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The Secret Key to the Heart of Decentralized Finance

Unlocking the Potential of Crypto Assets and Currencies to Advance the Financial Sector

Dissertation

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“The search for truth is more precious than its possession.”

Albert Einstein

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Abstract

The rise of decentralized financial applications, such as crypto assets and currencies, challenges traditional banking and finance's roles and value proposition. To remain competitive traditional finance organizations and institutions need to learn from innovations in decentralized finance. Hence, they must gain a broad and deep understanding of this emerging ecosystem. In addition, it is crucial to acquire specific design knowledge, to develop innovative but regulatorily compliant crypto assets and currencies. Furthermore, centralized institutions in this domain need to manage crypto assets and currencies effectively to mitigate risk while improving portfolio performance. In light of this paradigm shift, this dissertation seeks to guide the financial sector in designing and managing crypto assets and currencies.

To achieve this objective, I structure my dissertation along three research goals: first, establishing an understanding of decentralized finance, and second and third, providing guidance in the design and, respectively, management of crypto assets and currencies. To address the first research goal, I capture the state of the art in decentralized finance, develop a consolidating definition, devise a research framework, and propose future research directions (Essay 1). To achieve the second goal, I focus on guiding traditional finance organizations in designing crypto assets and currencies by developing novel information technology artifacts and proposing design suggestions, specifically, for blockchain-based equity tokens (Essay 2) and privacy-enhanced but regulatorily compliant digital payment systems (Essay 3). Lastly, to achieve the third goal, I provide investors with valuable insights into the efficient portfolio management of crypto asset and currency (Essay 4).

The findings of this dissertation contribute to the body of knowledge on crypto assets and currencies through exploratory, prescriptive, descriptive, and analytical research methods. Specifically, the pluralistic research approach permits the generation of richer and more reliable knowledge for both the information systems and finance research domains. Overall, this dissertation provides theoretical and practical insights into the design and management of crypto assets and currencies.

Keywords: *Banking, blockchain, crypto finance, DeFi, design science research*

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March 2023 Benjamin Schellinger

Introduction to *The Secret Key to the Heart of Decentralized Finance: Unlocking the Potential of Crypto Assets and Currencies to Advance the Financial Sector*

Abstract

This dissertation aims to guide organizations and institutions in the financial sector in designing and managing crypto assets and currencies. It consists of four essays published in or submitted to renowned academic journals in the information system and finance research domains. In these essays, I guide researchers and practitioners in designing useful information technology artifacts and provide insights into the portfolio construction and management of crypto assets and currencies. Overall, the results of this dissertation contribute to the body of knowledge on crypto assets and currencies through exploratory, prescriptive, descriptive, and analytical research methods. The introduction to this dissertation has six sections. First, I lay out the motivation for undertaking this inquiry in Section 1. In Section 2, I describe the digital innovation activities in the traditional banking and finance domain, and shed light on the concept of decentralized finance and the foundations of crypto assets and currencies. In Section 3, I derive the research gaps and questions along three motivated research goals that form the structure of this dissertation. In Section 4, I present the overall research design. The main results and contributions of each essay are presented in Section 5. Lastly, Section 6 summarizes this dissertation, discusses the results, points out the limitations of this study, and highlights future research opportunities.

Keywords: *Banking, blockchain, crypto finance, DeFi, design science research*

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1 Motivation

Since the invention of the Internet, digitization has been greatly transforming the banking and finance sector (Boyd and Smith, 1996; Grassi et al., 2022; Wewege et al., 2020). In particular, the rise of financial technology (FinTech) companies and the entrance of BigTech corporations have led to significant technological advancements and increased competition in the traditional finance (TradFi) domain over the past decade (Frost et al., 2019; Gomber et al., 2017; Sangwan et al., 2020; Wewege et al., 2020). Furthermore, decentralized financial applications enabled by blockchain and distributed ledgers, such as Bitcoin (Nakamoto, 2008), have emerged and increasingly challenged the principles of organizations and institutions in the TradFi domain (Beck et al., 2016; Buterin, 2014; Schär, 2021). In this context, blockchains promise several improvements, such as ensuring data integrity, automating transactions, and reducing operational costs (Garg et al., 2021; Zhang et al., 2020), thereby reshaping the roles and value creation in the financial sector (Linton, 2018; Sangwan et al., 2020; Schweizer, 2019; Wewege et al., 2020; Zhang et al., 2020). As a result, blockchain-based applications enable trustless financial services without relying on centralized entities, giving rise to an expanding ecosystem, often coined as decentralized finance (DeFi) (Chen and Bellavitis, 2020; Gramlich et al., 2022a; Schär, 2021).

DeFi redefines the dominant financial paradigm by increasing efficiency through automation, allowing for the development of interoperable applications, and democratizing the fundamentals of finance (Buterin, 2014; Schär, 2021; Zetzsche et al., 2020). Over the past years, the market of DeFi applications has grown substantially, as, for example, reflected by the all-time high of Bitcoin at the end of 2021 (Chainalysis, 2021b). This development also resulted in a tremendous increase in the user adoption of crypto assets and currencies (Lang, 2022). Specifically, crypto assets and currencies have the potential to disrupt TradFi infrastructures and processes, reducing the need for financial intermediaries (OECD, 2022; Sangwan et al., 2020; Wewege et al., 2020). The way they are recorded, trust is created, and their governance structures, substantially differentiate them from TradFi principles (Financial Stability Board, 2022; OECD, 2022). Crypto assets and currencies are, usually, recorded on distributed ledgers, such as blockchains, and only exist in electronic form, facilitated by cryptographic techniques (Frausing and Avital, 2021). Although the

market size and interconnectedness of decentralized financial applications, such as crypto assets and currencies, are still relatively small compared to those of TradFi institutions and organizations, innovations in DeFi are expected to provide greater diversity in the financial system and reduce the systematic importance of centralized organizations (European Securities and Markets Authority, 2022; Financial Stability Board, 2022).

However, to capitalize on the benefits of DeFi and, particularly, crypto assets and currencies, it is critical for centralized entities in the TradFi domain to develop a broad and profound understanding of the opportunities, principles, and implications of this nascent phenomenon. Although the financial sector is attempting to keep up with these technological advances through efforts such as providing custodial services for crypto assets and currencies (Chipolina, 2022), offering dedicated investment opportunities to customers (Fletcher et al., 2022), or – in the case of central banks – designing central bank digital currencies (CBDCs) to maintain money sovereignty (Kosse and Mattei, 2022), decentralized financial applications still involve great novelty and complexity (Gramlich et al., 2022a; Schär, 2021). Against this background, TradFi organizations and institutions in the financial sector are advised to learn from innovations in DeFi to maintain technological edge over competitors (Garg et al., 2021; Zhang et al., 2020). In addition, they must acquire specific design knowledge, to develop proprietary crypto assets and currencies inspired by innovations in DeFi. Therefore, TradFi organizations and institutions require strong guidance in designing innovative information technology (IT) artifacts (Hevner et al., 2004; Iivari, 2015). In this regard, it is important to comply with regulatory requirements by design (e.g., countering money laundering and terrorism financing), to promote the implementation and adoption of crypto assets and currencies in TradFi (Gramlich et al., 2022a; Zetzsche et al., 2020). However, there is still limited knowledge in the information systems (IS) literature on how to design such IT artifacts (Hartmann et al., 2019; Kiayias et al., 2022; Wüst et al., 2022). Furthermore, it is crucial to assess the suitability of traditional financial models to what extent volatility risks can be managed in crypto-asset and currency portfolios (Brauneis and Mestel, 2019; Eisl et al., 2015). In this context, providing novel insights into portfolio selection and construction can support TradFi organizations and institutions to make more-informed investment decisions and thus improve portfolio performance. Although research on the risk management of crypto-asset and currency portfolios in finance has progressed recently, further in-depth investigation is needed (Brauneis and Mestel, 2019; Eisl et al., 2015; Kajtazi and Moro, 2019; Liu, 2018; Platanakis et al., 2018; Wu and Pandey, 2014).

Overall, research on the design and management of crypto assets and currencies is still at an early stage. Therefore, IS scholars are encouraged to look beyond their own domain and conduct highly interdisciplinary research (Avital et al., 2017). In this regard, there are many calls for research (see, for example, Matsuo, 2020; Rogaway, 2015; Treiblmaier et al., 2021) from various disciplines and perspectives, including the IS and finance domains. Addressing these calls contributes to the knowledge base in this research area and can drive innovation in the financial sector (Zhang et al., 2020). Motivated by these calls and the limited knowledge in this emerging field, I define the overarching research objective of this dissertation[1] as

> *guiding the financial sector in designing and managing crypto assets and currencies.*

The introduction of this dissertation is organized as follows: In Section 2, I provide the necessary background to understand the current state of digitalization in the financial sector and the building blocks of crypto assets and currencies. In Section 3, I derive research gaps and questions along the three research goals (RGs) that form the structure of this dissertation. In Section 4, I present the overall research design. The main results and contributions of each essay are presented in Section 5. Lastly, Section 6 summarizes this dissertation, discusses the results, points out the limitations of this study, and highlights future research opportunities.

1 In addressing the findings of the individual essays in this dissertation, I use the term *"we"* to refer to the authors, since Essay 1, 2, and 3 were co-authored. The following sections partly include content taken from these essays. To improve the readability of the text, I avoid the typical identification of these citations.

2 Background

This section provides the necessary background to understand the individual essays in this dissertation. First, I will introduce the basic concepts of the financial system and the current development of digital innovation, including the role of blockchain, in traditional banking and finance. Then, I will describe the goals, potentials, and challenges of decentralized finance. Furthermore, I will explain the technical foundations and principles of crypto assets and currencies.

2.1 Digital Innovation in the Financial Sector

Traditional banking and finance can be considered one of the largest sectors in the global economy (Novicio, 2022), as reflected, for example, in financial services revenues, which amounted to USD 23.3 trillion in 2021 and are expected to increase to USD 37.3 trillion by 2026 (The Business Research Company, 2022). In general terms, the financial system encompasses the procurement and use of money or capital, and the process and settlement of payment transactions (Barth and Brumbaugh, 1997; Thakor, 1996). In more detail, the financial sector can be decomposed into financial markets, intermediaries, and infrastructures (Boot and Thakor, 1997; Thakor, 1996). The general purpose of financial markets is to connect market participants, thereby facilitating investment and funding opportunities for both capital providers and capital seekers (Fabozzi, 2008; Wurgler, 2000). In this light, investors seek to maximize the risk-return profile of investment choices by diversifying their assets in a global portfolio to improve overall performance (Markowitz, 1959; Markowitz, 1952). On the other hand, financing early-stage (e.g., via venture capital, private equity, or crowdfunding) and established enterprises (e.g., through initial public offerings) drives innovation, stimulates economic growth, and generates employment opportunities (Estrin et al., 2018; Schumpeter, 1934). In addition to commercial banking and other financial service institutions, central banks play an essential role in the financial system in managing money to maintain price stability and enforce monetary policies (European Central Bank, n.d.). In this context, to be perceived as money, crypto assets and currencies must perform three basic functions: being a medium of exchange, a unit of account, and a store of value (Deutsche

Bundesbank, 2019; Smith, 1910). Financial intermediaries (such as banks, brokers, and investment funds) control the flow of money and capital, and offer dedicated services to mitigate transaction costs, market risks, and information asymmetries (Adambekova and Andekina, 2013; Allen and Santomero, 1997). The centralized supply of basic financial services, such as lending and borrowing, also allows for solid economies of scale (Zetzsche et al., 2020). In addition, TradFi organizations can function as counter-parties, for example, in financial trades, to ensure sufficient market liquidity (Adambekova and Andekina, 2013; Gorton and Winton, 2003). Furthermore, the financial sector needs to create strong technical infrastructures that enable the efficient transfer of capital and currencies between market participants while ensuring their clearing and settlement (Deutsche Bundesbank, 2019). Because TradFi depends on trust, it requires rules, institutions, and regulation. In recent decades, following the failures of private ordering and self-regulation, the state has become an increasingly powerful actor in monetary sovereignty and financial regulation, e.g., after the 2008 financial crisis (Zetzsche et al., 2020).

