems along the used-car market example theorized by Akerlof (1970). Finally, also a proper introduction of the Cardossier project and blockchain was provided. All relevant information was communicated and explained to the students twice. First, a week in advance, preparation material in the form of a written document and a screencast was sent out. Second, at the beginning of the lecture, a vocal explanation and a live walk-through of the system were provided.

Just before the start of the game, the participating students were divided into two groups, and each group was instructed to use a separate instance that employed one of the two pricing modes. To ensure internal validity, we accounted for a random but equal distribution of the students between the two game instances (List et al., 2010), and applied a between-subject design (Qureshi & Compeau, 2009). Initially, 105 students signed up to participate in the experiment; however, one student had technical issues at the beginning of the game and ceased participation. Two other students sold their cars immediately after it was published for US$1 and US$10 as the participants had wrongly placed a decimal separator. Hence, in the end, we had 102 participants who seriously

[11] We acknowledge that no such thing as a universal actual value exists. However, to evaluate the cars and approximate their actual values, we used a standard assessment table that was provided to us by one of the leading used-car retailers in the country.

participated, of whom 49 participated in the intermediary-controlled (IC) instance, and 53 participated in the user-controlled (UC) instance. Each group had exactly 60 minutes for the market game.

After the experiment was conducted, we analyzed the log files and focused in particular on data trade and revenue to evaluate the effects of the two pricing and offering modes of TAHs. As each student participated in both roles (buyer and seller), in total, on the IC market, 49 cars were offered and on the UC market, 53 cars were offered. Of these 49 and 53 cars, 32 and 34 cars, respectively, were finally sold. The remaining sellers of cars did not reach a final agreement during the given 60 minutes. Hence 17 cars in the IC instance and 19 cars in the UC instance were not sold. In real life, these sellers would probably continue their sales and potentially generate additional revenue from TAH sales, so for the analysis, only the achieved results per sold used car were considered.

4 Effects of TAH Offering and Pricing Modes

To evaluate the effects of the above introduced two pricing and offering modes on data trade and revenue for its providers, we conducted an experimental market game where the participants had the chance to offer and buy TAHs during used-car sales. The following sections present the overall results for TAH trade and TAH revenue per sold car, which shows how its providers can optimize their revenue. We then analyze in more detail trade and revenue per TAH type, and how sellers made use of their ability to control pricing and offering, to understand why the UC mode advances trade and revenue.

4.1 TAH Trade and Revenue

Analysis of the average number of purchases of and the average revenue from TAH purchases for the 32 and 34 sold used cars (Table 20) shows that overall, both the average purchase of TAHs per sold used car and the average revenue from TAH sales per sold used car greatly increased in the UC instance.

Table 20. Effects of Offering and Pricing Mode on Trade and Revenue of TAHs

Instance	**(1) TAH Trade**	**(2) TAH Revenue (in US$)**		
	Avg. number of purchases per sold car	Avg. revenue per sold car	Avg. revenue for sellers per sold car	Avg. revenue for Cardossier per sold car
IC	2.25	56.22	22.73	33.49
UC	4.03	136.18	38.95	97.22

The results concerning TAH trade (1) show that the average number of purchased TAHs almost doubled in the UC instance, compared to the IC instance. While on the market that employed IC pricing and offering only 2.25 TAHs were purchased, on average, per sold used car, on the market where sellers had control over TAH offering and pricing, 4.03 TAHs were purchased, on average, per sold used car (Table 3, column 1). These figures include purchased TAHs of all types and categories. To test whether the average number of purchased TAHs per sold car is significantly different between the instances, we conduct a two-population t-test for the difference between the two means. The resulting t-statistics show a standard deviation of 1.93 for the average number of traded TAHs in the IC instance and 3.20 for the average number of traded TAHs in the UC instance. The resulting p-value of 0.0096 of a two-sided t-test shows that the difference between the two samples is statistically significant.

Looking at the achieved revenue from TAHs (2), the results show that the average revenue of TAH purchases more than doubled on the market that employed a UC offering and pricing mode, compared to the market that employed IC offering and pricing. While in the IC instance an average revenue per sold used car of US$56.22 was generated, in the UC instance, an average revenue per sold used car of US$136.18 was generated (Table 3, column 2). Splitting this up into the shares for sellers (Table 3, column 3) and the shares for Cardossier (Table 3, column 4), the results show that the large share of the average revenue increase is accounted to Cardossier. While the average revenue for sellers increased from US$27.73 in the IC instance, to US$38.95 in the UC instance, the average revenue for its providers increased almost by a factor of three from US$33.49 in the IC instance, to US$97.22 in the UC instance per sold used car. The resulting t-statistics for the average revenues achieved from TAH sales per sold used car show a standard deviation of 43.0394 for the average number of traded TAHs in the IC instance and 146.7679 for the average number of traded TAHs in the UC instance. The results of a two-sided t-test showed that the difference in revenue was statistically significant, with a p-value of 0.0107.

4.2 Trade and Revenue Distribution per TAH Type

Next, to understand how this increase in revenue for Cardossier compared to the rather small revenue increase for sellers came about, we take a deep dive into the achieved trade and revenue per TAH type. Remember, the revenue that was achieved from TAH data sales was distributed to 70% to the car sellers (i.e., owners), and 30% to Cardossier. The revenue achieved from TAH analysis was 100% accounted to Cardossier. Table 21 below gives an overview of the distribution of average TAH data and analysis purchases per sold used car and shows that a large share of the significant revenue increase, can be attributed to the increase in the number of TAH analysis purchases.

Table 21. Effects of Offering and Pricing Modes on Trade and Revenue per TAH Type

Instance	**Avg. TAH Trade and Revenue per sold used car**			
	(1) Data		**(2) Analysis**	
	Trade	Revenue ($)	Trade	Revenue ($)
IC	1.41	33.07	0.84	23.15
UC	1.18	59.40	2.85	76.78

While purchases of TAH data (1) slightly decreased, from an average of 1.41 purchased TAH data offerings per sold car in the IC instance to an average of only 1.18 purchased TAH data offerings per sold used car in the UC instance (Table 4, column 2), analysis (2) purchases increased by a factor of 3.4 from an average of 0.84 purchased TAH analyses per sold used car in the IC instance, to an average of 2.85 purchased TAH analyses per sold used car in the UC instance (Table 4, column 4). Surprisingly, however, while data trade decreased, the average revenue achieved from TAH data (1) purchases nearly doubled from an average of US$33.07 per sold used car in the UC instance to an average of

US$59.40 per sold used car in the IC instance (Table 4, column 3). The average revenue achieved for TAH analysis (2) trade followed the trend shown by the average number of trades. The average revenue achieved from TAH analysis purchases per sold used car increased by a factor of more than three from US$23.15 in the IC instance to US$76.78 in the IC instance (Table 4, column 5). Hence, we conclude that the significant difference in revenue increase, between sellers and Cardossier can be explained by the fact that much more TAH analysis was traded in the UC than in the IC instance.

4.3 The Use of User-controlled Pricing and Offering of TAHs

To understand why the average revenue from TAH data purchases increased despite the decrease in the average number of purchases, and why many more analyses were sold in the UC instance, we again take a deeper dive and analyze how sellers used their ability to manage the prices per TAH type. Table 22 summarizes these results and shows the distribution of the selected options by the sellers, per TAH type.

Table 22. Use of User-controlled Offering and Pricing

Use of UC offering and pricing	**(1) Data**				**(2) Analysis**		
	Free Publishing	Price Reduction	No Price Change (Default)	Price Increase	Full Takeover	Partial Takeover	No Takeover (Default)
Sum	65.69%	8.82%	8.82%	16.67%	33.33%	11.67%	54.90%

The results for pricing of TAH data (1) show that 65.69% of the sellers who sold their cars had published their data freely on the advertisement page of their cars. In other words, all interested buyers could freely view the verified TAH data. Another 8.82% reduced the prices for TAH data and offered it at marginal prices that ranged between US$2 and US$15 per information category. The same percentage of sellers did not change the data price settings, instead opting for the default prices. The remaining 16.67% of sellers decided to increase prices for TAH data offerings, ranging between US$25 and US$400 (up to 20 times higher than the default price). Thus, the decrease in data purchases in the UC instance can be explained by the great willingness of sellers to make their data available to potential buyers free of charge. Furthermore, the prices of up to US$400 explain why the average revenue from TAH data sales increased despite the decreased number of purchases.

The results for pricing of TAH analysis (2) show that almost half of the sellers made use of the option to fully (33.33%), or at least partially (11.67%) takeover costs for the analysis. The remaining 54.90% of the sellers decided not to take over any costs for buyers. Hence, buyers had to bear the full cost of analysis if they were interested in viewing it. Thus, the great increase in analysis sales can be explained by the fact that sellers subsidized the analysis purchases, motivating more buyers to purchase and view the analysis. All in all, this analysis shows that user-controlled pricing and offering resulted in a significant increase of trade with and revenue from TAH sales.

5 Discussion

This study asked *how to offer and price TAHs to advance data trade and revenue* for its providers. Drawing on prior works, we proposed a design scheme and evaluated its effects on trade and revenue for its providers against current approaches. This offers valuable insights, not only for academics but also for practitioners who aim to achieve high gains and acceptance of novel TAHs.

5.1 Pricing and Offering TAHs

The use of certificates to mitigate the impact of information asymmetries is not new. Current solutions that have been established include Carfax or Eurotax, for example. However, neither have they achieved widespread adoption, nor large-scale positive effects (The Economist, 2019). The introduction of blockchain gives rise to a novel approach to address the problems of information asymmetries by decentralizing system governance (M. Du et al., 2020; Zavolokina, Ziolkowski, et al., 2020) and hence enabling the collaboration of multiple stakeholders (Fridgen et al., 2017) towards more comprehensive and trusted car histories (Bauer, Zavolokina, & Schwabe, 2019). However, a single trusted third-party (e.g., the car manufacturer) could provide legitimate and reliable information to the same amount and degree. In any case, tokenizing it makes it possible to rethink how these novel data products can be used (i.e. offered and priced) (Drasch et al., 2020). Tokenization creates traceable data entries and dedicated ownership (Miscione et al., 2018, 2020), enabling users to trust record history. In other words, while calls for giving customers more control over their data have been around for a long time, in line with Koutroumpis et al. (2020), we argue that tokenization now also offers a way to do so without losing trust in data quality of those who eventually obtain the data, and we show how this can be instantiated in the case of tokenized car histories. Although this approach is in line with prior works that call for more pricing power of individuals (Parra-Moyano et al., 2020), and although it might sound reasonable from a user, legal, and IT perspective, it might seem counterintuitive from a business perspective. Businesses could fear handing over control of key product functions, like pricing and offering, as they do not know how this can be done and how this will impact their business, which would explain why such concepts have not yet been established.

