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RESEARCH ARTICLE

Decentralized Finance (DeFi): Benefits, Risks, and Risk-Mitigation Strategies

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Abstract
The 2008-2009 global financial crisis resulted in a loss of trust in traditional financial systems and the need to decentralize and democratize finance. This coincided with the birth of blockchain technology, marked by creating the pioneer cryptocurrency, bitcoin (BTC), in 2009. As blockchain technology has gained prominence, decentralized finance (DeFi) has emerged, transforming the financial landscape and offering financial services without the need for traditional financial intermediaries. While the disruption of traditional finance has opened up new opportunities, it has also introduced significant risks to the financial sector. In this study, we follow the PRISMA approach (systematic literature review) to identify several DeFi benefits and challenges, as discussed in the existing literature. Based on the Scopus database, we critically scrutinized 64 published articles to report that although DeFi promotes financial inclusion and enhances financial transparency and accountability, the ecosystem also faces security issues, regulatory ambiguities, and price volatility. By providing a balance between the benefits and risks associated with DeFi, this study will help investors and other stakeholders make informed decisions and will serve as a valuable resource for formulating strategies to better regulate the DeFi ecosystem.

Keywords: Decentralized finance, DeFi, benefits, risks, PRISMA

Introduction

From ATMs and mobile payment solutions to blockchain technology and central bank digital currencies (CBDCs), the evolution of financial technology (FinTech) has been rapid, particularly after the 2008 global financial crisis (GFC) (Pandey et al., 2023). In the aftermath of the GFC, stakeholders lost trust in the centralized nature of traditional financial systems, paving the way for the emergence of more decentralized systems (Chaklader et al., 2023). Centralized (traditional) finance (CeFi) relies on intermediaries such as banks and other financial institutions to provide financial services. There are many disadvantages related to this financial setup. First, the presence of intermediaries increases transaction fees and slows

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down transaction speeds because the central authority must validate transactions. Second, inhabitants of remote areas without financial institutions are deprived of access to financial services. In addition, there is no 24/7 service as most of these financial intermediaries have opening and closing hours. These constraints adversely affect the level of financial activities in an economy.

The development of bitcoin in 2009 marked the birth of cryptocurrencies and blockchain technology. By leveraging blockchain technology, particularly Ethereum, decentralized finance (DeFi) has emerged as an alternative to traditional financial institutions. By introducing decentralization and disintermediation in the provision of financial services, DeFi intensifies competition in the financial sector but also provides an opportunity for traditional financial institutions to integrate and improve their services (Renduchintala et al., 2022). The advantages and opportunities associated with DeFi are numerous. In particular, it addresses some of the drawbacks of traditional finance by reducing transaction costs, increasing transaction speed, enhancing financial inclusion, providing 24/7 financial services, and ensuring transparency in financial transactions (Chen & Bellavitis, 2020; Borisov, 2022).

DeFi also introduces new risks. By automating the provision of financial services through reliance on smart contracts, significant financial losses could result if malicious individuals exploit any potential vulnerabilities in the smart contracts. In addition, regulatory noncompliance and regulatory arbitrage are some issues that may arise due to the ambiguity surrounding the regulation of the DeFi ecosystem. Again, high market volatility could lead to impermanent losses for liquidity providers on DeFi platforms, while the limitations of the Ethereum blockchain pose scalability challenges and can reduce transaction throughput (Borisov, 2022).

The main aim of this study is to systematically review the existing literature on the advantages and challenges associated with DeFi using the PRISMA methodology. To achieve this, we specify the following objectives for our study:

· Investigating the benefits of decentralized finance (DeFi)

· An examination of the inherent risks and challenges in DeFi and a proposal for effective risk mitigation strategies

This study was motivated by many factors. First and foremost, as the DeFi space continues to gain popularity, widespread acceptance, and institutional adoption, investors continue to flood money into the ecosystem, increasing the total value locked (TVL) in DeFi systems (Werner et al., 2022). Hence, investors and other stakeholders must fully appreciate the related benefits and risks to make informed decisions. Second, this study will help traditional financial institutions, startups, and regulators come to terms with how DeFi has transformed

the financial sector so that they can better adapt to the ever-evolving landscape (Renduchintala et al., 2022). Moreover, the study suggests risk mitigation strategies for the identified DeFi risks and practical recommendations to aid regulators, policymakers, and other stakeholders in dealing with DeFi revolutionization.