For most of its history, the financial sector has not been exposed to large competition and thus lacked incentives to advance the status quo. Innovation and the advancement of digital technologies not only underpin the improvements in the real economy (Allen and Gale, 1999) but also impact innovation in TradFi (Boyd and Smith, 1996). It was not until the invention of the Internet and thus the democratization of providing and accessing information that the TradFi domain experienced increased competition by FinTech companies and non-financial incumbents (Grassi et al., 2022). Specifically the rise of digital financial technologies has considerably driven innovation in banking and finance, providing more customer-centric, faster, and more convenient financial services and products (Wewege et al., 2020). FinTechs disrupt prevailing infrastructures in the TradFi domain and thus can be defined as a "*new financial industry that applies technology to improve financial activities*" (Schueffel, 2016). In addition to FinTech startups, BigTech companies and non-financial incumbents drive digital innovation in the financial sector, mainly, through capitalizing on data analytics (Wewege et al., 2020). Regarding the technical advances, these organizations can develop novel and more viable products, improve pricing accuracy, reduce the cost of the intermediation process, and deploy new business models (Frost et al., 2019; Gomber et al., 2017; Jagtiani and Lemieux, 2019). Digital innovations, including mobile payments, artificial intelligence and robo-advisors, Big Data, blockchain, and initial coin offerings (ICOs), have provided novel tools for banking and finance, disrupting TradFi infrastructures and processes (Sangwan et al., 2020; Wewege et al., 2020). Hence, digital financial technologies helped to reduce transaction times, unchain geographical

constraints, and facilitate easier access to information (Ahmed and Broek, 2017; Coval and Thakor, 2005; Swan and De Filippi, 2017). The advent of emerging digital technologies, the innovations from FinTech companies, and requirements imposed by financial regulators and supervisors, such as the Revised Payment Services Directive (PSD2), have intensified competition and pressured banks toward opening up their systems (Premchand and Choudhry, 2018). Open banking and application program interfaces (APIs) enable banks to shift from a relationship with transactional customers to one that is more involved, valuable, and profitable, resulting in the development of new business models for financial services (Brodsky and Oakes, n.d.; Premchand and Choudhry, 2018). In this context, and analogous to the e-commerce business (Chircu and Kauffman, 1999), technical innovation has transformed the infrastructures and processes of TradFi, reshaping, in particular, the function of financial intermediaries (Grassi et al., 2022).

In particular, the advent of blockchain has challenged the principles of providing financial services, reducing the need for intermediaries (Guo and Liang, 2016; Linton, 2018; Wüst and Gervais, 2018; Yip and Bocken, 2018). Blockchain is a game-changing innovation, akin to the invention of the Internet, that revolutionized how information is transmitted, enabling the trustless transfer of value in peer-to-peer-based networks (Beck et al., 2016; Zhang et al., 2020). Indeed, blockchain can reduce the need for financial intermediation to various degrees and transform the roles and value creation in the traditional financial sector (Schweizer, 2019). However, there are still multiple barriers to the application and development of blockchain, representing a double-edged sword for the TradFi organizations and institutions (Zhang et al., 2020). For the financial sector to benefit from the merits of the blockchain (e.g., ensuring data integrity for audit trails, automating transactions, and reducing administrative and operational costs) they need to thoroughly understand and prepare for integrating blockchains (Garg et al., 2021). Research also indicates that blockchain and other financial technologies so far do not replace TradFi service providers (Grassi et al., 2022; Schweizer, 2019). In this context, the financial sector needs to increase its efforts in research and development, set relevant standards, establish cross-sectoral cooperation, and enhance financial supervision and regulation (Zhang et al., 2020). Technical innovations promise improvements in various aspects, yet efficiency gains in the processes of the involved intermediaries, for example, cannot always be realized (Lanfranchi and Grassi, 2021). Nevertheless, the financial sector needs to keep pace with technological advancements and digital innovations to compete with FinTech and BigTech companies and not be rendered obsolete. A pressing demand exists for further research from various

disciplines and perspectives to advance blockchain in banking and finance (Zhang et al., 2020).

2.2 The Emergence of Decentralized Finance

As described above, digital technologies have increasingly influenced TradFi infrastructures and principles in the past decade. The first generation of *crypto assets and currencies*, such as Bitcoin (see, Nakamoto, 2008), was based on blockchain and distributed ledgers. Therefore, the underlying technology made people question the need for intermediaries and centralized processes in providing financial services (Financial Stability Board, 2022). The next generation enabled the deterministic and automated code execution on blockchains via smart contracts and spawned new innovations, most notably the development of sophisticated decentralized financial applications (Buterin, 2014). As a result, a new ecosystem coined *decentralized finance (DeFi)* has emerged, enabling trustless financial services and instruments in a decentralized system (Chen and Bellavitis, 2020; Schär, 2021). Still, crypto assets and currencies are a crucial and integrative element to bootstrapping DeFi, in particular, for paying transaction fees or using DeFi services (Schär, 2021). DeFi is an emerging phenomenon in the crypto space that combines various strands, including finance, technology, and regulation (Zetzsche et al., 2020). At its core, DeFi incorporates elements from decentralization, blockchain, smart contracts, disintermediation, and open banking (Chen and Bellavitis, 2020; Schär, 2021).

From an architectural perspective, DeFi consists of five layers that are interconnected and depend on each other, as depicted in Figure 1 (Schär, 2021). At its infrastructural layer, DeFi is powered by blockchains to record transactions that are settled with native crypto assets. For this reason, crypto assets and currencies can also be considered the *heart* of DeFi. Smart contract protocols rely on these trustless infrastructures and form the back-end for DeFi applications. In addition, standardized smart contract templates facilitate interoperable protocols, allowing multiple individual DeFi-based services and products to interact with one other (Chen and Bellavitis, 2020). DeFi provides a high level of composability, often referred to as "Money Lego" (Katona, 2021). This feature allows these protocols to be integrated, forked, or rehashed to develop innovative products and services that advance open financial engineering (Schär, 2021).

The main goal of DeFi comprises the replication of the services and products offered by TradFi in a decentralized manner (Schär, 2021). DeFi eliminates trusted intermediaries

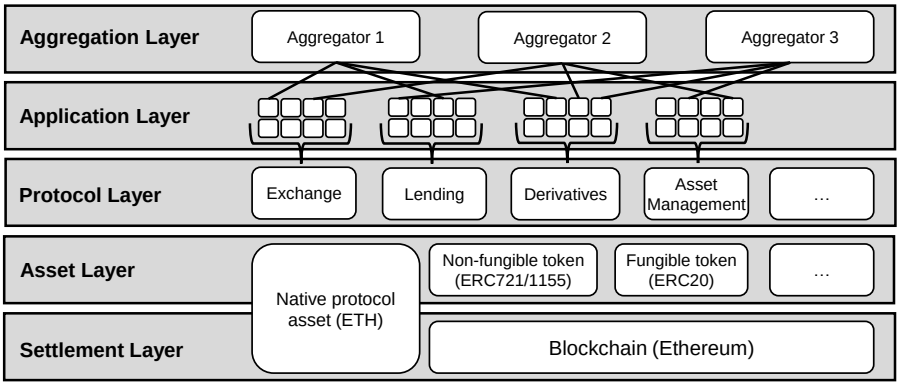

Figure 1: The DeFi stack on the Ethereum blockchain based on Schär (2021).

typically engaged in the TradFi domain, such as brokers or clearinghouses (Schär, 2021; Zetzsche et al., 2020). The integrity of the network is achieved through blockchains facilitating disintermediation (Butijn et al., 2020; Chen and Bellavitis, 2020), while smart contracts fill the role of custodians, escrow agents, and central counterparty clearinghouses (Schär, 2021). In addition, based on the decentralized governance of DeFi-based applications, users can gain control and co-determination rights in the development of protocols in DeFi, thus democratizing finance (Zetzsche et al., 2020). Furthermore, the availability of open-source code, the competition of developing new products (e.g., interfaces), and the composability of DeFi-based applications drive innovation in this ecosystem (Gramlich et al., 2022a; Schär, 2021). Overall, DeFi promises to make finance more interoperable, automated, transparent, accessible, democratized, and censorship-free (Chen and Bellavitis, 2020; Schär, 2021; Zetzsche et al., 2020). Application areas include stablecoins, borrowing and lending services, decentralized exchanges, insurance coverage, and asset management (Brennecke et al., 2022b; Gramlich et al., 2022a; Guggenberger et al., 2021).

However, DeFi is still in a nascent stage that involves various risks and challenges which need to be overcome (Chen and Bellavitis, 2020; Gramlich et al., 2022a; Schär, 2021). First and foremost, technical risks such as a flawed code base or blockchain reorganization due to forking events can have severe consequences for the integrity of the system (Beck et al., 2018; Chen and Bellavitis, 2020; Schär, 2021), as exemplified by the infamous "DAO hack" (Daian, 2016). Relying on intermediaries such as custodial services or oracles increases dependency on centralized actors vulnerable to attacks and manipulations, compromising the integrity of DeFi (Caldarelli and Ellul, 2021; Schär, 2021). Another issue arises in the transparent data storage capabilities of blockchains that attackers can exploit to extract additional value, such as through "front-running attacks" (Eskandari et al., 2020). In addition, the transparency of blockchains raises privacy concerns that violate

data protection laws (Chen and Bellavitis, 2020; Schellinger et al., 2022c). Furthermore, DeFi-enabled applications, such as privacy-oriented cryptocurrencies (e.g., ZCash) or "mixer" services (e.g., Tornado Cash), facilitate illegal activities by disguising the origin of funds, breaching anti-money laundering (AML) and counter-terrorism financing (CFT) regulations (Gramlich et al., 2022a; Zetzsche et al., 2020). Although countermeasures are taken at a supranational level, for example, by the European Union with the Markets in Crypto Assets Regulation (MiCAR) and AML directives, DeFi still lacks a harmonized regulatory environment (Gramlich et al., 2022a).

2.3 Foundations of Crypto Assets and Currencies

Crypto assets and currencies are typically enabled by blockchains. Blockchain is a type of distributed ledger technology (DLT)[2] and first emerged with the introduction of the cryptocurrency Bitcoin. Bitcoin refers to an electronic cash system using a public ledger based on a blockchain, allowing for peer-to-peer transactions without a central clearing authority (Nakamoto, 2008). In this context, blockchain resolves the core problem of preventing double-spending in digital currencies by enabling trustless execution and settlement of transactions in a decentralized system (Beck et al., 2016). Yet, the fundamental concepts used in blockchains have already been explored and proposed decades ago (Back, 2002; Chaum, 1983; Chaum et al., 1988; Dai, 1998). It was not until Nakamoto's 2008 white paper that the innovative combination of these concepts addressed the shortcomings of earlier proposals.

From a technical perspective, a blockchain is a replicated append-only database run in a peer-to-peer network that sequentially records transactions in batches, i.e., blocks (Butijn et al., 2020). These batches are chronologically linked via cryptographic hashing algorithms, concatenating into a chain of blocks, hence, a "blockchain" (Nofer et al., 2017; Rossi et al., 2019). Since blockchains operate as public ledgers and blocks are cryptographically linked, the network would immediately detect any alteration of the data and would thus reject the proposed blocks. Cryptographic primitives provide an integral security, integrity, and authentication feature in a decentralized system (Beck et al., 2016; Butijn et al., 2020). In addition, with no central authority involved, blockchains use consensus mechanisms (e.g., proof of work (PoW) or proof of stake (PoS)) to determine which blocks should be added to the ledger (Kannengießer et al., 2020; Xiao et al., 2020). In this light, linking a

2 For simplicity, in this dissertation, I will use the notion of blockchain to refer to all types of distributed ledger technologies.

scarce resource to hardware and energy (in PoW), capital (in PoS), or reputation (in proof of authority (PoA)) is crucial for the security of the network, such as preventing it from Sybil attacks (Sedlmeir et al., 2020; Zhang et al., 2019).

With the advent of the Ethereum blockchain, it was feasible to implement business logic through smart contracts using the Ethereum virtual machine and a built-in Turing-complete programming language (Beck et al., 2016; Buterin, 2014). Smart contracts are computer protocols deployed on blockchain and executed by participating nodes in the network without relying on a central party (Beck et al., 2016). These computer protocols are triggered when predefined conditions are met, enabling automated enforcement of code-based rules and logic (Wang et al., 2018). Thus, the application areas of smart contracts are manifold (Schellinger et al., 2022a; Vacca et al., 2021; Wang et al., 2018). However, the concept of self-executing contracts is not entirely new and was already proposed by Szabo (1997). For the development of smart contracts, several interface standards have been established to provide interoperability, i.e., Ethereum request for comments (ERC) such as ERC-20, ERC-721, or ERC-1155 on the Ethereum blockchain. The interface standards allow for creating various decentralized applications, which can track the ownership of digital assets, and more complex systems, such as decentralized autonomous organizations (DAOs) (Beck et al., 2016; Wang et al., 2019). In addition, the standards enable the implementation of digital tokens with a predefined supply and ownership structure.