Our proposed design for a user-controlled pricing and offering mode, however, shows how this can be implemented into an existing used-car market platform. Building on Stahl & Strausz (2017) – who argue that if certification is offered to sellers, it enables them to signal product quality and thus increase market transparency and revenue for certification providers – we take the concept further and not only offer TAH to sellers but also grant the sellers control over pricing and offering TAHs (in the UC instance) of these. Consequently, TAHs are no longer offered as intermediary information products to sellers (and/or buyers) as they are currently, but rather offered as a signaling tool for sellers. We do this not only for the TAH type data, where self-control by the co-producer of the data seems obvious, but also for analyses which are the services of businesses. Based on the natural assumption that the seller of a car at least partially co-produces the data, for example, by registering, driving, and servicing the car (and the companies take over the rest of the tasks, such as storing and processing), handing over control of the data to the sellers may be increasingly demanded in the future simply from a legal point of view (Schallbruch et al., 2021). However, analytics, meaning the preparation and contextualization of the data, are services that are carried out by companies, where companies may indeed be concerned about whether user-controlled pricing can achieve sufficient returns.

The results from the market game in the used-car market, however, show that there are no grounds for such fears. In fact, decentralizing the pricing and offering of TAHs – by granting sellers control over offering and pricing – can prove beneficial for platforms offering TAHs. First, in terms of revenue for its providers and second in terms of use (i.e., data trade). As sellers reduced the prices for their data offerings, or even published them for free, this sparked buyers' interest to purchase more analysis offerings. Sometimes sellers even promoted the sale of analysis offerings by subsidizing them. Consequently, this largely benefited the businesses operators in terms of achieved revenue. Besides direct financial benefits for businesses, the increase in trade, and hence, the usage of TAHs, can even foster the project's long-term success. As private users directly experience the benefits, it might motivate them to cooperate with the providers by granting businesses access to their data. This, in turn, can help such providers to stand out and succeed against currently existing third-party certifiers, by increasing the TAHs comprehensive.

5.2 Practical Implications for Cardossier and Similar Projects

Looking at the instance problem at hand, the results indicate that a user-controlled pricing and offering mode can indeed increase revenue for Cardossier. Offering TAHs not only as information products but rather as tools for sellers to signal product quality (Stahl & Strausz, 2017), can multiply data trade by a factor of almost two and the total revenue for the Cardossier consortium by a factor of more than two. If the experiment results hold up to further empirical tests, for the regional market that the Cardossier consortium aims to address (with approximately 800,000 used cars sold every year), this would mean an increase in revenue of more than US$160 million per year. This is more than one order of magnitude higher than the current annual budget of the Cardossier consortium, which can be a core component for solving the instance financing problem of Cardossier. However, this is only possible if the TAHs are embedded in a carefully crafted artifact design that involves attractive information, fair sharing of costs, and revenues between private users and business providers.

Finally, some of the insights can be transferred to other similar tokenization projects that span the application area of the car ecosystem but cover the life cycle of high-value assets (Risius & Spohrer, 2017). Examples could include life cycles of pieces of art or jewelry, or even the health information of humans and animals. While in these cases tokenized asset histories might not only be used for reducing information asymmetries but also for greater efficiency and affective treatments, keeping control over whom to grant access to which data within the competence of the individual might foster their engagement and adoption. As users experience greater control over their data, their willingness to collaborate in such initiatives could increase. Lastly, direct engagement and experience with the application and use of its products might lead to an increase in trust towards the decentralized system.

6 Conclusion

This paper studies how tokenized asset histories can be priced and offered to best leverage their potential for its providers. Our results show that granting users control over the offering and pricing of TAHs for their products significantly increases both the use of TAHs and the revenue achieved from the sale of TAHs for the network of operators. These insights are highly relevant and valuable for both academics and practitioners, as they unfold how the use and value of blockchain-based applications can be increased through different designs of its core functions. Hence, this study helps to get a step closer to the realization of tokenization projects. From an academic perspective, we take prior works on the application of blockchain for tokenized assets, especially in the used-car market (Notheisen, Cholewa, et al., 2017; Zavolokina, Ziolkowski, et al., 2020), but also in other domains, a step closer to realization by proposing a design for value capturing. From a practitioner's perspective, our study gives well-founded insights that help direct development efforts early on. Even more, our analysis allows the approximation of potential market acceptance and expected profits of tokenized asset histories, which are essential for businesses working on developing such. Yet, this study is not without limitations. First, this study relies on experiments conducted in one geographical location. While this provides great insights about market dynamics and user preferences in one area, it also motivates to repeat the experiment in other countries to test if the results still hold true. Second, despite our efforts to employ as realistic lab settings as possible, experimenting with real-world users would give even more reliability to the results. Besides these methodological limitations, we also want to call to attention that in this study, we did not take into account privacy aspects and regulatory demands with regards to data ownership. However, we encourage practitioners and academics working on such projects to consider and evaluate these aspects carefully. Further, while our study provides indications that user-controlled pricing and offering power could increase trust in the system, we encourage further investigation to deepen the insights. Finally, we would like to encourage future research to further investigate what the effects of increased market transparency and peer-to-peer tokenized asset history trade mean for established and future businesses.

ESSAY V – NO ROOM FOR ARGUMENT: THE IMPACT OF TOKENIZED INFORMATION ON BARGAINING

The content of this essay is based on the following working paper: Bauer, I., Parra-Moyano, J., Schmedders, K., & Schwabe, G., *"No Room for Argument: The Impact of Tokenized Information on Bargaining."*.

Abstract

Having developed a thorough understanding of the value creation and capturing processes of tokenized asset histories (i.e., multi-party certificates), this essay rounds up this dissertation by ensuring that saturation is reached with regards to the insights on increased market transparency and focus on deriving overarching insights for established and novel businesses. As the preceding essays suggest, changes in the socio-technical interactions (increased ability to send signals with higher fit) lead to increased market transparency; this essay takes another loop through the socio-technical system and analyzes the impact of increased market transparency – achieved through multi-party certification (i.e., tokenized information) – on bargaining activities of buyers and sellers and their associated transaction costs.

Transaction costs play a crucial role in all aspects pertaining economic exchanges. The activity of bargaining is particularly associated with such costs, which in many cases stem from the information asymmetry between the agents participating in the bargain. Thus, this essay studies the impact of increased transparency (achieved through (tokenized information) between bargaining agents on costs associated with the bargaining activity. Building on the classical transaction costs and bargaining literature, we develop a model, which serves as a sensitizing device, to explain the process whereby the availability of tokenized information impacts bargaining processes. Using data from a lab experiment in which 668 negotiations over the price of secondhand cars occurred, we show that the availability of tokenized information (hence, increased market transparency) results in lower bargaining costs and more efficient outcomes, which deters the

establishment of intermediaries who base their business models on the mitigation of information asymmetries, and in turn incentivizes the establishment of decentralized, peer-to-peer market structures.

1 Introduction

It is undeniable that bargaining is an economic activity of the utmost importance for society, determining elements as diverse as prices in a flea market, corporate valuations in the due diligence processes for mergers and acquisitions, the amount of permissible CO2 emissions in deals aiming to reduce global warming, prices for real estate and used goods, and workers' salaries, as well as (trade) deals that cause, and end, (trade) wars. However, bargains usually entail a high cost for the parties involved. The existence of such costs is problematic because—among other effects— it hinders the achievement of efficient outcomes and can, under some circumstances, even prevent agents from starting to bargain in the first place.

Recently, the development of blockchain technology has started to enable the recording of information in a new way—namely, through decentralized authenticated tokens. Tokens, a technical feature native to blockchain systems, are *"a digital, intangible, unique representation of something"* (Miscione et al., 2020). While in the bitcoin system this *something* is a cryptocurrency, in other systems it can be a digital representation of a real-world asset such as a car. Tokenized information is different from general information usually available to bargaining parties in that it provides proof-of provenance, every update made to it can be traced, and each piece of information has dedicated ownership (Miscione et al., 2020). Further, several parties can contribute to the generation of tokenized assets, by adding a piece of information to them in a decentralized manner. As a result of these features (decentralized data collection, immutability, and traceability), tokenized information is more extensive than information recorded in a centralized manner, and more trusted as it cannot be faked or "poisoned" (Marella et al., 2020).

Given the enormous potential of tokenized information for markets that suffer from information asymmetries (Bauer et al., 2020) and the fact that initial pilot studies on this topic have achieved sufficient maturity (Zavolokina, Ziolkowski, et al., 2020), it is worth studying whether—and if yes, how—the availability of tokenized information significantly impacts the bargaining costs and the outcomes of a bargain. In fact, tokenized information is already being generated and used in markets that typically suffer from information asymmetries and where parties bargain over the final price of goods, including the used-car market (Notheisen, Cholewa, et al., 2017). Examples of firms using tokenized information to determine goods or service prices in the presence of information asymmetries include the car manufacturer Mercedes-Benz (Rajamanickam, 2019) and the insurance company Allianz (Ledger Insights, 2021). Also, researchers propose that tokenized markets might lower transaction costs and urge established businesses to evolve (Sunyaev et al., 2021), yet little empirical insights exist yet.

Using data from an experimental market game in which 668 negotiation processes occurred, we measure how the availability of tokenized information about the negotiated good (a second-hand car) affects the bargaining cost experienced by the agents. Our results show that the availability of tokenized information results in lower bargaining costs and *fairer*, more efficient outcomes, which in turn favors the establishment of novel decentralized market structures (i.e. decentralized platfrom businesses).

The remainder of this paper is structured as follows. In Section 2 we introduce the relevant literature about bargaining and transaction costs and describe the properties of blockchain and how they enable the recording of tokenized information. Based on this literature review, we develop a model to explain *how* tokenized information affects the costs and outcomes of bargains. In Section 3 we describe our research design and our data collection. In Section 4 we present the results of testing the implications of our model. In Section 5 we derive insights from our results and discuss their potential and limitations. In Section 6 we conclude.

2 Prior Work and Theoretical Model Development

This section introduces the relevant literature about bargaining and transaction costs, as well as the relevant literature on blockchain technology as an enabler of tokenized information.

2.1 Bilateral, Structured Bargaining Models

In this review we direct our attention toward the most relevant bilateral, structured bargaining models. Bilateral, structured bargaining models clearly specify the bargaining rules and the sequence that govern two agents participating in a bargain (Camerer et al., 2019). When analyzing such models, we focus on studying the assumptions made about the information available to the bargaining agents, as well as on the outcome of the bargaining process, (i.e., whether and when an agreement is reached)[12].

The models introduced by (Nash, 1950) and (Rubinstein, 1982) are probably two of the most influential in the bargaining literature (Backus et al., 2020).These two models involve two players having complete information about their opponent's valuations. Agents in these models have some (low) costs associated with the bargaining process, such as a per-period discount factor or a per-offer cost applied to each period of the game. These models predict that if the agents participating in the model have complete information about all the elements of the bargain and if transactions cost are low, then all interactions should end in an immediate agreement, such that the game ends with the first offer being immediately accepted by the opponent.

Statements like *"If such-and-such conditions hold, then selfishly optimal individual decisions will lead to efficient aggregate outcomes,"* are called decentralization results (Farrell, 1987). The expected outcomes that result from the application of classical bargaining models of complete information, like those described by (Nash, 1950) and (Rubinstein, 1982), are examples of a decentralized outcome. However, that *"such-and-such conditions hold"* is rarely observed. In fact, the claim that voluntary negotiation will lead to fully efficient outcomes is implausible unless people know one another exceptionally well (Farrell, 1987).

Since the assumption of complete information is rarely observed in real-world scenarios, several models relax it, introducing the notion of incomplete information. (K. Chatterjee & Samuelson, 1983) introduce a static model to explain bargaining with incomplete information. In this model, the bargain ends after the first offer, and can result in either an agreement or a disagreement. One

[12] This review is inspired by the analysis conducted by Backus et al. (2019), with the difference that we carry it out with the intention of assessing the impact of tokenized information on the bargaining process while they analyze with the intention of assessing the predictive power of these models in the real-world setting of an online secondhand market.

model that explains alternating-offer bargaining games with incomplete information is that of (Perry, 1986), in which both the buyer and the seller have private valuations that are not common to their opponent. Like in the models of (Rubinstein, 1982) and (Nash, 1950), the agents described in the model by (Perry, 1986) face costs when making offers. The unique sequential equilibrium of this game is that the side with the lowest bargaining cost makes an offer, and the other party accepts or rejects, but never makes a counteroffer (Backus et al., 2020). Hence, in the model introduced by(Perry, 1986), either an agreement or a disagreement can occur following the first offer (which is also the last offer).

To understand games that require several offers and counteroffers if they are to end in an agreement, models of delayed agreement have been developed. In the model introduced by (Gul & Sonnenschein, 1988) an informed buyer (with a private valuation) alternates offers with an uninformed seller (with a known valuation). In equilibria this model predicts that an agreement always happens, but that the agreement can occur after several offers and counteroffers have been made between the agents.

With the aim of understanding bargaining situations of delayed disagreement (i.e., situations in which agents sequentially exchange offers and counteroffers and end up without agreeing on an outcome), (Cramton, 1991) derives a model in which both parties have private information about their valuations and after a sequence of offers and counteroffers discover that there are no gains to be had from a trade and walk away. The models that we have thus far described cover cases of both immediate agreement and immediate disagreement, as well as those of sequential agreement or disagreement, and are summarized in Figure 19.

Immediate agreement	**Immediate (dis)agreement**	**Delayed agreement**	**Delayed disagreement**
• Nash (1950) • Rubinstein (1982)	• Chatterjee and Samuelson (1983) • Perry (1982)	• Gul and Sonnenschein (1988)	• Cramton (1991)

Figure 19. Bilateral, Structured Bargaining Models by Type of Outcome

While there are several other bargaining models (such as the ones recently developed by (Davis & Hyndman, 2018), (Camerer et al., 2019), and (Haruvy et al., 2020), among others), those we have cited and described cover the four generic possible cases of bilateral, structured bargaining in relation to *whether* an agreement or a disagreement occurs, and *when* the agreement or the disagreement occurs. It is important to note that these models are neither correct nor incorrect, but are dependent on the satisfaction of the assumptions upon which they are derived. Since the assumptions required by models of complete information are more restrictive, these models do in general struggle to explain the broader scope of outcomes observed in experimental and real-world situations.

2.2 Transaction Costs

The activity of bargaining is associated with several (transaction) costs. The costs of transactions were first discussed by (Coase, 1937) in the context of organizational economics. According to Coase's work, individuals will choose to form firms to conduct transactions instead of trading bilaterally through contracts whenever the firm's costs of conducting a transaction are lower than the costs associated with bilateral trading. The results of the work of (Coase, 1937) are in line with transaction cost theory (Williamson, 1979), which states that the optimum organizational structure (either a firm or a market) in which agents continuously bargain is the one that achieves economic efficiency by minimizing the costs of exchange.

Transaction costs can be divided into three categories—namely, search and information costs, bargaining costs, and policing and enforcement costs (Dahlman, 1979). Search and information costs are the costs associated with the search for the relevant information and bargaining parties required for the transaction to occur. Bargaining costs are the costs related to the actual bargaining activity, such as the cost of making the offers and the time spent over the bargain. Policing and enforcement costs are the costs associated with ensuring that contracts are enforced and honored. Given the focus of the present paper, hereafter we focus on bargaining and search and information costs.

Each type of transaction cost is subject to four variables—namely, *frequency of exchange*, *asset specificity, uncertainty, and threat of opportunism*. Both uncertainty and the threat of opportunism are influenced by information asymmetries. Information asymmetries emerge in settings in which the distribution of information between the agents participating in a transaction is unequal (Akerlof, 1970). When bargaining over the price of a good, the party with the information disadvantage cannot discern the actual quality of the good. Consequently, and to avoid a disadvantageous deal, the less informed party tends to only accept offers that incorporate the risk of disadvantageous transactions. In some cases this can lead to long and tedious bargaining processes with high costs. In extreme cases, information asymmetries might lead markets to completely collapse (Akerlof, 1970).

Information asymmetries can be mitigated using signals—pieces of information that can be sent from the party with more information to the party with less (Spence, 1973). Signals enable less informed parties in a bargaining situation to screen the market and form beliefs. Such beliefs help the agents engaged in bargaining to determine whether the terms of the bargain are acceptable or not, and impact both *whether* and *when* an agreement or a disagreement is reached. Therefore, while the costs of signaling and screening belong to the category of search and information costs, they ultimately have an impact on the bargaining process, since they determine the set of outcomes that can result from the process (Feng et al., 2015). The set of outcomes that can result from the process determines the width of the transaction space (Susarla, 2012; Susarla et al., 2010), which is the space of possible offers and counteroffers that the bargaining parties will consider. Reductions in information asymmetry reduce the transaction space because extreme offers (offers that are far away from the actual value of the good) are not made. In a similar fashion, and regardless of the outcome of the bargaining, more information affects the number of offers and counteroffers needed to end the bargaining by increasing the number of concessions made by originally more informed parties (Stuhlmacher & Champagne, 2000), such that when the amount of available information increases, fewer offers and counteroffers are expected. At this stage it is important to note that reductions in information asymmetry reduce the transaction costs associated with a bargain (Bapna et al., 2016). Summarizing: the availability of more information reduces the number of offers and counteroffers and the transaction space; whereas the reduction in the transaction space eliminates the possibility of extreme offers being made, which therefore reduces the number of (extreme) offer and counteroffers that are made. Figure 20 illustrates the relationship between the availability of information, the transaction space, and the number of offers and counteroffers made during the bargaining.

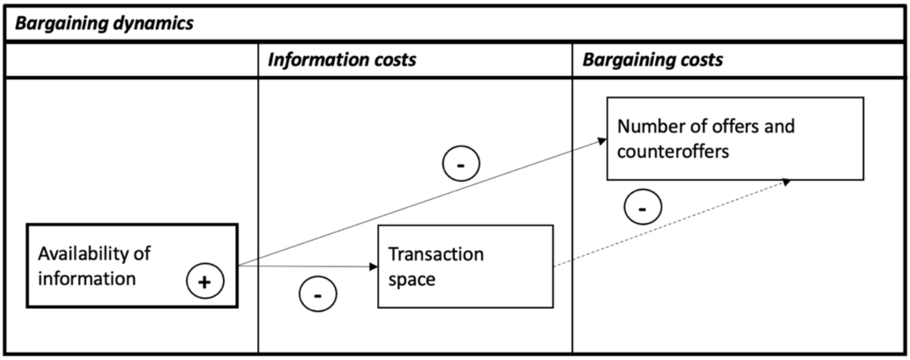

Figure 20. Relationship Between the Availability of Tokenized Information, the Transaction Space, and the Number of Offers and Counteroffers

While the relationship between the availability of information and the time required to negotiate is yet unclear (Heitzman & Klasa, 2021), there is evidence that in bilateral trading the bargaining process is completed more rapidly when there is less information asymmetry, simply because there is less disagreement between the agents (Backus et al., 2020). Hence, a reduction in the information asymmetry between bargaining agents results in speedier bargains. Additionally, since the availability of more information reduces the transaction space, some of the (extreme) offers that could initially have been made by the agents are not made. Hence, the reduction in the time necessary for the bargain to be struck can be attributed both to the greater availability of information and to the reduction in the transaction space. These relationships are represented in Figure 21.