To keep track of tokens and interact with blockchains and decentralized applications, users use software-based, digital wallets (Narayanan et al., 2016). Digital wallets generate and securely store cryptographic asymmetric key pairs (i.e., a private and a public key). The only way to access crypto assets and currencies and verifiably prove ownership is by using the private key. Therefore, the private key should never be disclosed to third parties, which is why it is also known as the *secret key*. In general, it is important that digital wallet interfaces are designed to enable interaction between users on platforms and network participants (Butijn et al., 2020).

Since smart contracts and the blockchain cannot automatically query and verify data from the outside, they rely on external data feeds (“oracles”). These oracles allow the interaction of the deterministic on-chain environment and the outside world by providing relevant information to the blockchain. However, the choice and management of oracles can severely affect the integrity of the data, resulting in the “oracle problem” (Caldarelli and Ellul, 2021). Manipulated or poorly managed oracles increase the risk of flawed or altered inputs that could compromise the integrity of the blockchain (Sheldon, 2021). The

oracle problem leads to controversial real-world decentralized applications due to losing decentrality (Caldarelli and Ellul, 2021; Schär, 2021).

Owing to the redundant processing of transactions in blockchain systems, performance and scalability issues arise (Zhou et al., 2020). Moreover, the transparent data storage of blockchain leads to increased privacy issues, violating data protection laws (Kannengießer et al., 2020; Schellinger et al., 2022c; Sedlmeir et al., 2022). To address scalability and privacy issues, blockchain applications such as Tornado Cash on Ethereum or the cryptocurrency ZCash use zero-knowledge proofs (ZKPs) (Ben-Sasson et al., 2014; Partala et al., 2020). ZKPs are cryptographic protocols convincing a verifier that a mathematical statement about data is valid without disclosing the information itself (Goldwasser et al., 1989). The prover supplies only the information necessary to evaluate the statement's veracity through a proof, yet does not have to reveal supplementary (confidential) pieces of information (Ben-Sasson et al., 2019; Ben-Sasson et al., 2013). ZKPs permit the enforcement of predefined rules, thus ensuring computational integrity without requiring the verifier to perform repetitive computations (Ben-Sasson et al., 2013). Given the properties of ZKPs, blockchains benefit because of the data parsimony, as sensitive data is stored off-chain, and only the correctness of transactions is verified on-chain, preserving sensitive data (Ben-Sasson et al., 2019; Partala et al., 2020; Sedlmeir et al., 2022). As a result, blockchains using general-purpose ZKPs have already been developed in an organizational context, advancing blockchain technology, for example, in medical supply chains or the insurance sector (Mattke et al., 2019; Zhang et al., 2021). In addition, ZKPs play a central role in digital identity systems by adding a privacy-preserving layer, for example, providing selective disclosure features using anonymous credentials (Schellinger et al., 2022b; Stokkink and Pouwelse, 2018). Recently, ZK-rollups have emerged that provide scalability and privacy-by-default solutions in blockchains (Layer-1) enabled by off-chain operations (Marukhnenko and Khalimov, 2021). In ZK-rollup settings, an operator generates a succinct ZKP for each state transition, usually including a batch of transactions that are committed to a rollup smart contract (Layer-2) on the blockchain for integrity verification (Gluchowski, 2021). This form of Layer-2 solution is widely used in DeFi, for example, provided by StarkNet or Polygon Zero (alchemy, 2022), to scale computational operations and reduce transaction fees on-chain (Gluchowski, 2021).

Blockchain-based systems do not rely on centralized entities and are mostly pseudonymous (Butijn et al., 2020). However, there is a strong need to ensure the system's integrity. Since it is impossible to punish malicious actors in a pseudo- or anonymous network (as identities are not known), incentive mechanisms must be established to promote honest

behavior. In this light, most public blockchains reward validating nodes with newly minted native protocol tokens (e.g., BTC in Bitcoin or ETH in Ethereum) as soon as a block has been found (Bano et al., 2019; Buterin, 2014; Nakamoto, 2008). In blockchains, native protocol tokens represent a unit of account that allows to transfer a value and to atomically settle and serve as "fuel" for the executions of transactions in a decentralized system (Buterin, 2014). Typically, the network uses them as a store of value or an internal medium of exchange within blockchain systems (Baur and Dimpfl, 2021; Gramlich et al., 2022a). These token types can be considered the simplest form of decentralized financial applications. In this context, native protocol tokens are usually termed "cryptocurrencies" (Schär, 2021).

However, the design and purpose of tokens can vary widely. In this light, the distinct interface standards of smart contracts allow for the creation of digital tokens that can have *fungible* properties, *non-fungible* properties, or both (Sunyaev et al., 2021). These properties can specify a right or class of an asset similar to stocks, equity, or voting rights in TradFi, hence, the term "crypto asset" (Oliveira et al., 2018). Crypto assets and currencies exist solely in electronic form, facilitated by cryptographic primitives (i.e., based on public key infrastructures) and blockchain-based infrastructures (Frausing and Avital, 2021). On a conceptual level, tokens[3] can be divided into utility and security tokens (Catalini and Gans, 2019). Moreover, innovative asset classes have emerged in the form of "fractional ownership" powered by non-fungible tokens (NFTs), for example, in stocks or digital artwork (Barbereau et al., 2022). Furthermore, DAOs can issue tokens for governance purposes, such as in decision-making processes, to stimulate user activity and provide economic incentives for holders and the protocol (Jensen et al., 2021). With the introduction of "stablecoins", the high volatility of most crypto assets and currencies could be reduced by pegging it to the price of a fiat currency, such as the US dollar (Brennecke et al., 2022b; Bullmann et al., 2019; Lipton et al., 2020). Given these rapid developments in the crypto space, efforts have increased among central banks worldwide to design a central bank digital currency (CBDC) that provides a regulatory-compliant form of blockchain-based stablecoins (Bank for International Settlements, 2022).

Overall, the underlying technologies of crypto assets and currencies present a great potential to disrupt traditional banking and finance practices. Therefore, the financial sector needs to learn from innovations in DeFi to stay competitive in the long term. This situation stresses the necessity for in-depth research endeavors across multiple disciplines to develop a common knowledge base and, ultimately, to facilitate the convergence of the two fields.

3 In this dissertation, I will use the generic term "crypto assets and currencies" to refer to all token types.

3 Structure and Research Gaps

This section discusses the derivation of research gaps and promising research questions in the field of crypto assets and currencies. Specifically, I structure this section around three specific research goals (RGs) derived from the overarching research objective:

RG1: *Establishing an understanding of decentralized finance*
RG2: *Providing guidance in designing crypto assets and currencies*
RG3: *Providing guidance in managing crypto assets and currencies*

RG1 is concerned with exploring the field of decentralized finance and provides the theoretical foundation for investigating RG2 and RG3. In particular, in pursuing RG1, I aim to establish a comprehensive understanding for both researchers and practitioners by capturing the state of the art and identifying worthwhile research avenues within the field of DeFi. To achieve RG2, I focus on guiding the financial sector to design crypto assets and currencies (Hevner et al., 2004; Iivari, 2015). By following these guidelines, organizations and institutions in the TradFi domain can learn from innovations emerging in DeFi to develop novel IT artifacts. By achieving RG3, I provide insights into constructing and managing efficient crypto-asset and currency portfolios to improve their performance (Brauneis and Mestel, 2019; Eisl et al., 2015). These insights will allow institutional and individual investors to make more-informed investment decisions.

To examine the stated overarching research objective (see Section 1) and the three research goals, in particular, I seek to answer six related research questions through individual essays. The contribution of these essays ranges from explorative (e.g., understanding and conceptualizing DeFi), descriptive (e.g., presenting correlation coefficients of crypto-asset and currency portfolios) over prescriptive (e.g., providing guidelines to the design of crypto assets and currencies through design principles (Gregor, 2006)) to analytical (e.g., constructing crypto asset and currency portfolios). Throughout this dissertation, I have considered the current relevance of the essays' individual topics in their respective research domains and practice. In addition, I sought to ensure methodological rigor in all inquiries. Against this background, each of these essays (i.e., conceptualization, design of IT artifacts, and portfolio optimization) contributes to the literature in the IS and finance

domains. In addition, the findings of this dissertation can have real-world implications for organizations and institutions (Hevner et al., 2004; Iivari, 2015; March and Smith, 1995; vom Brocke et al., 2020), specifically, in the banking and finance sector. Table 1 shows the essays included in this dissertation assigned to the individual RGs.

Table 1: Essays addressing the dissertation's research goals.

Research Goals	**Title**
RG1 *Establishing an understanding of decentralized finance*	**Essay 1** A Multivocal Literature Review of Decentralized Finance: Current Knowledge and Future Research Avenues (Gramlich et al., 2023)
RG2 *Providing guidance in designing crypto assets and currencies*	**Essay 2** Kickstarting Blockchain: Designing Blockchain-based Tokens for Equity Crowdfunding (Guggenberger et al., 2023) **Essay 3** Reconciling Privacy and Compliance in Central Bank Digital Currencies (in revision)
RG3 *Providing guidance in managing crypto assets and currencies*	**Essay 4** Optimization of Special Cryptocurrency Portfolios (Schellinger, 2020)

RG1: Establishing an Understanding of Decentralized Finance

Blockchain-based financial applications and services have seen tremendous growth in the past years, leading to a new phenomenon coined DeFi (Behrens, 2022; Chainalysis, 2021a; Gramlich et al., 2022a). DeFi is an ecosystem with a rapid degree of innovation and bears the substantial potential to disrupt traditional financial institutions and organizations, and reshape the future of financial activities (Chen and Bellavitis, 2020). However, there are still significant challenges to overcome, for example, integrating existing infrastructures, improving scalability, and harmonizing laws (Chen and Bellavitis, 2020; Derviz, 2021; Meegan and Koens, 2021), while the socioeconomic implications still need to be explored (Gramlich et al., 2022a; Meyer et al., 2022; Zetzsche et al., 2020). Owing to the complexity of this new phenomenon, it is crucial not only for organizations and institutions in the banking and finance sector, but also for policy-makers, regulating bodies, and individuals to build a broad and in-depth understanding of DeFi. In particular, practitioners and researchers from

different domains involved with this subject need to be aware of the inherent risks and know how to realize the potentials (Gramlich et al., 2022a; Schär, 2021). Although researchers have already started to address this novel phenomenon (see, e.g., Chen and Bellavitis, 2020; Schär, 2021; Schueffel, 2021; Zetzsche et al., 2020), a systematic and comprehensive analysis of the body of knowledge is lacking. In addition, the literature does not provide a general conceptualization of DeFi from multiple dimensions, such as technical, regulatory, and organizational (Matsuo, 2020). Also, there is no common ground in the understanding or widely used and established definition of DeFi (Katona, 2021). A better understanding of this phenomenon will aid organizations and institutions from the banking and finance sector in making strategic decisions to create innovative business models. Moreover, a systematic classification of DeFi can foster the adoption of this emerging field through diligently established frameworks imposed by policy-makers and regulators. To address these open issues, we raise the following research questions:

- *How can DeFi be defined?*
- *What is the state of research regarding DeFi, and how can it be conceptualized?*
- *Where might one find worthy future research avenues in the field of DeFi?* (Essay 1)

RG2: Providing Guidance in Designing Crypto Assets and Currencies

The funding of enterprises is decisive in mitigating their operational risks and ensure sustainable growth (Denis, 2004; Economidou et al., 2018; Estrin et al., 2018). Yet, this initiative entails a multitude of problems, such as geographical limitations, permissioned access, high costs, and slow processes owing to the involvement of many (centralized) agents (Chen et al., 2018; Denis, 2004; Economidou et al., 2018; Estrin et al., 2018; Gompers and Lerner, 2004). Over the past years, potential solutions have emerged to facilitate entrepreneurship funding, including equity crowdfunding, blockchain-based crowdfunding through initial coin offerings (ICOs), and, most recently, security token offerings (STOs). Although equity crowdfunding provides investors with equity-like rights, similar to shares and thus opposed to reward-based crowdfunding (Dresner, 2014; Heieck et al., 2018; Moritz and Block, 2014), it misses liquidity, incurs bureaucracy and high costs, and requires intermediaries (Roth et al., 2020; Zhu and Zhou, 2016). Blockchain-enabled ICOs have emerged as an alternative crowdfunding vehicle for early-stage ventures that solved many downsides of centralized equity crowdfunding in terms of efficiency (Chen et al., 2018; Heieck et al., 2018). Yet, the ICO phenomenon lost momentum very quickly, mostly owing to missing legal and regulatory frameworks (e.g., investor protection) and constrained configurability (Liebau and Schueffel, 2019). Against this background, the

introduction of STOs drew upon the deficiencies of both the traditional funding process and the poorly regulated ICO phenomenon. Tokens issued through an STO are compliant with prevailing regulation (e.g., that in the United States or Germany) and grant its holder an underlying value (Kranz et al., 2019; Mattke et al., 2021; Mazzorana-Kremer, 2019). Although blockchain- and smart contract-based funding via an STO can have merits over conventional equity crowdfunding (Heieck et al., 2018; Muneeza et al., 2018; Zhu and Zhou, 2016), practitioners and IS researchers lack the knowledge on how to design such alternative infrastructures (Hartmann et al., 2019). Specifically, the banking and finance industry might be interested in integrating blockchain-based infrastructures to make funding more accessible and efficient to create new markets. Ultimately, enabling this new form of equity crowdfunding can facilitate funding for early-stage entrepreneurs. Hence, we pose the following research question:

> *How can blockchain be incorporated as an alternative infrastructure for equity crowdfunding?* (Essay 2)

Over the past years, the use of cash as a means of payment has constantly been shrinking because of the repercussions of the COVID-19 pandemic (Deutsche Bundesbank, 2022) and stronger competition from BigTech companies, private organizations, cryptocurrencies, and stablecoins (European Central Bank, 2020). As a result, to maintain monetary sovereignty, central banks globally started initiatives to develop and launch CBDCs (Kosse and Mattei, 2022). In these discussions, the design of a CBDC to incorporate high privacy guarantees has garnered the attention by central banks, policy-makers, researchers, and the general public (Tronnier, 2020). Both the traditional banking and finance sector and centralized digital payment platforms might have interest in harvesting so far "confidential" financial transaction data of users (Panetta, 2021). Yet, centralized systems bear high risks of getting attacked or abused, while from a user's perspective, preserving privacy is vital, for example, to avoid identity theft (see e.g., Chaum et al., 2021; Choi et al., 2021; Kahn, 2019; Kahn et al., 2005). Hence, the privacy dimension should play a central role in designing a CBDC, which only cash can currently ensure to a satisfying degree. In general, cash-like privacy is difficult to establish in digital payment systems owing to their lack of compliance with AML and CFT regulations (Bank of Canada, 2020; European Central Bank, 2022). For decades, researchers have worked on enabling cash-like privacy in digital payments (such as "e-cash" or "ZCash"). Still, they have started only recently to address the regulatory requirements in CBDCs (Bontekoe, 2020; Kiayias et al., 2022; Wüst et al., 2022). However, researchers need to holistically assess their practical feasibility and build on existing design knowledge, which is both currently lacking. Moreover, it is important

to analyze CBDC systems from technical, legal, and socioeconomic perspectives (Hevner et al., 2004). Furthermore, scholars are encouraged to conduct highly interdisciplinary research in the IS domain (Avital et al., 2017). We follow the call by Rogaway (2015) to foster the use of applied cryptography in practice to counteract privacy issues and mass surveillance. To address this gap, we define the following research questions:

> *How to design a CBDC that supports cash-like privacy while enabling compliance with AML and CFT regulations?* (Essay 3)

RG3: Providing Guidance in Managing Crypto Assets and Currencies

With the advent of implementing business logic through smart contracts that enabled the issuance of digital tokens without any central entity (Buterin, 2014) – which is also reflected in the subsequent emergence of the ICO phenomenon – a new class of crypto assets and currencies was born. However, investors need to distinguish between payment tokens (i.e., "coins") and further types of tokens that have a specific utility, represent equity, or are backed by other assets. Specifically, investors should be aware of the design and purpose of tokens, because they can have (negative) legal and fiscal implications (Catalini and Gans, 2019; Hahn and Wons, 2018). As mentioned above, ICOs lacked compliance with legal and regulatory requirements, particularly, regarding investor protection laws. Consequently, the missing regulatory certainty bears extreme financial risks for private and institutional investors, e.g., in the event of scams (Wiśniewska, 2018). Thus, large price fluctuations in the overall crypto-asset and currency markets that increase the risk of losing the initial investment have also been acknowledged by empirical studies (see e.g., Cermak, 2017; Charles and Darné, 2019; Dyhrberg, 2016; Katsiampa, 2017; Klein et al., 2018; Pichl and Kaizoji, 2017). Theory on portfolio constructions states that reducing overall risk by allocating various but different assets and asset classes and optimizing their individual weights can increase portfolio performance (Markowitz, 1959; Markowitz, 1952). In this light, research in the finance domain examined the diversification effects of combining crypto assets and currencies, such as Bitcoin, with traditional financial assets (Eisl et al., 2015; Kajtazi and Moro, 2019; Wu and Pandey, 2014) and the effects of constructed crypto-asset and currency portfolios (Brauneis and Mestel, 2019; Liu, 2018; Platanakis et al., 2018). Although these empirical studies highlighted the merits of adding crypto assets and currencies to a well-diversified portfolio, they do not distinguish between "coins" and "tokens". My research takes upon this inquiry and raises the following research question:

> *How do pure coin and token portfolios optimized by maximizing the Sharpe ratio perform against benchmark portfolios?* (Essay 4)

4 Research Design

This dissertation[4] comprises four research essays, each addressing the aforementioned research goals, based on a cumulative approach, where results are disseminated through journal publications. The essays have either been published in renowned IS and finance journals, or are currently under review. Table 2 provides an overview of the essays' publication history and current review processes. A summary of my publications that are not part of this dissertation is presented in Appendix 8.2.

Table 2: Overview of the four essays in this dissertation.

Essay	Title	Publication Outlet	Status
1	A Multivocal Literature Review of Decentralized Finance: Current Knowledge and Future Research Avenues	Electronic Markets *(VHB-JOURQUAL3: B, Scopus: 94%)*	Accepted for publication
2	Kickstarting Blockchain: Designing Blockchain-based Tokens for Equity Crowdfunding	Electronic Commerce Research *(VHB-JOURQUAL3: C, Scopus: 96%)*	Published
3	Reconciling Privacy and Compliance in Central Bank Digital Currencies	European Journal of Information Systems *(VHB-JOURQUAL3: A, Scopus: 97%)*	In revision (2nd round)
4	Optimization of Special Cryptocurrency Portfolios	Journal of Risk Finance *(VHB-JOURQUAL3: B, Scopus: 69%)*	Published

Research in the IS domain combines various disciplines, for example, computer or management sciences, allowing researchers to take different epistemological and methodological perspectives on the object of investigation. Against this background, IS scholars are encouraged to adopt a pluralistic research design and draw on the various methods of other disciplines for inspiration and expanding the knowledge base through alternative

4 For copyright reasons, the public version of this dissertation includes a summarized version of the published papers.

methodological approaches (Avital et al., 2017). Following a pluralistic approach by combining qualitative and quantitative research methods can produce richer and more reliable data (Della Porta and Keating, 2008; Mingers, 2001), compared to a singular approach. Regarding the inquiries in this dissertation and consistent with Mingers (2001), I opted for qualitative (Essay 1-3) and quantitative (Essay 4) research methods. In Essay 1, I applied a multivocal literature (Garousi et al., 2016; Garousi et al., 2019), whereas, in Essays 2 and 3, we followed the six iterative steps in the framework proposed by (Peffers et al., 2007) of the design science research (DSR) paradigm to design, develop, and evaluate IT artifacts (Gregor and Jones, 2007; Hevner et al., 2004; March and Smith, 1995; vom Brocke et al., 2020). To optimize crypto-asset and currency portfolios, in Essay 4, I followed a quantitative research design using a traditional mean-variance approach (Markowitz, 1959; Markowitz, 1952). Ultimately, the blended use of qualitative and quantitative research methods allowed me to take a much broader view of my findings and contribute holistically to the body of knowledge on crypto assets and currencies in IS and finance research.

The research process in Essay 1 comprises two stages: analyzing the DeFi literature and developing a DeFi research classification framework. As noted in Section 3, research in the field of DeFi has not provided a systematic, structured, and comprehensive literature analysis. In addition, analyzing the most pressing issues in DeFi is a prerequisite for deriving worthwhile future research questions. To reach our goal, we applied a multivocal literature review (Garousi et al., 2016; Garousi et al., 2019) that complements a conventional systematic literature review (Kitchenham and Charters, 2007). This approach allowed us to identify the state of the art in DeFi and obtain richer results because it included the review of business reports, technical white papers, and non-peer-reviewed articles (Garousi et al., 2016; Kamei et al., 2021). We defined our search string, reviewed the academic literature as proposed by Kitchenham and Charters (2007) in nine renowned scientific databases (e.g., ACM Digital Library, AIS eLibrary, and IEEE Xplore), applied predefined inclusion and exclusion criteria, and ran forward and backward search (Webster and Watson, 2002). Subsequently, we followed the specific guidelines for a multivocal literature review that supplemented our academic database (Garousi et al., 2019), which involves inclusion and exclusion criteria and an assessment of the quality of the items. Our approach yielded 79 literature items (50 for the academic and 29 for the "gray" literature) that provided the basis for further analysis. Based on the literature review, we derived a consolidating definition, conceptualized the state of research, and identified future research avenues of DeFi. Through an iterative procedure of collecting, analyzing, and synthesizing existing DeFi definitions in the literature, we were able to build a consolidating definition of

DeFi. Subsequently, the definition provided a starting point for conceptualizing DeFi. The conceptualization was based on the well-established research classification framework proposed by Risius and Spohrer (2017) that has been adapted to the context of blockchain, originally introduced by (Aral et al., 2013). Although other pioneering blockchain-related research frameworks exist (see, for example, Casino et al., 2019; Hughes et al., 2019; Rossi et al., 2019), they do not meet our specific requirements. Therefore, we chose to adhere to the framework of Risius and Spohrer (2017). Our specific DeFi research classification framework included different levels of analysis (e.g., users and society) and activities (e.g., design and features), thereby synthesizing current knowledge in the DeFi domain while extending the scope and dimensions of this complex subject (Matsuo, 2020). Along with the structured and comprehensive presentation of the identified literature, the framework allowed us to systematically derive future research directions in DeFi.

The research design of Essays 2 and 3 was embedded in the widely accepted DSR paradigm, which aims to design, develop, and evaluate IT artifacts, has a real-world impact, and provides suggestions for design and action (Gregor and Jones, 2007; Hevner et al., 2004; March and Smith, 1995). Following this approach allows researchers to find creative design solutions to prevailing problems between engineering and behavioral sciences via a constant build-and-evaluate procedure (Baskerville et al., 2018; Eekels and Roozenburg, 1991; Hevner et al., 2004; March and Smith, 1995). In addition, research projects based on the DSR paradigm require the demonstration of methodological rigor and problem relevance of IS as a field in academia (Hevner et al., 2004; vom Brocke et al., 2020). The overarching goal of DSR centers on the generation of prescriptive knowledge (Gregor and Hevner, 2013; vom Brocke et al., 2020). The contribution of DSR to the design knowledge includes the design of an IT artifact or concepts, and inducing design theory (Baskerville et al., 2018; Gregor and Jones, 2007). Thus, research should lever existing prescriptive knowledge in the solution space of similar problems (Gregor et al., 2020; Gregor and Hevner, 2013; Hevner et al., 2004; vom Brocke et al., 2020). Ultimately, the contribution to the design knowledge focuses on developing innovative IT artifacts (vom Brocke et al., 2020; Winter and Albani, 2013).