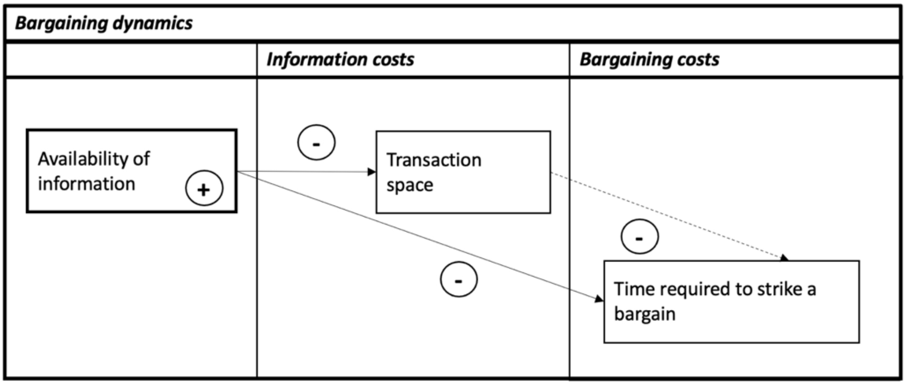

Figure 21. Illustration of the Relationship Between the Availability of Information, the Transaction Space, and the Time Required to Conclude a Bargain

The reason why the time required to conclude a bargain is crucial is that time is associated with costs (Cramton, 1991). Cross, (1969) in fact, states: *"The most important characterization which we, in this study, will apply to the bargaining process is that it is fundamentally time dependent. It is widely appreciated that the passage of time has a cost in terms of both dollars and the sacrifice of utility which stems from the postponement of consumption, and it will be our position throughout this study that it is precisely this cost which motivates the whole process. If it did not matter when the parties agreed, it would not matter whether or not they agreed at all."* Simply engaging in bargaining leads the agents involved to incur costs, which is sometimes also referred to as the disutility of bargaining (Scott Morton et al., 2011). For this reason, shorter bargaining processes are less costly than longer ones.

Beyond the pure economic costs associated with the bargaining process, there is evidence that bargaining activities trigger anxiety in the agents involved (Brooks & Schweitzer, 2011), that specific emotions such as anger, sadness, disappointment, anxiety, envy, or regret can affect the behavior of negotiators (Brooks, 2015), and that some agents involved in bargaining will simply agree to the first offer that satisfies their minimum needs just to avoid the mental distress of continued bargaining (Leary et al., 2013).The fact that some agents fear such distress also explains the marketing power of *no-haggle* policies (very common in the used-car market, for example), by which retailers stick to whatever price they decide to sell at and simply do not negotiate (Desai & Purohit, 2004).

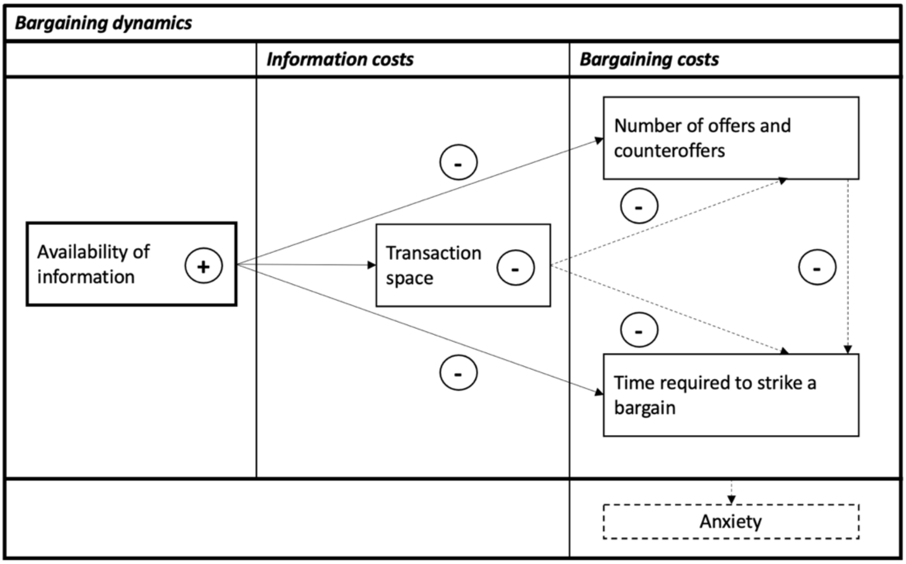

Figure 22. Illustration of the Relationship Between Information, Information Costs, and Bargaining Costs

All the relationships thus far explained are summarized in Figure 22, which illustrates the relationship between an increase in the availability of information, a reduction in the transaction space, a reduction in the number of offers and counteroffers, and a reduction in the time required to conclude a bargain. It is important to note that while we assume that lower bargaining costs (i.e., a lower disutility incurred when bargaining) would result in reduced anxiety, this is not something we can measure in the context of this paper, which is why we only present anxiety reduction as an appendix in the figure, with no clear relationship to information availability. Furthermore, at this stage we are theorizing regarding the relationship between the number of offers and counteroffers and the time required to conclude a bargain. Since, all else being equal, offers and counteroffers lying further away from the actual value of the good (i.e., those that, while extreme, are not the most extreme and therefore not those that delimit the transaction space) are less likely to be made, no time is consumed evaluating them, which in turn results in a speedier striking of bargains.

2.3 Tokenized Information

Recently, a novel technology for recording and processing information in a decentralized manner has emerged. This technology has been given the name *blockchain*, or *distributed ledger* (Babich & Hilary, 2020), in reference to the way in which it stores information in blocks that are linked to one another by means of a cryptographic procedure (Zheng et al., 2017). The first system based on blockchain was Bitcoin, the cryptocurrency first described by (Nakamoto, 2008). The actual innovation behind Bitcoin was the protocol it used. This protocol prevented Sybil attacks—a type of attack seen in peer-to-peer networks that refers to abuse of a digital network via the creation of multiple, illegitimate virtual personas (Siddarth et al., 2020). By preventing Sybil attacks, the protocol also solved the "double-spending problem" intrinsic to digital currencies (i.e., the problem that in the absence of a central authority, any holder of a digital currency could spend the same unit of the currency twice). It is important to note that the double-spending problem is (like any bargaining problem) related to information asymmetry: the (first) holder of a particular Bitcoin knows if that particular unit has been spent twice or not, whereas in the absence of a central authority that verifies payments, the receiver of that Bitcoin cannot certainly know. In the presence of such information asymmetry, the receiver of a Bitcoin would perceive it (even if the Bitcoin had not been spent twice) to be valueless (or at least as less valuable than if the system could ensure that the Bitcoin had not been spent twice). This would result in the collapse of the Bitcoin market, which is a classical example of the collapse of markets with information asymmetry as already described by (Akerlof, 1970).

Bitcoin solved the double-spending problem by introducing the role of the "miner." Miners are agents that process and record transactions in files called "blocks." The protocol incentivizes miners to only process and record valid transactions made up of Bitcoin units that have not been spent twice. Since the ledger is public and distributed among all the miners that wish to participate in the system, any receiver of a Bitcoin can trace the origin of the Bitcoins received and verify that these units (or any other unit) have not been spent twice (Halaburda et al., 2020). In this sense, Bitcoin solved the problem of information asymmetry between payers and payees by providing a signal (tokenized information about the unique digital ownership of that Bitcoin, stored in the ledger) to the payees.

Abstracting from the initial application example of cryptocurrencies, the blockchain technology that underlies the cryptocurrency has been proposed for a variety of other use cases that seek to address problems of information asymmetry and avoid problems of double-spending of digital assets (Sunyaev et al., 2021). Examples include, but are not limited to, the used-car market and uncertainty regarding the quality of goods (Notheisen, Cholewa, et al., 2017); land registries and associated uncertainties regarding ownership of a physical asset (Miscione et al., 2020); and art, where authenticity and ownership of both digital and physical assets can be assured (Franceschet et al., 2021). By using a blockchain infrastructure, businesses from a variety of industries have started to tokenize information about digital and physical goods and hence to address issues of information asymmetry in their respective application domains. This type of tokenized information enables the creation of a "digital twin" (Schmidt & Wagner, 2019) of a physical or digital good, ensuring proof of provenance and dedicated ownership of the stored information about the good (Franceschet et al., 2021). As a consequence, information (e.g., quality, attributes, history, and ownership) on a good that is managed via a blockchain is traceable and has a dedicated owner (Zavolokina, Ziolkowski, et al., 2020), which increases trust and has been proven to positively affect markets that suffer from information asymmetries (Bauer, Zavolokina, & Schwabe, 2019).

At this stage, it is important to recall that in the context of bargaining, information can be used as a signal. This signal's "fit" is the extent to which the signal is correlated with the unobservable quality of whichever underlying good it refers to (Connelly et al., 2011). An increase in (correct) available information about a good enable signals of a higher fit. What blockchain achieves is the trusted aggregation of reliable information from multiple sources (Wan et al., 2020), which can be used as a signal. Hence, when used as a signal, tokenized information is superior to information that is centrally managed and easily replicable and fakeable, in that due to its distributed nature it is more extensive (i.e., it relates to more aspects of the thing it describes) than information that is centrally stored (Chod et al., 2020). This is simply because more information is available when multiple, distributed parties can share the information that (only) they know about the good in question. It is also, at this point, crucial to explain why we refer to *tokenized* information, and not merely to *decentralized* information: While the benefits of tokenized information stem from its decentralized nature, precisely because of this decentralized nature decentralized information cannot be trusted. It is, in fact, the immutable and transparent processing of the information that makes decentralized information also trusted information (Marella et al., 2020). In other words, while decentralized information might or might not be trustworthy, tokenized information can be decentralized (and therefore more extensive) while being trustworthy.

While prior research has delivered initial prototypes of how such blockchain-based systems that enable the tokenization of information about high-value assets might work (Notheisen, Cholewa, et al., 2017) and of how such systems should be designed to address the needs of market participants (Zavolokina et al., 2019), along with early indications that market acceptance and effectiveness exist (Bauer et al., 2020), little is known about how tokenized information may impact bargaining processes and their associated costs and thus, what consequences this might come with for established and future businesses.

2.4 The Impact of Tokenized Information on Bargaining

From the literature review of the previous subsections, it has emerged that the information available to bargaining agents determines both *whether* and *when* an agreement or a disagreement is reached in a bargaining process. Models of immediate agreement (Nash, 1950; Rubinstein, 1982) or immediate disagreement (Perry, 1986) are associated with lower bargaining costs than models of delayed agreement (Gul & Sonnenschein, 1988) or delayed disagreement (Cramton, 1991). Additionally, we have seen that the availability of information affects the cost of the bargaining process itself (due to the fact that the availability of information affects uncertainty and the threat of opportunism). Since models of delayed agreement are associated with higher costs than are models of immediate agreement (due to the time required to conclude the bargain and the costs associated with making offers), there is a direct link between the information available to the bargaining agents and the cost of bargaining. Moreover, since the existence of transaction costs (of which bargaining and information costs are two components) affects the organization of the economy by favoring that transactions occur either within firms or in markets (Coase, 1937), the availability of information ends up affecting the structure of markets too.