In Essay 2, we embedded our inquiry in the DSR paradigm (Beck et al., 2013; Hevner et al., 2004) and developed an instantiation of a blockchain-based equity token to facilitate entrepreneurial crowdfunding (March and Smith, 1995). Since design knowledge should apply to the identified class of problems, we abstracted our design principles to blockchain-based equity tokens. To achieve this goal, we applied the widely accepted research approach of Peffers et al. (2007). This iterative research design allowed us to design, develop, and

evaluate a prototype of a blockchain-based equity token for crowdfunding (March and Smith, 1995). First, we identified the main practical problems of funding early-stage companies in the literature, focusing on traditional equity crowdfunding and innovative forms such as ICOs. Based on this analysis, we defined areas for improvement and derived 14 design objectives that helped us develop an innovative solution. The development stage comprised the design and implementation of our equity token on Ethereum, because it is the largest blockchain that provides standard token interfaces (Yang et al., 2020). Subsequently, we thoroughly evaluated our design artifact to demonstrate its utility, efficacy, and quality (Hevner et al., 2004; Venable et al., 2012). First, we tested the prototype's core features on an Ethereum test network to evaluate utility. Second, to assess efficacy, we used a criteria-based evaluation of the equity token's merits against the identified areas of improvement (Gregor and Hevner, 2013). Third, we conducted two rounds of semi-structured interviews with seven experts in blockchain, early-stage funding, especially crowdfunding, and IT transformation, by the end of 2020 to evaluate the quality of our instantiation (Drever, 1995; Myers and Newman, 2007). We used this evaluation to derive design knowledge in the form of generalizable design principles for equity tokens (Baskerville et al., 2018; Peffers et al., 2007).

Similarly to Essay 2, we designed our research project in Essay 3 according to the DSR paradigm (Gregor and Jones, 2007; Hevner et al., 2004; March and Smith, 1995). Specifically, we developed a CBDC system architecture that reconciles cash-like privacy with AML and CFT requirements. The DSR paradigm helped us to generate prescriptive knowledge (Gregor and Hevner, 2013), realizing digital payment systems with cash-like private but regulatorily compliant transfers based on the case of CBDCs. To structure our research endeavor, we used the iterative build-and-evaluate process applied in Essay 2 (Gregor and Hevner, 2013; Peffers et al., 2007). One of the major problems we encountered was the common belief that cash-like privacy could not be reconciled in digital payment systems with AML and CFT regulations (Iivari, 2015; vom Brocke et al., 2020). In addition, we noted that practice and the IS literature lacked comprehensive design knowledge and an evaluation with key stakeholders (vom Brocke et al., 2020). In the next step, we derived design objectives for our artifact that focused exclusively on the reconciliation of cash-like privacy and regulatory compliance. To rigorously design and develop our CBDC system architecture, we exapted knowledge from cryptography and privacy research (i.e., electronic cash, privacy-oriented crypto assets and currencies, and digital ID concepts) to solve problems in the digital payment realm (Gregor and Hevner, 2013; vom Brocke et al., 2020). The development of the artifact comprised an account-based system architecture and an instantiation

of central transaction types through cryptographic ZKPs that enforce predefined transaction, turnover, and balance limits. To demonstrate the utility, functionality, and effectiveness of our CBDC system architecture and the use of ZKPs and digital IDs in digital payment systems, we conducted semi-structured interviews (Bhattacherjee, 2012; Kallio et al., 2016; Myers and Newman, 2007). The interviews involved 44 leading experts from different domains (e.g., central banks, regulators, law enforcement authorities, payment companies, and academia) and ran over four cycles during 2021 and 2022 (Hevner et al., 2004). To analyze the interviews systematically, we applied open and axial coding (Saldaña, 2015) using MAXQDA data analysis software and discussed unclear categorizations among the author team. We also presented our CBDC system architecture at events in the application domain (e.g., banking and finance, regulation, and identity management) to improve our artifact (Hevner, 2007; Peffers et al., 2007). The instantiation, iterative improvements, and evaluation of our CBDC artifact allowed us to derive nascent design principles (Hevner et al., 2004; Peffers et al., 2018; Peffers et al., 2007). As the last step, disseminating our key findings included publishing a preliminary study and the source code of our CBDC system architecture, making supplementary audio and video material available online, and participating in expert panels (Hevner et al., 2004).

In Essay 4, I applied a traditional mean-variance approach (Markowitz, 1959; Markowitz, 1952) to construct a coin and token portfolio. The mean-variance portfolio analysis estimates the risk and return of a portfolio that can be optimized through effective diversification (i.e., by maximizing the expected quadratic utility function). The portfolio should be constructed of uncorrelated assets to distribute the assets' individual risk and thus reduces the overall portfolio risk (Markowitz, 1959; Markowitz, 1952). As an extension of the traditional mean-variance approach, I used the Sharpe ratio to optimize the weighting of the coins and tokens in the portfolios (Sharpe, 1966) as a departure from other studies in this context (Brauneis and Mestel, 2019; Liu, 2018; Platanakis et al., 2018). The Sharpe ratio reflects the mean return per unit of standard deviation, which was maximized in this inquiry. The portfolio construction was subject to the "full investment" and "long-only" constraints. It should be noted that rebalancing, transaction costs, and short-selling options were not considered in this study. Overall, I selected 20 crypto assets and currencies based on their total market capitalization and divided them into a coin (e.g., Bitcoin, ETH, and Litecoin) and a token (e.g., Tether, Golem, and Augur) portfolio. Historic daily average prices of crypto assets and currencies were retrieved from the *Coinmarketcap* platform from August 1, 2017, to May 31, 2018, resulting in the "in-sample period". The data time frame is so short because of the recent emergence of tokens and, thus, the limited data availability then.

After the construction and optimization process, the portfolios were back-tested from June 1, 2018, to May 31, 2019 ("out-of-sample period"). The performance of the optimized coin and token portfolios was compared to that of alternative portfolio strategies, such as a $1/N$ portfolio, minimum variance portfolio, and a market index for cryptocurrencies. I used various indicators to compare the performance, including the mean return, standard deviation, annualized return, volatility, and the Sharpe ratio. In addition, I considered two other performance measures: the "Sortino ratio" (Sortino and Meer, 1991; Sortino and Price, 1994), which accounts for downward deviation, and the "Omega ratio" (Keating and Shadwick, 2002), which detects all higher moment effects by splitting the average profit on the average loss based on a given threshold. Ultimately, to test the robustness of my results, I calculated the maximized utility for each portfolio strategy using different levels of the risk aversion parameter.

Due to the interdisciplinary (i.e., the IS and finance domain) and pluralistic research (i.e., qualitative and quantitative methods), this dissertation does not inherently follow one single philosophical stance. The ontological and epistemological assumptions of this dissertation culminate in *interpretivism* and *functionalism*, depending on the individual essays (Burrell and Morgan, 2017; Crotty, 1998; Iivari, 2015; Orlikowski and Baroudi, 1991). In this context, the research design, specifically, the data presentation and analysis level, implicitly determines the underlying philosophical position (Bryman, 2016; Cohen, 1969). The inquiry in Essay 1 reflects interpretivist assumptions, as we sought to understand the DeFi phenomenon, proposed a consolidating definition, developed a concept (i.e., a DeFi research classification framework), and suggested future research opportunities. Similarly, the research projects in Essays 2 and 3, which followed the DSR paradigm to develop innovative crypto-asset and currency artifacts, emphasized an interpretivist stance (Goldkuhl, 2012; Iivari, 2015). In these essays, the research design was structured to the extent, that the evaluation of the designed IT artifact was carried out using qualitative methods, e.g., semi-structured interviews and a criteria-based assessment (Iivari, 2015). Research in finance generally follows objectivism from an ontology perspective, as the underlying assumptions reside in the rational behavior of individuals (Bisman, 2010; Ryan, 2002). In constructing efficient portfolios, investors seek to maximize their utility (Markowitz, 1952; Sharpe, 1966). Against this background, the optimization of the crypto-asset and currency portfolios in Essay 4 was based on a functionalism paradigm because of the generation of problem-oriented knowledge (Burrell and Morgan, 2017).

5 Summary of Results

This section presents an overview of the results of four research essays. Each essay investigates a particular research area and addresses worthwhile research questions in this context (see Section 3). The synthesis of the essays provides an in-depth understanding of crypto assets and currencies and contributes holistically to the body of knowledge in the IS and finance research domains.

5.1 Essay 1: A Multivocal Literature Review of Decentralized Finance: Current Knowledge and Future Research Avenues

Essay 1 analyzed the phenomenon of the DeFi ecosystem. To gain a comprehensive understanding of DeFi, we extracted knowledge from both the academic and "gray" literature through a multivocal literature review. In this essay, my co-authors and I examined 79 items and presented their major contributions in a structured manner along a research framework adapted from Risius and Spohrer (2017). Our devised DeFi research classification framework allowed us to observe a high density of contributions regarding research activities in the dimension of "Measurement & Value" at an application level, including topics such as market efficiency and manipulations, and protocol vulnerabilities. In contrast, we have also found that little attention has been paid to DeFi from a managerial and organizational perspective, especially, in the banking and finance sector, e.g., the convergence of DeFi and TradFi. In addition, we developed a consolidating definition of DeFi that is universally applicable: *"DeFi is a decentralized financial system that enables financial services and instruments to be offered and used without the need for intermediaries as the system is based on public blockchains and smart contracts."* Furthermore, we presented the state of the art of DeFi research along our devised framework and summarized ten key take-aways, e.g., re-centralization issues of, for example, oracles in DeFi, under-researched risks occurring from market contagion, and the low maturity of DeFi applications. Ultimately, we identified gaps in the literature and proposed worthwhile research directions regarding user adoption, potential regulatory approaches, and enhancing the scalability of blockchains, among others. Thus, this essay contributes to a comprehensive and in-depth understanding of this

phenomenon. In addition, we contributed to the body of knowledge of DeFi. Moreover, we provided researchers with a common understanding of the notion of DeFi.

5.2 Essay 2: Kickstarting Blockchain: Designing Blockchain-based Tokens for Equity Crowdfunding

In Essay 2, we investigated and evaluated the potential of blockchain and smart contracts as an alternative infrastructure for equity funding in the context of crowdfunding. In this context, blockchains and smart contracts promise improvements in the funding processes. However, design knowledge of regulatorily compliant equity tokens was lacking and required a better theoretical understanding. Thus, we followed the DSR paradigm to design, develop, and evaluate an equity token prototype for crowdfunding. Our IT artifact demonstrates that using blockchain improves the efficiency, transparency, and interoperability of conventional equity crowdfunding. The configurability features of smart contracts not only allow for the fractionalization of equity but also enable compliance with regulations. As a result, the proposed artifact provides greater access to formerly exclusive asset classes and may lead to greater liquidity in the market. Overall, we contribute to the theory development of blockchain-based equity tokens by providing a design artifact (Hevner et al., 2004). In addition, we extend the blockchain-based crowdfunding model proposed by Haas et al. (2015) by substituting banks and payment service providers with blockchain; by adding smart contracts to automate authentication, custodial, and payouts services; and also considering key stakeholders for the crowdfunding process, such as attorneys, regulating bodies, and auditors. Finally, we derive prescriptive knowledge in the form of seven design principles, aiding practitioners to effectively design equity tokens. Therefore, we proposed the following design principles:

DP1: *"Lever a combination of blockchain and other distributed technologies."*
DP2: *"Lever token metadata to include granular transaction requirements."*
DP3: *"Follow token standards and standard interfaces to increase interoperability."*
DP4: *"Central administration should only be incorporated as a last resort."*
DP5: *"Allow for multiple tranches over the token life cycle."*
DP6: *"Use a public blockchain to facilitate transparency."*
DP7: *"Give power to the machine."*

5.3 Essay 3: Reconciling Privacy with Compliance in Central Bank Digital Currencies

Essay 3 examined the feasibility of cash-like private transfers of CBDCs that addressed requirements related to AML and CFT regulations. My co-authors and I followed the DSR paradigm to develop an account-based CBDC system architecture enabled by ZKPs and digital IDs. Inspired by the underlying concepts of ZCash (Ben-Sasson et al., 2014), such as ZKPs, Merkle tree data structures, and "nullifiers" (i.e., a commitment or hash of spent transactions) that we incorporated in our design, we called our artifact zCBDC. We evaluated our instantiation with 44 experts from various domains, who helped us to refine our zCBDC artifact. The interview cycles improved our zCBDC system architecture by connecting digital IDs systems, including proofs of non-expiration and non-revocation to block sanctioned individuals, integrating semi-private transfers to, for example, businesses, and regular clearance of the "privacy pool" to counteract malicious activities. During the interviews, we were also able to address risks and implement mitigation measures to prevent, for example, the use of "money mules" (aggregating purchased CBDC accounts to bypass limits specified by AML and CFT regulations), by linking a government-issued unique ID to a CBDC account. The findings demonstrate that ZKPs could enable cash-like privacy and ensure compliance with regulatory constraints in digital payment systems by enforcing specified balance and turnover limits. In addition, we found that a unique and strongly tied government-issued digital ID can be considered a precondition for CBDCs with cash-like privacy assurances. Our zCBDC artifact combines elements from various research domains, including cryptography, privacy-by-design concepts, digital ID, and CBDCs. We contribute to the design knowledge by providing a design artifact (zCBDC) that reconciles cash-like privacy with AML and CFT regulations (Hevner et al., 2004), by conducting a thorough evaluation with key stakeholders in various domains (vom Brocke et al., 2020), and by deriving three nascent design principles on the role of ZKPs and digital IDs for developing cash-like private and compliant digital payment systems:

DP1: *"Use ZKPs to reconcile privacy and compliance."*

DP2: *"Anonymize accounts, not tokens, to maximize the level of flexibility in implementing regulatory and monetary policies."*

DP3: *"Use unique digital identities to facilitate cash-like privacy."*

5.4 Essay 4: Optimization of Special Cryptocurrency Portfolios

Essay 4 focused on optimizing two crypto-asset and currency portfolios consisting of coins (i.e., representing a medium of exchange) and security and utility tokens. To understand the investment capabilities and the role of diversification effects regarding these two special portfolios, I constructed them using a mean-variance approach and optimized them by maximizing the Sharpe ratio. Subsequently, the portfolios were benchmarked against alternative strategies and back-tested for robustness using the annual maximized utility indicator. The descriptive analysis shows a positive moderate to strong correlation within the coin portfolio. For example, Bitcoin, Ethereum, and Litecoin positively correlate, hampering diversification effects. A moderate correlation was observed within the token portfolio allowing for more efficient diversification than the coin portfolio. In this regard, Tether appears to be completely uncorrelated with other tokens in the portfolio. The benchmarking results demonstrated that in the context of coin portfolios, the global minimum variance portfolio and the portfolios optimized with a maximum utility (MU) of 10 and 50 (indicating a higher risk aversion) outperformed other models. In contrast, the token-based global minimum variance portfolio and MU(10) model indicated the best strategies. Notably, alternative portfolio strategies consistently outperformed the specific Sharpe ratio portfolios for both coins and tokens. Overall, the MU portfolio of coins with a risk aversion of 10 yielded the best performance. The empirical results of all portfolio models were confirmed through a robustness test. Specifically, an increase in the risk aversion parameter lowered the utility. The theoretical contribution of this essay is that it advances the state of knowledge in the emerging field of crypto assets and currencies, and traditional portfolio diversification in finance research. In addition, the findings should help investors make more-informed investment decisions about managing crypto-asset and currency portfolios. Lastly, the results of this empirical study provide insights for policy-makers about how to supervise this novel asset class to better protect investors.

6 Discussion and Conclusion

In this section, I summarize the information presented so far and discuss my dissertation's theoretical contributions and practical implications. In addition, I highlight my study's limitations and future research opportunities.

6.1 Summary

Given the potential of decentralized finance to disrupt the financial sector, this dissertation aims to help organizations and institutions design and manage crypto assets and currencies in this domain. To achieve this objective, I structured my dissertation along three research goals (RGs): establishing an understanding of decentralized finance (RG1), providing guidance in designing crypto assets and currencies (RG2), and managing crypto assets and currencies (RG3). The research design of the essays relied on qualitative and quantitative methods. Hence, the pluralistic research approach in this dissertation permits the generation of richer and more reliable knowledge for both the IS and finance research domains relative to a singular approach.

To address RG1, I captured the state of the art in DeFi, presented a consolidating definition, developed a specific research classification framework, and proposed future research directions (Essay 1). RG2 focused on guiding organizations and institutions in the financial sector in designing crypto assets and currencies. I provided information technology artifacts and proposed design suggestions for innovative blockchain-based equity tokens (Essay 2) and cash-like private but regulatorily compliant central bank digital currencies (CBDCs) (Essay 3). Lastly, by pursuing RG3, I aimed to provide researchers, and institutional and individual investors valuable insights into constructing and managing efficient crypto-asset and currency portfolios to improve their overall performance (Essay 4).

Against this background, I provide theoretical and practical insights into the design and management of crypto assets and currencies. The essays contribute to the body of knowledge on crypto assets and currencies through exploratory, prescriptive, descriptive, and analytical research approaches. Ultimately, I guide researchers and practitioners in designing useful

IT artifacts and providing insights into the portfolio construction of crypto assets and currencies.

6.2 Contributions to Theory and Practical Implications

In light of the stated research objective of this dissertation, the results of the essays contribute theoretically and practically to the body of knowledge by answering compelling research questions relevant to advancing both theory and practice in this field. I aimed at responding to context-driven calls in the IS and finance domains, among others, regarding the conceptualization of DeFi from multiple stakeholders' perspective (Matsuo, 2020), providing design knowledge on blockchain-based tokens (Kranz et al., 2019; Perdana et al., 2021; Treiblmaier et al., 2021), and examining the diversification effects of crypto-asset and currency portfolios (Petukhina et al., 2021). In addition, I followed the recommendation of Mingers (2001) to take a pluralistic approach to achieve the overarching research objective of my inquiry by blending qualitative and quantitative research methods.

The essays in this dissertation contribute to theory development while contextualizing the findings to the current literature and expanding the body of knowledge in the respective domains. To address RG1, Essay 1 established an in-depth understanding of the emerging phenomenon of decentralized finance. Specifically, I captured the state of the art in DeFi along a DeFi research classification framework based on Risius and Spohrer (2017) and developed a consolidating definition in this context that is universally applicable (Katona, 2021). In addition, the framework enabled the systematic identification of research gaps and the development of recommendations for future research directions, providing a call to action for scholars in the field.

RG2 focused on guiding the financial sector in designing crypto assets and currencies. In this light, we designed novel IT artifacts and proposed nascent design suggestions for crypto assets and currencies in Essays 2 and 3 (Gregor and Hevner, 2013; Hevner et al., 2004; Iivari, 2015; vom Brocke et al., 2020). In Essay 2, we designed an innovative blockchain-based infrastructure for crowdfunding and provided generalizable design principles for designing equity tokens. Moreover, the theoretical contribution of Essay 2 resides in the extension of the blockchain-based crowdfunding framework of Haas et al. (2015), as we incorporated blockchain, smart contracts, and other key stakeholders (e.g., IT auditors) in our model. In Essay 3, we provided a CBDC system architecture that reconciles cash-like privacy with concurrent AML and CFT regulations. Our developed CBDC artifact represents a solution

to a relevant privacy-trade-off problem and can be instantiated into digital payment systems in general (Iivari, 2015; Iivari, 2017). Moreover, we argued in Essay 3 that using a unique and strongly linked government-issued digital ID can facilitate compliant CBDCs that feature cash-like privacy guarantees. Against this background, we provided nascent design principles to the role of cryptographic ZKPs and digital IDs in payment systems, particularly, CBDCs (Hevner et al., 2004; Peffers et al., 2018; Peffers et al., 2007). Specifically, we contribute to various research strands in cryptography, privacy-by-design concepts, CBDCs, and, especially, the emerging field of digital identity management (Sedlmeir et al., 2021). In both essays, we designed novel crypto assets and currencies that comply with regulatory requirements (e.g., current AML and CFT regulations in the European Union), which remains a major challenge for the integration and adoption of DeFi (Zetzsche et al., 2020). Especially, our suggested design principles show merits in developing such IT artifacts to comply with regulations by design, as strongly confirmed by, for example, law enforcement and regulatory experts in our evaluation stages. These findings contribute to the general understanding and capabilities of crypto assets and currencies powered by blockchain, smart contracts, ZKPs, or a combination of them (Gregor and Hevner, 2013; Iivari, 2015). Accordingly, I have addressed RG2 by providing nascent design principles to build such sophisticated crypto assets and currencies that can be used to draw on these insights and be adapted to specific environments (Gregor et al., 2020; Gregor and Hevner, 2013; Hevner et al., 2004). Overall, I contribute to the design knowledge in the IS domain by providing design artifacts and prescriptive knowledge in the form of concrete design suggestions (vom Brocke et al., 2020; Winter and Albani, 2013).

In Essay 4, I achieved RG3 by contributing to the research area of constructing and managing efficient crypto-asset and currency portfolios. The empirical findings of optimizing special crypto-asset and currency portfolios are consistent with previous results in the literature (Brauneis and Mestel, 2019; Kajtazi and Moro, 2019; Liu, 2018; Platanakis et al., 2018). However, the aggregation of the various MU and global minimum variance portfolio strategies (Petukhina et al., 2021) demonstrated that a naïvely diversified (i.e., $1/N$) portfolio is considerably outperformed. Lastly, the risk aversion parameter increase during the robustness check resulted in the lower utility of both coin and token portfolios, similar to the findings of Liu (2018). Overall, the essays contribute theoretically to the body of knowledge on crypto assets and currencies in both the IS and finance research domains, and lay the groundwork for future research in this emerging field.

In addition to contributing to the literature, this dissertation has practical implications, especially, for organizations and institutions in the TradFi domain. In general, I provide an

in-depth, comprehensive understanding of the DeFi phenomenon (Essay 1), including a multidimensional presentation of current challenges, risks, and potentials in this ecosystem. Organizations and institutions in the financial sector can use these insights to make well-founded strategic decisions to incorporate crypto assets and currencies into legacy systems and, thus, remain competitive in this domain. In addition, the multidimensional classification of DeFi knowledge can assist policy-makers in creating appropriate frameworks and regulations on DeFi that foster innovation for the benefit of the economy and society. Overall, the findings of all essays demonstrated that regulators should take a more open approach to regulate crypto assets and currencies. For example, this approach includes know-your-customer procedures that are required to comply with AML and CFT regulations, or enhanced investor protection in the context of portfolio management. To address regulatory requirements of AML and CFT, novel technologies such as cryptographic ZKPs can enable compliance by design, for example, for enhanced privacy guarantees related to the General Data Protection Regulation (GDPR), and thus meet societal requirements. Moreover, this dissertation provides design artifacts (Gregor and Hevner, 2013; Hevner et al., 2004) for the development of blockchain-based equity tokens (Essay 2) and cash-like private but compliant CBDCs (Essay 3). Given these insights, organizations and institutions in the financial sector can learn how to design proprietary crypto assets and currencies. For example, crowdfunding platforms can integrate blockchain-based infrastructures to facilitate more efficient equity funding procedures (Essay 2). Also, organizations are guided on how to design digital payment systems that reconcile strong privacy assurances with policy requirements (Essay 3). In this context, the derived design principles in Essays 2 and 3 guide TradFi organizations and institutions in designing innovative crypto assets and currencies. Finally, the findings in Essay 4 foster the understanding of institutional and individual investors in constructing and managing crypto asset and currency portfolios. Specifically, these practical insights help investors improve risk management and make more-informed investment decisions.

6.3 Limitations

Owing to the complexity of the research design, this dissertation has limitations. Here, I will present the two most pressing limitations of this dissertation. A detailed description of the underlying limitations of the individual essays can be found in each essay's discussion or conclusion section.

First, research on crypto assets and currencies is still nascent, rendering prior research deprecated or obsolete. Against this background, the dissertation is subject to time constraints that I will elaborate briefly. As identified in the process of our multivocal literature review (MLR) in understanding the phenomenon and presenting the state of the art in DeFi research, the foundations of DeFi may already be deprecated. This limitation is mainly driven by the fast development and high level of innovations in DeFi. In addition, our approach to design regulatorily compliant blockchain-based equity tokens that incorporate sophisticated know-your-customers procedures through smart contracts, could be implemented more efficiently using cryptographic ZKPs or digital IDs based on the self-sovereign identity (SSI) paradigm (see, for example, Schlatt et al., 2021). The far-reaching capabilities of ZKPs and general digital identity management concepts are illustrated in Essay 3. Furthermore, the availability of data in the portfolio construction and, thus, the risk assessment of special crypto-asset and currency portfolios was limited because of their short existence, especially, regarding price data on tokens. Also, the selected coins and tokens for the in-sample period have declined massively in market value. In contrast, novel crypto assets and currencies based on proof-of-stake-based consensus algorithms have gained increasing ground recently.

Second, the designed IT artifacts in this dissertation have not been evaluated in a real-world setting (e.g., field testing with end-users). Although the artifacts in Essays 2 and 3 were evaluated from a practical perspective for their feasibility, efficacy, and usefulness by experts in various areas, these artifacts are only proofs of concept. However, this limitation is typical of research in emerging digital technologies and the context of DSR (Hevner et al., 2004). To increase the credibility and validity of our design artifacts, we ensured methodological rigor in our evaluation cycles (Bhattacherjee, 2012; Gregor and Hevner, 2013; Myers and Newman, 2007) and diligently selected top experts with extensive backgrounds in their fields (e.g., central banks, law enforcement authorities, or research institutions). In addition, the team composition was very diverse and comprised of researchers in different disciplines (e.g., economists and computer scientists in Essay 3), which allowed us to take a more differentiated perspective on the research object. Furthermore, the prototypes lacked an implementation in practical environments and dedicated performance testing, which falls outside this dissertation's scope.

6.4 Future Research and Outlook

This study provides valuable theoretical and practical insights, whereas the limitations highlighted in the previous section are opportunities for future research in this emerging field.

As illustrated throughout this dissertation, the field of DeFi and crypto assets and currencies, in particular, is still in its early stages and requires further interdisciplinary research. Given the immaturity of DeFi, researchers and practitioners should keep an open mind on this subject and steer clear of preconceived expectations that DeFi is either a panacea for problems of TradFi or a new, inherently vicious financial system. In this regard, the recent proposal of Weyl et al. (2022) promises to transform DeFi from coordinating bottom-up by building, participating, and governing networks through non-transferable soulbound tokens. These soulbound tokens aim to encode the trust networks of the real economy to create traceability and reputation, enabling a richer, more pluralistic decentralized society. Notably, "whales" (i.e., entities with tremendous power due to holding substantial amounts of the free float of crypto assets and currencies) and venture capitalists are accumulating large shares across each level of the DeFi technology stack (Schär, 2021), drawing parallels to the centralization issues in Web2. Future research should take upon this call to examine the feasibility, efficiency, and utility of soulbound tokens and a decentralized society to wholly unlock the value propositions of DeFi. In addition, crypto assets and currencies still face significant challenges, for example, owing to their high carbon footprint (Sedlmeir et al., 2020) or the increasing re-centralization of protocol governance (Buterin, 2021). Because of these negative developments in DeFi, a movement called regenerative finance (ReFi) has emerged to drive innovation towards realizing a more holistic, plausible, and democratic Web3 (Curve Labs, 2022). Against this background, innovations in the DeFi ecosystem should be studied from a deeper ethical, environmental, and moral perspective, which requires interdisciplinary research. Ultimately, crypto assets and currencies involve socio-technical constructs that are novel and important objects of social inquiry (Brennecke et al., 2022a; Hayes, 2019). In this view, decentralized financial applications require an in-depth investigation of their impact on human-machine interaction.

As pointed out earlier, the designed artifacts in this dissertation lacked implementation and testing in realistic, practical environments. Specifically, the prototype developed in Essay 2 was "only" deployed on an Ethereum test network. However, incorporating the equity token infrastructure into crowdfunding platforms or multilateral trading facilities in the traditional financial sector would allow for a more realistic assessment of the efficiency and usefulness

of blockchain-based tokens (Hevner et al., 2004). In general, further examination of the artifacts' technical performance and security proofs (for example, the employed ZKPs in Essay 3) is important for the robustness of the artifact (Wüst et al., 2022). Also, an assessment of the utility and perceived added value of the artifacts by end-users is strongly required. With the advent of CBDCs and future digital payment systems (Essay 3), the role of institutional and technical trust in crypto assets and currencies (Frausing and Avital, 2021) could be extended to the perceived value of privacy by end-users, indicating a worthwhile research endeavor. In addition, the proposed design suggestions in this dissertation can be a starting point for IS research and practice to build novel IT artifacts (Gregor et al., 2020) through tokenizing other traditional asset classes (e.g., bonds, real estate, or receivables). Future research could therefore employ such artifacts in practice to assess their impact and use specific research methods (e.g., Sein et al., 2011) to not only gain more valuable insights to contribute to the theoretical discourse but also to inform practice.

Research in finance could use the insights from the portfolio construction and optimization in Essay 4 and employ more sophisticated techniques such as the model provided by Black and Litterman (1992) and include transaction fees. In general, the availability of more recent data would allow for a more robust time series analysis. The inclusion of newer types of crypto assets and currencies to the portfolio, for example, DeFi governance tokens (e.g., Uniswap), stablecoins (e.g., USD Coin), or "fan tokens" (e.g., Paris St. Germain Fan Token), can yield diversification effects. Furthermore, the use of sophisticated hedging instruments (e.g., futures), leverage positions, and fixed income, such as liquidity protocol (LP) tokens generated by providing liquidity to DeFi protocols (e.g., AAVE) or staking rewards (e.g., native tokens such as ETH), offers new opportunities for investors to diversify their portfolios. Future research should therefore analyze recent advances in this area from a risk and portfolio management perspective. In this context, empirical-quantitative studies are beneficial to inform institutional and individual investors on how to effectively manage and optimize their portfolios.

Although I used a pluralistic approach throughout this dissertation, researchers are urged to continuously take upon my findings from a broad methodological perspective to produce richer and more reliable data (Della Porta and Keating, 2008; Mingers, 2001) relative to a single methodology. The underlying school of thought for this inquiry was heavily influenced by interpretivism, particularly, constructivism (Iivari, 2015), because of the research methods used in the individual essays (i.e., artifact design and conceptualization). Against this background, IT artifacts could be developed and updated using a more pragmatic philosophical stance (Goldkuhl, 2012) through, for example, conducting action

design research (ADR), which allows for intervention in more practical settings (Sein et al., 2011). Furthermore, future studies can take a more positivist approach to the IT artifacts presented in this dissertation, for example, to test the technical performance or assess user adoption of crypto assets and currencies. In this regard, quantitative research methods, such as structural equation modeling (e.g., Urbach and Ahlemann, 2010), can be beneficial to understand the constructs and relationships essential to the long-term success of crypto assets and currencies inspired by DeFi. Additionally, the creation of a taxonomy (e.g., Nickerson et al., 2013) of DeFi and crypto assets and currencies as well as the derivation of essential archetypes in this context can be a promising endeavor. As a result, classifying these emerging technologies can provide policy-makers with a sound basis for implementing innovation-promoting laws and regulations.

In summary, this dissertation contributes to the emerging field of DeFi and the literature on crypto assets and currencies, thereby revealing the secret key to the heart of decentralized finance. The results of my dissertation provide valuable insights for researchers and practitioners into designing and managing crypto assets and currencies. Specifically, organizations and institutions in the financial sector can benefit from these findings, which can help them maintain a competitive edge on technical advances. In the long run, it will be interesting to observe whether TradFi and DeFi will converge. Therefore, researchers from various disciplines and practitioners are advised to collaborate closely toward achieving a trustless, democratic, and efficient financial system.

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8 Appendix

8.1 Declarations of Co-Authorship and Individual Contributions

Essays 1, 2, and 3 in this cumulative dissertation were co-authored, while Essay 4 was authored solely by myself. To distinguish the individual contributions, I will provide details of the research settings and my contribution to each project below.[5]

Essay 1: A Multivocal Literature Review on Decentralized Finance: Current Knowledge and Future Research Avenues

This research paper was co-authored by Vincent Gramlich, Tobias Guggenberger, Marc Principato, Benjamin Schellinger, and Nils Urbach. The co-authors contributed as follows:

Vincent Gramlich co-developed the research project. He contributed by analyzing the results of the literature review, developing the theoretical contribution, and engaging in textual elaboration, especially in the results and discussion section. Additionally, he participated in research discussions and provided feedback on the paper's content and structure. Thus, Vincent Gramlich's co-authorship is reflected in the entire research project.

Tobias Guggenberger co-initiated and co-developed the research project. He contributed by developing the paper's theoretical foundation, analyzing the results of the literature review, developing the theoretical contribution, and engaging in textual elaboration, especially in the introduction, conceptual background, method, discussion, and conclusion section. Additionally, he participated in research discussions and provided feedback on the paper's content and structure. Thus, Tobias Guggenberger's co-authorship is reflected in the entire research project.

Marc Principato co-developed the research project. He contributed by developing the paper's theoretical foundation, analyzing the results of the literature review, developing the open research agenda, developing the theoretical contribution, and engaging in textual

5 I submitted signed copies that declare the authors' individual contributions to this dissertation.

elaboration, especially in the conceptual background, method, results, discussion, and conclusion section. Additionally, he participated in research discussions. Thus, Marc Principato's co-authorship is reflected in the entire research project.

Benjamin Schellinger co-initiated and co-developed the research project. He contributed by developing the paper's theoretical foundation, analyzing the results of the literature review, developing the theoretical contribution, and engaging in textual elaboration, especially in the introduction, conceptual background, results, discussion, and conclusion section. Additionally, he participated in research discussions and provided feedback on the paper's content and structure. Thus, Benjamin Schellinger's co-authorship is reflected in the entire research project.

Nils Urbach supervised the research project and provided mentorship. Further, he participated in research discussions, provided feedback on the paper's content and structure, and engaged in textual elaboration. Thus, Nils Urbach's co-authorship is reflected in the entire research project.

Essay 2: Kickstarting Blockchain: Designing Blockchain-based Tokens for Equity Crowdfunding

This research paper was co-authored by Tobias Guggenberger, Benjamin Schellinger, Victor von Wachter, and Nils Urbach. The co-authors contributed as follows:

Tobias Guggenberger co-developed the research project. He contributed by developing the paper's theoretical foundation, conducting and analyzing the expert interviews, developing the theoretical contribution, and engaging in textual elaboration. Additionally, he participated in research discussions and provided feedback on the paper's content and structure. Thus, Tobias Guggenberger's co-authorship is reflected in the entire research project.

Benjamin Schellinger co-developed the research project. He contributed by developing the paper's theoretical foundation, conducting and analyzing the expert interviews, developing the theoretical contribution, and engaging in textual elaboration. Additionally, he participated in research discussions and provided feedback on the paper's content and structure. Thus, Benjamin Schellinger's co-authorship is reflected in the entire research project.

Victor von Wachter initiated and co-developed the research project. He contributed by developing the paper's theoretical foundation, designing, developing, and testing of the IT-artifact, conducting and analyzing the expert interviews, developing the theoretical

contribution, and engaging in textual elaboration. Additionally, he participated in research discussions and provided feedback on the paper's content and structure. Thus, Victor von Wachter's co-authorship is reflected in the entire research project.

Nils Urbach supervised the research project and provided mentorship. Further, he participated in research discussions, provided feedback on the paper's content and structure, and engaged in textual elaboration. Thus, Nils Urbach's co-authorship is reflected in the entire research project.

Essay 3: Reconciling Privacy with Compliance in Central Bank Digital Currencies

This research paper was co-authored by Matthias Babel, Alexander Bechtel, Jonas Gross, Benjamin Schellinger, and Johannes Sedlmeir. The co-authors contributed as follows:

Matthias Babel co-developed the research project. He contributed by designing, developing, an instantiating the IT artifact, conducting and analyzing the expert interviews, developing the theoretical contribution, and engaging in textual elaboration, especially in the conceptual background, evaluation, and discussion section. Additionally, he participated in research discussions and provided feedback on the paper's content and structure. Thus, Matthias Babel's co-authorship is reflected in the entire research project.

Alexander Bechtel co-developed the research project. He contributed by developing the paper's theoretical foundation, conducting expert interviews, and engaging in textual elaboration, especially in the introduction, theoretical foundation, discussion, and conclusion section. Additionally, he participated in research discussions and provided feedback on the paper's content and structure. Thus, Alexander Bechtel's co-authorship is reflected in the entire research project.

Jonas Gross co-developed the research project. He contributed by developing the paper's theoretical foundation, conducting expert interviews, and engaging in textual elaboration, especially in the introduction, theoretical foundation, discussion, and conclusion section. Additionally, he participated in research discussions and provided feedback on the paper's content and structure. Thus, Jonas Gross' co-authorship is reflected in the entire research project.

Benjamin Schellinger co-developed the research project. He contributed by developing the methodological approach, conducting and analyzing the expert interviews, developing the theoretical contribution, and engaging in textual elaboration, especially in the conceptual

background, method, evaluation, and discussion section. Additionally, he participated in research discussions and provided feedback on the paper's content and structure. Thus, Benjamin Schellinger's co-authorship is reflected in the entire research project.

Johannes Sedlmeir initiated and co-developed the research project. He contributed by developing the paper's theoretical foundation, designing the IT artifact, developing the theoretical contribution, and engaging in textual elaboration in each section. Additionally, he participated in research discussions and provided feedback on the paper's content and structure. Thus, Johannes Sedlmeir's co-authorship is reflected in the entire research project.