Given that a new type of information has become available—namely, tokenized information—and that this type of information is trusted (Wan et al., 2020) more extensive (Chod et al., 2020) than non-tokenized information, it is of interest for scholars and practitioners to ask the following question: *How does the availability of tokenized information impact bargaining costs and the outcomes of bargaining?*

Since there is a direct link between information availability, information costs, bargaining costs, bargaining outcomes, and the optimal structure of a market, answering this question is of the utmost importance for scholars studying in the fields of bargains, transaction costs, and information. Also, since digital markets in which negotiations between peers determine transaction prices are growing (Ray, 2020), practitioners designing the structures of firms and markets can make direct use of this answer.

Moreover, there is an additional important dimension of the availability of information to bargaining parties—namely, the question of the fairness (understood in the widest possible way) of the bargained outcome. If market participants would observe all the possible outcomes from behind a Rawlsian "veil of ignorance" (Rawls, 1973)—a veil that prevents agents from knowing anything about their initial position in a system before they have agreed on the rules governing the system—how would they like the information availability to be? While there are several approaches to understanding and measuring fairness, there is agreement that a lack of mutual trust can prevent otherwise mutually beneficial exchanges (Noreen, 1988). Rawls himself proposes the *maximin* principle as one possible approach to increasing the fairness of a system (Rawls, 1974). The maximin principle states that a social system should be designed to maximize the benefit of those who will be worst off in it. Several studies have already related information availability to agents in a system to the fairness of the system's outcomes, including in the context of property rights (Gächter & Riedl, 2005), decision-making (Armbruster & Delage, 2015), and dynamic bargaining (Davis & Hyndman, 2018). Since being better or worse off in a market with information asymmetry depends partly on the availability of information, answering our research question might also shed light on how to design bargaining systems (markets) that increase the fairness of outcomes from the Rawlsian perspective by maximizing the benefit of those who are, initially, worse off. Hereafter, we will focus on bargains pertaining to the field of goods in markets with information asymmetries, such as for example, bargains over the price of used cars.

2.5 Model Development

Building on the literature review, we hereafter present a theoretical model to explain how and why the availability of tokenized information affects the measurable elements of bargains. Figure 23 illustrates that theoretical model, which given its explanatory nature falls into the category of a model for explaining (Gregor, 2006). By developing this model, we aim to find causal relationships between the availability of tokenized information and the measurable elements of bargains that have been broadly studied in the literature. The measurable elements of bargains that we have identified in our literature review are 1) the transaction space, 2) the number of offers and counteroffers required to reach an outcome, 3) the time spent bargaining, 4) the difference between the price paid and the actual value of the good, 5) the revenue of the buyer, and 6) the revenue of the seller.

The illustration represented as Figure 23 shall serve as a "sensitizing device" (H. K. Klein & Myers, 1999) that aids readers in their understanding of the process whereby the availability of tokenized information impacts bargaining processes. Specifically, the availability of tokenized information reduces the transaction space, since the extreme values that buyer and seller could have considered for the prices of the good become unrealistic (because they are either too high or too low). The availability of tokenized information also reduces the number of offers and counteroffers that are made, due to the fact that tokenized information is (by its nature) available to all parties, since there is less space for arbitrary valuation of goods, which tends to unify the valuation criteria of the bargaining agents. Because of the referred unification of the valuation criteria, the time required to reach the outcome (regardless of the nature of that outcome) also shrinks.

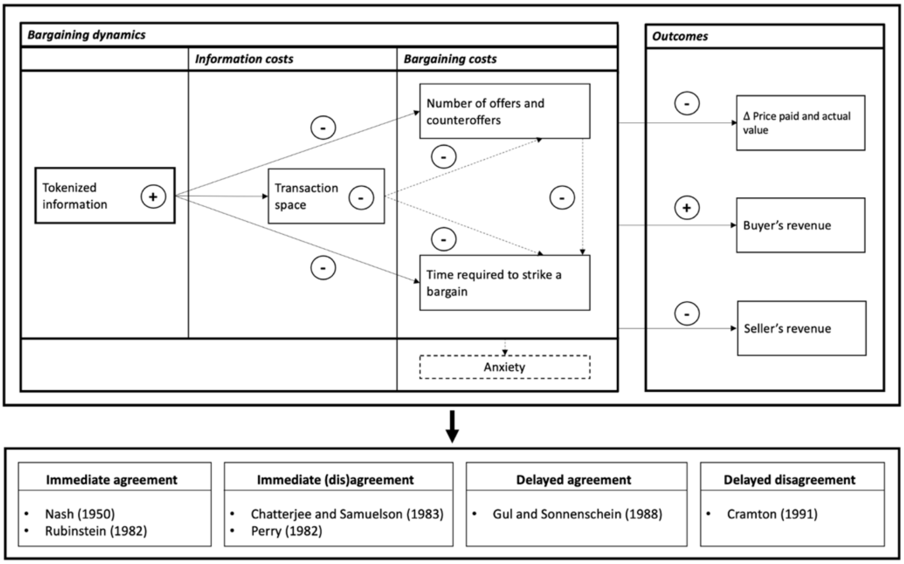

Figure 23. A Model Relating the Availability of Tokenized Information to Information and Bargaining Costs, the Outcomes of Bargaining, and Structured, Bilateral Bargaining Models

Beyond the direct impact of the availability of tokenized information on the transaction space, on the number of offers and counteroffers, and on the time required to strike the bargain, there is an interplay between these three elements. Namely, the transaction space shrinks, reducing the number of offers and counteroffers made by the agents because some offers that would have been made now fall outside of the transaction space. Additionally, the fact that the transaction space shrinks reduces the time required to reach an agreement—simply because the agents will not consider making or assessing offers that fall outside of the transaction space. Ultimately, the fact that fewer offers and counteroffers are actually made also results in a reduction in the time required to reach an outcome, because the agents need to evaluate fewer offers and can devote less time to making offers.

We theorize that these bargaining dynamics have an impact on the bargaining outcomes we can measure—namely, the difference between the price paid and the actual value of the good, the revenue of the buyer, and the revenue of the seller. That the difference between the price paid and the actual value of the good decreases can be explained by the additional information available to the uninformed party: (unfavorable) offers that may have been accepted by the uninformed party (the buyer), are now disregarded and not accepted, which results in increased revenue for the buyer and decreased revenue for the seller.

Finally, and since the availability of information is related to the fundamental assumptions made by bargaining models, we would expect the availability of tokenized information to affect the fraction of outcomes explained by models of perfect information, like those of (Nash, 1950) and (Rubinstein, 1982). Hence, we establish a relationship between the bargaining dynamics and bargaining outputs, on the one hand, and the fraction of outcomes explained by such models, on the other.

The nature of this model enables us to empirically test if the relationships that we derive from the literature are also observable, and hence if the availability of tokenized information has a significant impact on bargaining processes. In Section 3, we introduce the experimental setting whereby we gathered data to test the implications derived from the model, which we later analyze in Section 4.

3 Research Design

To test the validity of the model derived in Subsection 2.5 and therefore to study the impact of tokenized information on bargaining processes, we apply experimental techniques by using a market game. This market game (in the following called CarMarket) simulated the used-car market and allowed us to embed tokenized information provided by a system called CarFile. CarFile is a simplified replica of a real-world distributed car ledger (Cardossier), built, operated, and maintained by a group of car-related businesses (including importers, retailers, garages, insurers, road traffic authorities, and a mobility service provider) that collect and maintain data about all cars in their regional market. According to (Stebbins, 2001), besides serving to validate theoretical models, experimental techniques are well-suited to the discovery and description of phenomena and their correlations in the course of exploratory research. Further, experimental techniques enable one to explore market dynamics and agents' behavior, and hence inform early the design of novel systems (Roth, 2002). While there are certainly critics of lab experiments (Levitt & List, 2007), contrary research has shown that many findings from such experiments indeed prove to be generalizable. (Camerer, 2011), for example, argues that experimenting in comparable lab settings can provide substantial grounds for deriving general theory. Besides proving beneficial for economics research, lab experiments have also been shown to be a successful method when applied to both the exploration and the evaluation of the effects of information systems (Hashim et al., 2014).

3.1 Experiment Set-up

CarMarket was designed and implemented as a replica of the extant, well-established used-car-market platform AutoScout24. To facilitate this process, we were granted access to all relevant information by the platform. While AutoScout24 offers a variety of services in addition to a platform for the buying and selling of used cars, for our study we limited the replica platform to the core functionalities relevant for testing the effects of the availability of tokenized information on the bargaining process. Our chosen functionalities included the registration of users and cars as well as the core marketplace functions of offering and searching for used cars. To these functionalities from AutoScout24 we added the possibility for users to negotiate via a chat function, as well as the possibility of closing a deal online via the platform. The ability to provide tokenized information was also embedded into the replica platform. Figure 24 shows CarMarket and its core user functions following registration as well as the integration of tokenized information, made possible by CarFile. Figure 25 shows how negotiations took place via the chat function when tokenized information was available.

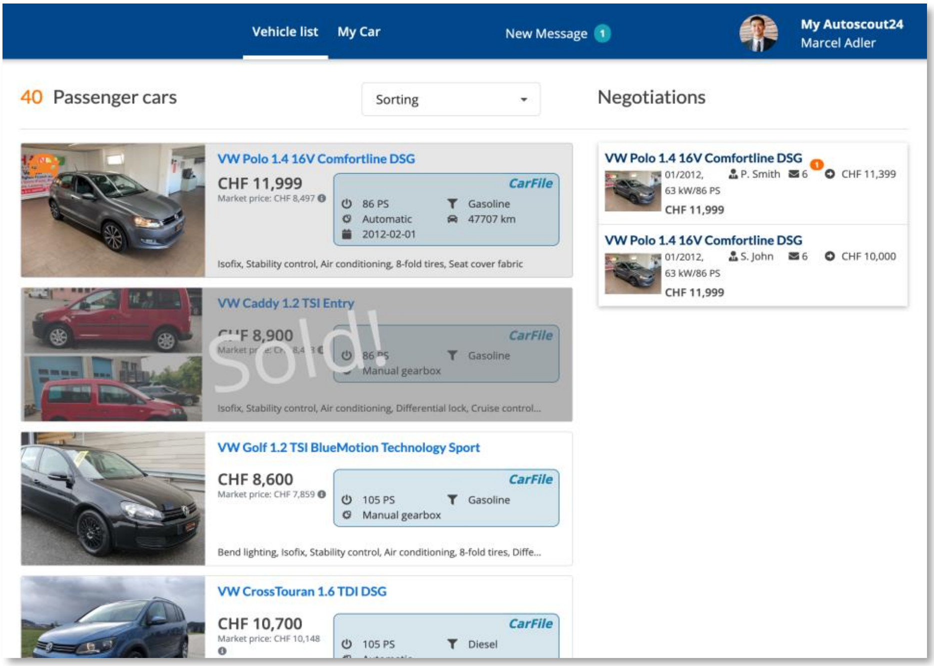

Figure 24. The Landing Page of the Marketplace CarMarket, with the Tokenized Information and Ongoing Negotiations Section on the Right

For the experiment, CarMarket was installed on two different serves and made accessible to users via two different URLs. One of these instances had tokenized information integrated; the other did not. In the following we refer to the instance that did not have tokenized information integrated as the Classical Market and to the instance that did have tokenized information integrated as the CarFile Market. To ensure external validity, and hence to ensure that we were providing a comparable lab setting (Camerer, 2011), we discussed and developed CarMarket iteratively in collaboration with AutoScout24 as well as with experts from the real-world Cardossier consortium.

For the experiment, AutoScout24 also granted us access to data on real used cars then available on the used-car market. We ensured that a certain portion of cars of below-average quality and a certain portion of cars of above-average quality were included in the sample, following current research on the used-car market (Blundell et al., 2019; European Parliament, 2018b; The Economist, 2019). The additional data used for simulating tokenized information was created in collaboration with the Cardossier consortium.

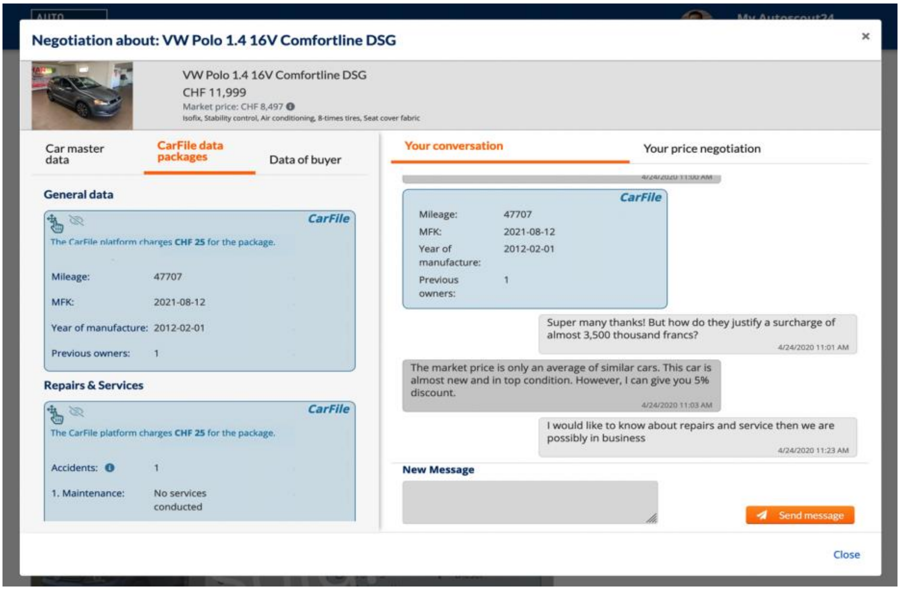

Figure 25. The Chat Function Integrated into CarMarket, Showing how Tokenized Information can be Used During Bilateral, Structured Negotiations

Prior to the large-scale experiment, we conducted multiple smaller tests of the experiment both with experts from Cardossier and with students. Drawing on Cardossier experts' views, we ensured the validity and accuracy of the experimental market game setting with regard to its resemblance to reality (Levitt & List, 2007). The tests performed with a smaller student test group enabled us to test understandability as well as the internal validity of the experiment, each with non-experts.

3.2 Data Collection and Analysis

After smaller pretests, we conducted the large-scale experiment in December 2020 with 97 students from our local university. The students were strongly incentivized to act realistically by the opportunity to earn bonus points for their final exam. The number of bonus points awarded depended on what they achieved in the used-car sales, including what they spent on information and earned by selling tokenized information. Roughly 80 percent of students enrolled in the selected class participated in the experiment, indicating that the incentive of the chance to earn bonus points for the final exam did indeed work. The objective of all players was to maximize their achieved revenue. This was calculated based on the following variables:

- The actual value[13] of the car (X), *which can be either above or below the car's market price*
- The price (P), *the final purchase/sale price for which a participant finally buys/sells the car*
- Settlement bonus—if *a deal was reached, both buyer and seller received a settlement bonus*
- The participant's expenditures (IC), on tokenized information purchases
- The participant's revenues (IR), from tokenized information sales

The revenues for buyers and sellers were calculated accordingly as follows:

- Revenue **Buyer** = $((X + SB)\ - P\ - IC)$
- Revenue **Seller** = $\big((P + IR + SB) - X - IC\big)$

[13] *We acknowledge that a universal actual value does not, in fact, exist. To evaluate the cars and approximate their actual values we used a standard-assessment table provided to us by one of the leading used-car retailers in the country. Additionally, two expert evaluations of all cars used during the game were conducted, one each by employees of two businesses that are part of the Cardossier consortium and who are also major players in the field. The mean value of these three evaluations formed the actual value of the cars for the analysis.*

We chose to add a settlement bonus (SB) to account for the fact that actors who enter the used-car market generally have an incentive to buy or sell a used car given their personal circumstances (e.g., the need for fast cash; the need for a car in order to commute, due to a new job; etc.). The SB was set at an amount high enough for buyers and sellers to be incentivized to close a deal if it was within an acceptable range, but not so high that they would accept a deal at any price. The level of the SB was discussed within the research team and tested during smaller pretests with students.

Using students as study objects can yield just as reliable results as using actual customers if they have sufficient knowledge of the study environment (Höst et al., 2000). Hence, to ensure sufficient background knowledge the students were, a few lectures prior to the experiment, introduced to the notion of the market for lemons. Also, all relevant information regarding the market game was communicated and explained to the students twice. A week in advance of the experiment, preparation material in the form of written documentation, as well as a screencast that provided a walk-through of the web application and its key features, was sent to them. Then, at the beginning of the lecture during which the experiment was carried out, an aural explanation and a live walk-through of the system were provided.

Just before the game began, the participating students were randomly divided into two groups, and each group was assigned to a separate instance: Classical or CarFile. To ensure internal validity, we ensured a random but equal distribution of the students between the two game instances (List et al., 2010), and applied a between-subjects design (Qureshi & Compeau, 2009). Initially, 97 students signed up to participate in the experiment. However, one participant sold his or her car—immediately after it was published on the platform—for USD 1, having wrongly placed a decimal separator. Thus, we had 96 participants, of whom 48 participated in the Classical Market and 48 in the instance where tokenized information was available, CarFile Market. Each player played the same game twice but a different role (i.e., once as a seller and once as a buyer). Once the students had familiarized themselves with their roles and their task, each group had exactly 60 minutes to complete the market game.

Once the experiment was complete, we analyzed the log files, focusing our analysis on the time spent on negotiations and the use and costs of tokenized information, in order to evaluate the effects of tokenized information on the bargaining process.

4 Analysis

This section presents the results of the experimental market game conducted to study the impact of the availability of tokenized information on the transaction costs associated with bargaining, bargaining outcomes, and assumptions about perfect information.

4.1 Analysis of the Effects of Blockchain-enabled Information on Transaction Costs and Bargaining Outcomes

To test the impact of the availability of tokenized information on the transaction costs associated with bargaining, we conduct a series of population tests to measure whether any of the outcomes are significantly affected by the availability of tokenized information. Specifically, we look for significant differences between the Classical and the CarFile setting in seven values that we identified in the literature review (considering that the transaction space is delimited by the space between the maximum and the minimum offer), which are expected to be impacted by the availability of tokenized information. The results of these tests are reported in Table 23.

Table 23. Comparison of Metrics for the Classical and CarFile Settings

	Metric	**Classical**	**CarFile**	**Relative Difference**	**P-value**	**Power**
Information costs	Diff. maximum offer and actual value	854.94	637.42	-25.44%	0.00	98%
	Diff. minimum offer and actual value	1,046.01	697.55	-33.31%	0.00	99%
Bargaining costs	Avg. number of offers and counteroffers made and received by each player	3.4	2.7	-20.59%	0.00	89%
	Avg. time to close a deal	39.07	26.00	-33.45%	0.00	100%
Market Outcomes	Diff. price and value	998.71	557.90	-44.14%	0.00	98%
	Revenue Buyer	127.60	550.55	+431.15%	0.00	88%
	Revenue Seller[14]	1,872.40	1,552.98	-20.57%	0.08	83%

We start by measuring the difference (in absolute terms) between the maximum offer received by a seller and the actual value of the car. We observe that this difference shrinks from USD 854.94 to USD 637.42 when we move from the Classical to the CarFile instance. This constitutes a reduction of 25.44 percent in the difference between the average maximum offer received by a seller and the actual value of the car. Note that the average value of the cars is USD 11,424.02 in the Classical setting and USD 11,325.93 in the CarFile setting. In a similar fashion, we also measure the difference (in absolute terms) between the minimum offer received by a seller and the actual value of the car. In this case, we observe that this difference shrinks from USD 1,046.01 to USD 697.55, again when we move from the Classical to the CarFile instance, constituting a relative reduction of 33.31 percent. The significantly lower figures for these two metrics in the

[14] The sum of the revenues of the buyers and sellers in the CarFile column does not add up to USD 2,000 since in the CarFile instance the cost of information (IC) and the revenue from information (IR) are subtracted from and added to, respectively, the sum of the revenues of the buyers and sellers.

CarFile instance imply a reduction of the actual transaction space, the space in which offers and counteroffers are made.