Essay 4: Optimization of Special Cryptocurrency Portfolios

This research paper was authored by Benjamin Schellinger. The author contributed as follows:

Benjamin Schellinger initiated and developed the research project. I conducted the literature review, ran the portfolio selection and optimization, evaluated the portfolios, elaborated on the discussion, and carried out the textual elaboration. Thus, my authorship is reflected in the entire research project.

8.2 Overview of Other Publications

Table 3: Overview of other peer-reviewed articles.

Authors & Year	**Title**	**Publication Outlet**	**Status**
Djamali et al. (2021)	Asset Logging in the Energy Sector: A Scalable Blockchain-based Data Platform	Energy Informatics *(Scopus: 61%)*	Published
Guggenberger et al. (2021)	Insured? Good! Designing a Blockchain-based Credit Default Insurance System for DeFi Lending Protocols	Proceedings of the 4th Middle East & North Africa Conference for Information Systems	Published
Schellinger et al. (2022c)	Yes, I Do: Marrying Blockchain Applications with GDPR	Proceedings of the 55th Hawaii International Conference on System Sciences *(VHB-JOURQUAL3: C)*	Published
Brennecke et al. (2022b)	The De-Central Bank in Decentralized Finance: A Case Study of MakerDAO	Proceedings of the 55th Hawaii International Conference on System Sciences *(VHB-JOURQUAL3: C)*	Published
Brennecke et al. (2022a)	The Human Factor in Blockchain Ecosystems: A Sociotechnical Framework	Proceedings of the 17th International Conference on Wirtschaftsinformatik *(VHB-JOURQUAL3: C)*	Published
Schellinger et al. (2022a)	Blockchain Use Cases and Concepts in Sports: A Systematic Review	Proceedings of the 30th European Conference on Information Systems *(VHB-JOURQUAL3: B)*	Published
Ante et al. (2023)	Enhancing Trust, Efficiency, and Empowerment in Sports: Developing a Blockchain-Based Fan Token Framework	Proceedings of the 31st European Conference on Information Systems *(VHB-JOURQUAL3: B)*	Accepted for publication

Table 4: Overview of other publications.

Authors & Year	**Title**	**Publication Outlet**	**Status**
Bogensperger et al. (2021)	Welche Zukunft hat die Blockchain-Technologie in der Energiewirtschaft?	Project-related whitepaper	Published
Gross et al. (2021)	Designing a Central Bank Digital Currency with Support for Cash-Like Privacy	SSRN	Published
Schellinger et al. (2022b)	Mythbusting Self-Sovereign Identity (SSI). Diskussionspapier zu selbstbestimmten digitalen Identitäten	Fraunhofer whitepaper	Published
Gramlich et al. (2022a)	Decentralized Finance (DeFi) – Foundations, Applications, Potentials, and Challenges	Fraunhofer whitepaper	Published
Amend et al. (2022)	Föderale Blockchain Infrastruktur Asyl: Pilotierung und Evaluation des FLORA-Assistenzsystems im Kontext der AnkER-Einrichtung Dresden	Fraunhofer whitepaper	Published
Gramlich et al. (2022b)	Decentralized Finance – The Rise of a New Paradigm? An Introduction to the Technical Foundations, Application Areas, Potentials, and Challenges of DeFi	REthinking: Finance	Published

A Multivocal Literature Review on Decentralized Finance: Current Knowledge and Future Research Avenues

Author(s):
Gramlich, Vincent; Guggenberger, Tobias; Principato, Marc; Schellinger, Benjamin; Urbach, Nils

Accepted in:
Electronic Markets

Abstract:
While Decentralized Finance (DeFi) has the potential to emulate and, indeed, outperform existing financial systems, it remains a complex phenomenon yet to be extensively researched. To make the most of this potential, its practitioners must gain a rigorous understanding of its intricacies, as must information systems (IS) researchers. Against this background, this study uses a multivocal literature review to capture the state of research in DeFi. Thereby, we (1) present a consolidating definition of DeFi as we (2) analyze, synthesize, and discuss the current state of knowledge in the field of DeFi. We do so while adapting the blockchain research framework proposed by Risius and Spohrer (2017). Furthermore, we (3) identify gaps in the literature and indicate future research directions in DeFi. Even though our findings highlight several shortcomings in DeFi that have prevented its widespread adoption, our literature review shows a large consensus on DeFi's many promising features and potential to complement the traditional financial system. To that end, this paper is presented to encourage further research to mitigate the current risks of DeFi, the payoff of which will be an enriched financial ecosystem.

Keywords:
Blockchain; crypto economy; crypto finance; DeFi; literature review; research agenda

Kickstarting Blockchain: Designing Blockchain-based Tokens for Equity Crowdfunding

Author(s):
Guggenberger, Tobias; Schellinger, Benjamin; von Wachter, Victor; Urbach, Nils

Published in:
Electronic Research Commerce

Abstract:
Blockchain-based tokens seek to overcome the friction and opaqueness of the legacy financial infrastructure in the company funding process, particularly in the early-stage and equity crowdfunding domain. While Initial Coin Offerings and Security Token Offerings proposed a solution for crowdfunding, early-stage companies still face challenges in using blockchain as an alternative equity funding infrastructure. In this context, the idea of blockchain-based equity tokens remains hypothetical. In addition, the literature lacks design theory for the development and implementation of blockchain-based equity tokens. This research bridges this gap by designing, developing, and evaluating an equity token prototype for crowdfunding, following the design science research (DSR) approach. We propose a refined crowdfunding model and derive seven design principles that contribute to the design theory of equity tokens. The research results show that blockchain-based equity tokens improve efficiency, transparency, and interoperability while meeting regulatory requirements and facilitating secondary market trading.

Keywords:
Blockchain; design science; equity crowdfunding; initial coin offering; security token offering; tokens

Reconciling Privacy with Compliance in Central Bank Digital Currencies

Author(s):
Babel, Matthias; Bechtel, Alexander; Gross, Jonas; Schellinger, Benjamin; Sedlmeir, Johannes

In revision (2nd round):
European Journal of Information Systems

Extended abstract:
In response to the general decline of cash and the increasing competition from private organizations and decentralized forms of money (Deutsche Bundesbank, 2022; European Central Bank, 2020), central banks around the world are considering developing digital central bank currencies (CBDCs) (Kosse and Mattei, 2022). So far, various design options for a CBDC have been debated in this context. In these discussions, the preservation of privacy represents a central element in developing a CBDC (Tronnier, 2020). Today, user data is kept confidential by payment service providers, which, however, requires high-security standards and trust that this data will not be shared without authorization (Panetta, 2021). Exploiting this sensitive data could harm users, for example, resulting in an identity theft (Chaum et al., 2021; Kahn, 2019). Therefore, protecting users' privacy plays a vital role in the design of a CBDC (Tronnier, 2020), which today can only be achieved with cash transactions. However, implementing "cash-like" privacy in a digital payment system, such as a CBDC, is difficult to achieve due to the high compliance requirements regarding anti-money laundering (AML) and combating terrorist financing (CFT) regulations (Bank of Canada, 2020; European Central Bank, 2022).

Although research in this area has already demonstrated the technical feasibility of cash-like privacy in digital payments (e.g., "e-cash" by Chaum (1983) or "ZCash" by Ben-Sasson et al. (2014)), regulatory requirements have yet to be addressed (Bontekoe, 2020; Wüst et al., 2022). Therefore, there is an urgent demand in the information systems (IS) research domain to evaluate the practical feasibility of a cash-like private CBDC from a technical, legal, and socioeconomic perspective (Hevner et al., 2004). Our research endeavor responds to the

call of Rogaway (2015), who recommends using cryptographic primitives in real-world applications to satisfy privacy guarantees and prevent mass surveillance. Specifically, we aim to disprove the widely held belief that a high level of privacy protection is incompatible with prevailing compliance requirements, thus bridging the current gap in the literature in this field. Against this background, we pose the following research question:

> *How to design a CBDC that supports cash-like privacy while enabling compliance with AML and CFT regulations?*

To answer our research question, we embedded our research project in the context of the design science research (DSR) paradigm (Gregor and Jones, 2007; Hevner et al., 2004; March and Smith, 1995). In this regard, the guidelines of Peffers et al. (2007) helped us structure our approach to rigorously build and evaluate information technology (IT) artifacts and generate prescriptive knowledge (Gregor and Hevner, 2013). As a first step, we identified the main problems in practice and the lack of knowledge in the IS literature regarding the trade-offs between privacy and compliance requirements of CBDCs and derived design goals for our IT artifact (Armelius et al., 2021; Auer and Boehme, 2021). In the design and development process, we exapted knowledge from other research domains (e.g., cryptography) (Gregor and Hevner, 2013; vom Brocke et al., 2020). As a result, we developed and partially instantiated an account-based CBDC system architecture enabled by cryptographic zero-knowledge proofs (ZKPs) and digital IDs. To demonstrate and assess the feasibility of our artifact, we conducted semi-structured interviews involving 44 leading experts from various domains (e.g., central banks) that helped us refine our artifact (Bhattacherjee, 2012; Kallio et al., 2016; Myers and Newman, 2007), for example, to integrate semi-private transfers to businesses or to mitigate the risk of creating multiple accounts using unique digital IDs. In addition, we presented our CBDC system at various events, published a pre-print of our key findings, and provided the source code of our artifact (Hevner et al., 2004).

Our findings show that ZKPs can reconcile cash-like privacy with compliance requirements, particularly, regarding AML and CFT regulations, in digital payment systems by enforcing predefined transaction, turnover, and balance limits. In addition, we found that a unique and strongly binding digital ID (issued by a government) can be a prerequisite for a CBDC with cash-like privacy properties. Against this background, we contribute to design knowledge by providing a design artifact, i.e., our "zCBDC" system, that balances cash-like privacy with AML and CFT regulations (Hevner et al., 2004). Given the methodological rigor of our research, we derived three nascent and generalizable design principles on ZKPs and

digital IDs for developing cash-like private but compliant digital payment systems (Hevner et al., 2004; Peffers et al., 2018; Peffers et al., 2007). We also streamlined previously isolated research domains (i.e., economics, computer science, and IS) and contribute to the knowledge base. From a practical perspective, central banks and other organizations could use our artifact to develop a CBDC that protects users' privacy, thereby preventing data exploitation. In this context, our findings reinforce consumer protection organizations' demand for strong privacy in CBDCs. In addition, we provide policymakers and regulators with insights into privacy-enhancing technologies that harmonize regulatory requirements in the financial sector.

Keywords:
Anonymity, CBDC, digital identity, payment system, regulation, zero-knowledge proof

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Optimization of Special Cryptocurrency Portfolios

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Abstract:
Purpose:
This paper elaborates on the optimization of two particular cryptocurrency portfolios in a mean-variance framework. In general, cryptocurrencies can be classified to as coins and tokens where the first can be thought of as a medium of exchange and the latter accounts for security or utility tokens depending upon its design.

Design/methodology/approach:
Against this backdrop, this empirical study distinguishes, in particular, between pure coin and token portfolios. Both portfolios are optimized by maximizing the Sharpe ratio and, subsequently, compared with alternative portfolio strategies. Findings: The empirical findings demonstrate that the maximum utility (MU) portfolio of coins, with a risk aversion of $\lambda = 10$, outweighs alternative frameworks. The portfolios optimized by maximizing the Sharpe ratio for both coins and tokens indicate rather poor performance. Testing the maximized utility for different levels of risk aversion confirms the findings of this empirical study and confers them more robustness.

Research limitations/implications:
Further investigation is strongly recommended as tokens represent a new phenomenon in the cryptocurrency universe, for which only a limited amount of data is available, which restricts the sampling. Furthermore, future work is to include more sophisticated optimization models using different constraints in portfolio creation.

Practical implications:
In light of the persistently substantial volatility in cryptocurrency markets, the empirical findings assert that portfolio managers are advised to construct a global minimum variance portfolio. In the absence of sophisticated optimization models, private investors can invest according to the market values of cryptocurrencies. Despite minor differences in the risk and reward ratios of the portfolios tested, tokens tend to be more speculative, especially if the Tether token is excluded, which may require enhanced supervision and investor protection by regulating authorities.

Originality/value:
As the current literature investigates on diversification effects of blended cryptocurrency portfolios rather than making an explicit distinction, this paper reflects one of the first to explore the investability and role of diversifying coins and tokens using a classic Markowitz approach.

Keywords:
Bitcoin; cryptocurrencies; Markowitz; portfolio diversification; portfolio optimization; Sharpe ratio