We continue by measuring the average number of offers and counteroffers received and made by a seller in each of the settings. The significant change in this number as we move from the Classical to the CarFile setting—namely, from 3.4 to 2.7—constitutes a reduction of 20.59 percent in the number of offers and counteroffers needed for sellers and buyers to reach a bargain when tokenized information is available.

We also measure the time required to strike a bargain (regardless of the outcome of the bargaining process). We observe that in the CarFile setting, the average time required to complete the bargaining decreases, in comparison to the Classical setting, from 39 minutes to 26 minutes. This is a reduction of 33.45 percent.

To measure the impact of the availability of tokenized information on the bargaining process itself and to study TI's impact on the outcome of the process, we study the difference between the prices paid for cars sold and their actual value, both in the Classical and in the CarFile setting. We observe that this difference shrinks from USD 1,010.16 to USD 618.76 as we move between settings, a reduction of 38.75 percent.

We then measure the relative revenues of buyers and sellers, incorporating all the costs and revenues that can be measured in USD (i.e., the relative revenues of buyers and sellers as defined in Subsection 3.2.). We observe that the relative revenue of buyers increases in the presence of tokenized information, from USD 127.60 to USD 550.55, an increase of 431.15%. The relative revenue of sellers, meanwhile, decreases in the presence of tokenized information, from USD 1,872.40 to USD 1,552.98, a reduction of 20.57%. Note, however, that the p-value of the population test to account for differences between the sellers in each group is 8%, meaning that the reduction is significant for a confidence level of 90%, but not for a confidence level of 95% or higher.

For all these populations tests we conduct a power analysis as a robustness check to ensure that the sizes of the groups allow us to draw (probabilistically) correct conclusions about the rejection of the tested hypotheses. The power of all the conducted tests (i.e., the probability of correctly rejecting the null hypothesis when it is false) is significantly above the required standard of 80 percent.

A summary of the results appears in Figure 26, which also relates our empirical results with the model derived in Section 2. The availability of tokenized information reduces the transaction space by 25.44%. Since the space is reduced, fewer offers and counteroffers are made. Precisely 20.59% fewer offers are required to conclude the bargaining process, irrespectively of its outcome. While the actual extent of the impact that this reduction of the transaction space has on the number of offers and counteroffers made depends on the distribution governing the transaction space, we argue that a reduction in the transaction space eliminates extreme offers (and that this is the case regardless of the distribution of plausible offers within the transaction space). In a similar fashion, the availability of tokenized information reduces the time span of the bargaining process by 33.45%.

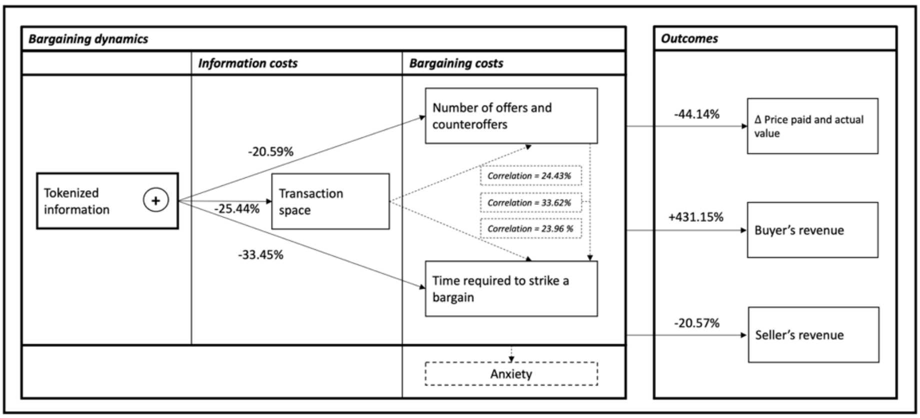

Figure 26. Illustration of the Impact of Tokenized Information on the Bargaining Process

We are aware of the potential direct relationships between the size of the transaction space, the number of offers and counteroffers, and the time required to conclude the bargaining process (dashed lines in Figure 26).The correlation between these three elements is also shown in Figure 26, and points toward a relationship between these elements. However, given the nature of our experiment we cannot reach any kind of causal relationship between these three elements. Regardless of this, and due to the reduction in the levels of each of these three elements (which are ultimately transactions cost in the form of information or bargaining costs), we observe significant changes in the outcome of the bargaining process, whereby—as we move from the Classical to the CarFile setting—the difference between the price paid and the actual value of the car shrinks by 44.14%, the buyer's revenue increases on average by 431.15%, and the seller's revenue decreases by 20.57%.

4.2 Analysis of the Effects of Blockchain-enabled Information on Assumptions About Perfect Information

Since the availability of information is one of the assumptions that determine the equilibria outcomes of bargaining models (Cramton, 1991; Gul & Sonnenschein, 1988; Nash, 1950; Perry, 1986; Rubinstein, 1982), it is worth studying to what extent the presence of tokenized information contributes to fulfilling the assumptions of the respective models. The satisfaction of the assumptions made by the respective models has a direct effect on the fraction of observed cases that each model can predict. Hence, we analyze the fraction of the observed cases, in each setting, that falls into the equilibria of the four models we have considered—namely, models of immediate agreement (Nash, 1950; Rubinstein, 1982), immediate disagreement (Perry, 1986), delayed agreement (Gul & Sonnenschein, 1988), and delayed disagreement (Cramton, 1991). When comparing the fraction of cases that fall into the equilibria of the respective models (reported in Table 24), we observe no significant difference whatsoever between the Classical and the CarFile settings.

Table 24. Comparison of Explained Cases by Model

	Metric	**Classic**	**CarFile**	**P-value**	**Power**
Information availability	Nash (1950), Rubinstein (1982)	1.80%	3.94%	0.08	25%
	Perry (1986)	38.56%	37.28%	0.63	15%
	Gul and Sonnenschein (1988)	10.53%	13.26%	0.14	19%
	Cramton (1992)	40.36%	41.93%	0.34%	26%

5 Discussion

In our analysis we have focused on studying the impact of tokenized information on three different types of elements. The first type encompasses the transaction costs associated with the bargaining activity. These include differences in the transaction space (which fall in the category of information costs), the number of offers and counteroffers required for bargaining to conclude, and the difference between the prices paid for goods and the actual value of the goods (both of which fall in the category of bargaining costs). The second type of element encompasses the market outcomes (i.e., the relative revenues) of both buyers and sellers and the difference between the price of goods and their value. The third type of element is related to assumptions regarding perfect information required by the most relevant bilateral, structured bargaining models. In the following, we discuss our results and the implications of the availability of tokenized information with regard to each of these aspects and state the limitations of this work as well as potential streams of future work on this topic.

5.1 The Impact of Tokenized Information on Transaction Costs

Blockchain technology enables the recording of information about the history of a good, be it digital or physical, in a decentralized, immutable, and transparent manner. This type of information can be used to support negotiations that suffer from an asymmetric distribution of information. Our study, in line with prior proposals (Sunyaev et al., 2021), shows how tokenized information—which is trusted (Wan et al., 2020) and more extensive (Chod et al., 2020) than centralized information—significantly reduces the transaction costs associated with the activity of bargaining. Specifically, when agents have access to such reliable and authenticated information about traded goods, the costs of gathering reliable information are smaller than in markets where such information is not readily available and needs to be sought out and verified. Consequently, bargaining agents with better information tend to make offers that are closer to the actual value of the good that they are bargaining over. This results in a reduction of the transaction space. This result is in line with (Susarla et al., 2010) and (Susarla, 2012), who show how higher information availability is related to a reduction in the transaction space, and hence that a reduction in information asymmetry is related to lower bargaining costs (Bapna et al., 2016). Put simply, our results show how the availability of tokenized information—which by its decentralized nature is trusted and more extensive than centralized information—reduces the cost of acquiring reliable information, which in turn results in offers closer to the actual value of the good being traded.

The bargaining costs that we have studied in this paper are related to the effort required to make the offer (Cross, 1969) and the time required for the bargaining (Cramton, 1991). From our analysis, it emerges that when agents have access to tokenized information the average number of offers and counteroffers that bargaining entails shrinks. Since making an offer requires effort, having access to tokenized information results in lower bargaining costs. One possible explanation for this phenomenon is that when agents are better informed they make offers that are closer to the actual value of the car, which helps them to reach an agreement or a disagreement faster than in the absence of tokenized information.

Moreover, we observe that in the CarFile setting, the average time required to conclude the bargaining significantly decreases. This significant reduction implies that in the presence of tokenized information the costs of bargaining shrink. This result is particularly interesting since it not only affects those parties that end up agreeing on the outcome of a bargaining process but also those that end up not agreeing on any deal. The reason for this is that the goods leave the market faster, and those agents that would end up not agreeing on a transaction simply end all their bargaining sooner, therefore devoting less resources to bargaining processes that would anyway end up in disagreement.

The reduction in the time and number of offers required to finalize a bargain is positive not only from a purely transactional perspective, but also from a psychological one. Shorter bargaining processes with fewer offers and counteroffers can help reduce the anxiety potentially suffered by the agents involved (Brooks & Schweitzer, 2011), prevent the negative emotions potentially experienced by the agents (Brooks, 2015), and make the whole bargaining process more transparent, such that agents who suffer from some level of mental distress when bargaining do not simply agree to the first offer that satisfies their minimum needs (Leary et al., 2013) and enjoy a clear indication of the actual value of the goods for which they are bargaining.

Furthermore, we can say that tokenized information serves as a signal (Spence, 1973) whose fit (Connelly et al., 2011) is higher than that of a signal enabled by centralized information. Hence, tokenized information permits market participants to bargain in a faster, less costly, more straightforward manner in the resulting (reduced) transaction space. In pure economic terms, and setting the reduction in psychological distress produced by bargaining aside, we can state that the availability of tokenized information about a good reduces the cost of searching for information and the bargaining cost of making (and evaluating) an offer.

Finally, our results imply that the availability of tokenized information contributes to satisfying the assumptions about low transaction costs described or required by the models introduced by (Coase, 1937, 1960) and (Williamson, 1979). We posit that greater availability of tokenized information would make (decentralized, peer-to-peer) transactions in the open market relatively cheaper than transactions made within the boundaries of the firm. Should this be correct, we should observe—according to the work of (Coase, 1937)—a contraction of the firm in favor of more decentralized types of structures. This would be in line with the work of (Farrell, 1987), since the *"such-and-such conditions"* required for *"selfishly optimal individual decisions"* to lead to *"efficient aggregate outcomes"* would hold more tightly thanks to the availability of tokenized information.

One could of course argue that all the results observed and discussed here simply stem from a greater availability of information and have little or nothing to do with blockchain technology. There is, however, a fundamental difference between *more information and tokenized information*—namely, the distributed nature of the latter. It is the distributed nature of the tokenized information that increases its value, since it enables a larger number of stakeholders to collaborate and to provide any information they have that is relevant to the bargain. While technologies other than blockchain could theoretically ensure that such distributed information is *trusted*, blockchain is currently the only technology that achieves this goal. This justifies our use of the term *tokenized information*.

5.2 On Market Outcomes and Fairness

The results reported in Section 4.1 show how the difference between the agreed price of a car and the actual value of a car shrinks by 33.45% in the presence of tokenized information. This difference seems to favor buyers (who experience an average increase in their relative revenue of 431.15%) at the expense of sellers (who see their revenue fall by 20.57%). In markets with information asymmetries like the used-car market, buyers are usually worse off since they have less information and risk buying an overpriced good. This is also reflected in our data, where we observe that the relative revenue of the buyers in the Classical game is USD 127.60 USD, while that of the sellers is USD 1,872.40.

From a Rawlsian perspective, fairness in a social system increases when the position of those who are worse off is "maximized" (Rawls 1974). This is the embodiment of the *maximin* principle. In this regard, when tokenized information is available we see the relative revenue of those worse off (the buyers) increase from USD 127.60 to USD 550.55 (an increase of 431.15%). We argue that the availability of tokenized information (at least in this context) contributes to the implementation of the maximin principle. As such, we posit that if agents (buyers and sellers) could choose which game to participate in (either the Classical game or the CarFile game), they would—from behind a Rawlsian "veil of ignorance"—prefer to participate in the CarFile game (i.e., the game in which tokenized information is available).

5.3 On Assumptions about Perfect Information

Our results show no significant difference in the fraction of outcomes explained by either of the bargaining models that we have studied (Cramton, 1991; Gul & Sonnenschein, 1988; Nash, 1950; Perry, 1986; Rubinstein, 1982) when tokenized information is introduced. The main difference between these models lies in their assumption about (perfect) information being available to the bargaining agents. It is fundamental to note that for information to be perfect it needs to represent to the private valuations of the counterparties, and not only the characteristics and history of the goods that are the object of the bargaining. Since in our model the availability of tokenized information refers to the history of the good and not counterparties' valuations, it is natural that we do not observe significant differences in the fraction of the outcomes explained by models of complete (and perfect) information, such as those of (Nash, 1950) or (Rubinstein, 1982).

We consider this insight of particular interest since it clearly manifests the limitations of blockchain technology in the context of tokenization. While several aspects of information can be tokenized (positively influencing market outcomes and reducing the costs associated with bargaining), there are other, more subjective aspects, such as preferences, tastes, or needs, that are (currently) more difficult (or impossible) to record in a blockchain and therefore to tokenize.

5.4 Implications

Scholars studying bargaining processes, transaction costs, and market structures can use our results to study how blockchain technology changes the information available to agents in a market. For example, they can study the direct relationship between the availability of tokenized information and the variables affecting transaction costs (particularly uncertainty and the threat of opportunism faced by the bargaining agents). Further, they can study how the bargaining behavior of agents changes, and how price formation is affected by the availability of tokenized information. Moreover, since the availability of tokenized information affects the prices of the goods sold and therefore the revenues of the parties involved in the bargaining process, our results imply that the availability of tokenized information affects the level of *fairness* in economic systems. Finally, since the availability of tokenized information affects bargaining costs, our results show that there is a relationship between the technology (blockchain) that makes available a new type of (more extensive and trusted) information and the optimal market structure (either one in which transactions occur within the boundaries of the firm, or one in which transactions occur in a peer-to-peer manner). This establishes an interesting relationship between technology and market structure.

Practitioners designing bargaining schemes and markets can benefit from our results as they can better foresee how incorporating blockchain technology into their systems can affect the behavior and willingness to pay of their clients.

Further, in line with Sunyaev et al. (2021), we argue that firms that are currently exploiting an advantageous position in terms of (centralized) information processing and signaling might anticipate the threat that tokenized information poses by making peer-to-peer transactions more convenient, and already begin to explore other types of structures (such as, for example, no-haggle prices informed by tokenized information) in order that they may evolve and continue generating value for their customers. Also, market designers aware of the cost that bargaining implies for those participating in a market might wish to calculate and compare the value added by the availability of tokenized information and that added by the availability of centralized information. Furthermore, since tokenized information is a signal of the type described by (Spence, 1973), if agents were able put a price tag on their time and on the (psychological) costs they incur when making and evaluating offers, this paper could help any agent participating in a market to estimate the value of tokenized information (i.e., the value of the signal) relative to the value of the information available as standard in bargaining markets, by multiplying these price tags with the reported average reduction in bargaining time. Finally, sellers of used goods such as cars can make use of the advantages of tokenized information to better argue in favor of no-haggle policies, such that buyers can enjoy less expensive transactions and trust that while avoiding the psychological distress of the bargain they are not bearing the costs of overpaying for goods.

5.5 Limitations and Future Work

While our study advances current research in that it provides interesting insights into the market effects of the availability of tokenized information, it comes with certain limitations. These, of course, open avenues for future research. First and foremost, our study is built on the assumption that data on high-value goods (e.g., cars) is available and can be offered as a novel information product to buyers and sellers. While prototypes have shown that it is technically possible to collect and maintain data from a variety of stakeholders via a blockchain (Zavolokina, Ziolkowski, et al., 2020), many economic and legal challenges will need to be resolved before tokenized information can actually be *offered* in these markets. A major economic challenge, and one that the stakeholders of the

Cardossier consortium themselves struggle with, is how to price tokenized information. Despite the great potential that sharing and trading data on high-value goods promises, as long as the question of fair pricing schemes remains unresolved the act of offering such novel information products—in our case, tokenized information from multiple parties via CarFile—will have a hard time becoming reality. Future research should engage with this gap and explore whether current pricing schemes are applicable for tokenized information or whether there are novel approaches that might offer even better outcomes. Besides this and other economic challenges, the legal question of the privacy of car-related data—and also, more specifically, of *driver*-related data—needs to be resolved before tokenized information about cars can be made available during the negotiation process.

Second there is the question of the methodological limitations of our work. We acknowledge that an experimental negotiation in a classroom setting is not the same as a real-life negotiation with (quite possibly tens of) thousands of dollars at stake. However, the use of experiments in economics has been proven useful (Roth, 2002), and our close relationship with industry experts ensured a design and setup that were as close as possible to a real-world scenario. Future research could, however, address this particular limitation and repeat our experiment in a real-world setting, for example by accompanying and analyzing the introduction of such a system in a real-world environment. Further, in an effort to analyze the effects of tokenized information on bargaining and its associated costs, our study used the application case of the online used-car market. We encourage future research to challenge the applicability of our results to other application areas.

Finally, we would like to point out that while our study provides important quantitative insights into the effects of tokenized information on bargaining processes and their associated costs, further qualitative studies would be worthwhile in order to explore in greater depth the behavioral changes of the different agents.

6 Conclusion

This paper analyzes the impact of tokenized information on bargaining processes and their costs, for goods for which information asymmetry exists. Based on our results and analysis, we can state that the availability of tokenized information reduces transactions costs (both information search and bargaining costs) and changes the outcomes of the bargaining process, increasing the revenue of less informed parties while reducing the revenue of more informed parties. This, in turn, results in market outcomes that are—from a Rawlsian maximin perspective—*fairer*.

We can state that the availability of tokenized information results in a shorter, less expensive bargaining process, which entails less distress for the involved parties. Further, we can state that from a Rawlsian fairness perspective, the availability of tokenized information can help to foster the maximin principle and increase the fairness of social systems. This might have interesting implications, since it links an interdisciplinary economic and technical concept like tokenized information with broader concepts of social relevance. In times in which scholars are called to study *“how technology can play a pivotal role in the endeavors aimed toward addressing social justice”* (Aanestad et al., 2021), these results might contribute to that objective, enriching discussion and starting to link technologies such as blockchain with broader topics of great social relevance. We present limitations regarding the assumptions that our study is built on, the methodological limitations with regard to how our study was conducted, and limitations in the scope of our study, all of which impact the conclusions that can be derived. All these limitations, however, also provide avenues for future research, avenues that we delineate.

On a final note, we would like to emphasize that blockchain technology enables the generation and the processing of tokenized information, both in a distributed manner. The availability of this type of information is, today, changing the way in which agents trade in markets and contributing to fulfilling some of the assumptions required for decentralized results to emerge. Thus, blockchain technology can contribute to a more complete fulfillment of the assumptions required by some of the traditional economic and managerial models discussed in this paper, which would in turn increase each of these models’ applicability.

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Education

Nov. 17 – April 22	**Doctoral Program at the University of Zurich** Department of Informatics, Information Management Research Group
Sept. 14 – June 16	**M. Sc. in Business Administration and Information Systems,** Copenhagen Business School, DK
Sept. 15 – Dec.15	**Exchange Term in Business Information Systems** York University, Schulich School of Bus., Toronto, CA
Oct. 11 – June 14	**B. Sc. in Information Engineering and Management** Karlsruhe Institute of Technology, Karlsruhe, DE
Sept. 01 – July 10	**A-Lavels (Abitur)** Gymnasium Landau an der Isar, Landau an der Isar, DE

Professional experience

Nov. 17 – Dec. 21	**Research Assistant in Information Management** University of Zürich, Department of Informatics, CH
Sept. 16 – Nov 17	**Technology Consultant for Financial Services** PricewaterhouseCoopers GmbH, Frankfurt am Main, DE
Jan. 16 – Jul. 16 & Mar. 15 – Aug. 15	**Student Worker in Group Risk Management** Danske Bank A/S, Copenhagen, DK
Mar. 13 – Jun. 14	**Intern / Student Worker IT Inhouse Consulting** PricewaterhouseCoopers AG, Frankfurt am Main, DE
Mar. 13 – Jul. 13	**Teaching Assistant for Electronic Markets** Karlsruhe Institute of Technology, DE
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