The structure of the remainder of this paper describes the methodology employed in section 2; presents, analyzes, and discusses the results in section 3; and then provides a conclusion and suggests recommendations in section 4.

Methodology

We apply the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology to systematically review the literature on the advantages and risks associated with DeFi. The PRISMA approach is advantageous because it makes the literature review transparent and reproducible (Kim et al., 2023).

Search Strategy

In order to achieve our research objectives, we constructed an advanced search using the following equation:

((Decentrali?e* W/3 financ* OR "DeFi" OR "De-Fi" OR blockchain W/3 financ* OR crypto W/3 financ* OR cryptocurrency W/3 financ* OR web3 W/3 financ* OR digital W/3 financ*) AND ("benefit*" OR "risk*" OR "advantage*" OR "disadvantage*" OR "opportunities" OR "challenge*" OR "pros" OR "cons" OR "significance" OR "vulnerabilities" OR "importance" OR "threat*" OR "innovation*" OR "issue*" OR "solution*" OR "problem*" OR "application*" OR "limitation*" OR "drawback*"))

We used the "AND" and "OR" Boolean operators to ensure that relevant articles were captured and maximized coverage, respectively. The application of the "W/3" within operator ensured that our search did not miss relevant articles by including phrases in which the specified words were up to three words apart.

Additionally, by incorporating the "?" wildcard after "Decentrali," we ensured that articles were included regardless of whether they had the word spelled out as "decentralize" or "decentralize." Moreover, the "*" wildcard was applied to ensure that our net was widely cast in search of terms in various forms, such as "finance" and "financial." Overall, our search was comprehensive, and we ensured that no relevant article was overlooked.

We performed our search in Scopus. Scopus is a comprehensive database that extensively covers multiple disciplines. It also allows for advanced and complex searches by using

Boolean operators, proximity operators, and wildcards. By leveraging the Scopus filters, researchers can refine search results as required. In addition, by providing article abstracts and keywords, Scopus eases the initial screening stage (Musa et al., 2023).

Filtering and screening relevant studies

After the initial search, we proceeded to the filtering and screening stages. The inclusion and exclusion criteria outlined in Table 1 were used to eliminate irrelevant articles and ensure the selection of only articles in line with the study objectives. The screening process was divided into two stages. In the initial stage, we assessed the relevance of the titles and abstracts of the studies. In the subsequent stage, for the articles that passed the initial screening, we thoroughly examined their full texts to ensure that we exclusively included articles aligning with the study's intended focus.

Table 1

Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Articles in English	Non-English language articles
Research articles	Review papers, conference papers, reviews, books, book chapters, notes, short surveys
Scientific Journal articles	Non-journal articles, conference proceedings/Procedia articles
Open access articles	Studies whose full texts are not accessible

Data extraction

After screening for relevant studies, pertinent information was extracted from the selected studies. Initially, we conducted a descriptive analysis of the selected articles, considering factors such as publication years, research approach (primary or secondary), and research methods (quantitative, qualitative, or mixed). Subsequently, we compiled and succinctly summarized pertinent data from all selected studies regarding the advantages and risks associated with DeFi.

Data Synthesis, Analysis, Discussion, Conclusion, and Recommendations

Next, we combined the data extracted from the selected studies to comprehensively understand the benefits and risks associated with DeFi. We analyzed and interpreted the results and discussed the implications of our findings. Furthermore, we summarized the results concisely and drawn well-informed conclusions. To provide a balanced perspective, we also considered the limitations of our review and put forth recommendations for further research and practical applications.

Presentation of Results

In this section, we present, analyze, and discuss the findings of our review, ranging from the initial article search results to the data extracted from the selected articles.

Initial Search and Screening Results

We initiated the search process by using the search equation in the SCOPUS database, targeting the article title, abstract, and indexed keywords. This initial search, conducted on November 12, 2023, yielded 911 documents.

Next, we refined the search results by filtering research, journal, English, and open-access articles. This process reduced the selection to 185 documents. Subsequently, a two-stage screening process was conducted. In Stage 1 screening, we assessed the titles and abstracts of 185 documents and eliminated 75 articles that were completely unrelated to decentralized finance (DeFi). In stage 2 screening, we thoroughly examined the complete texts of the 110 articles selected from stage 1, and we found that 64 of these articles were closely aligned with the primary focus of our study. Thus, we included them in our analysis. The flowchart presented in Figure 1 outlines the systematic literature review process, which spans the initial search to the final selection of included articles.

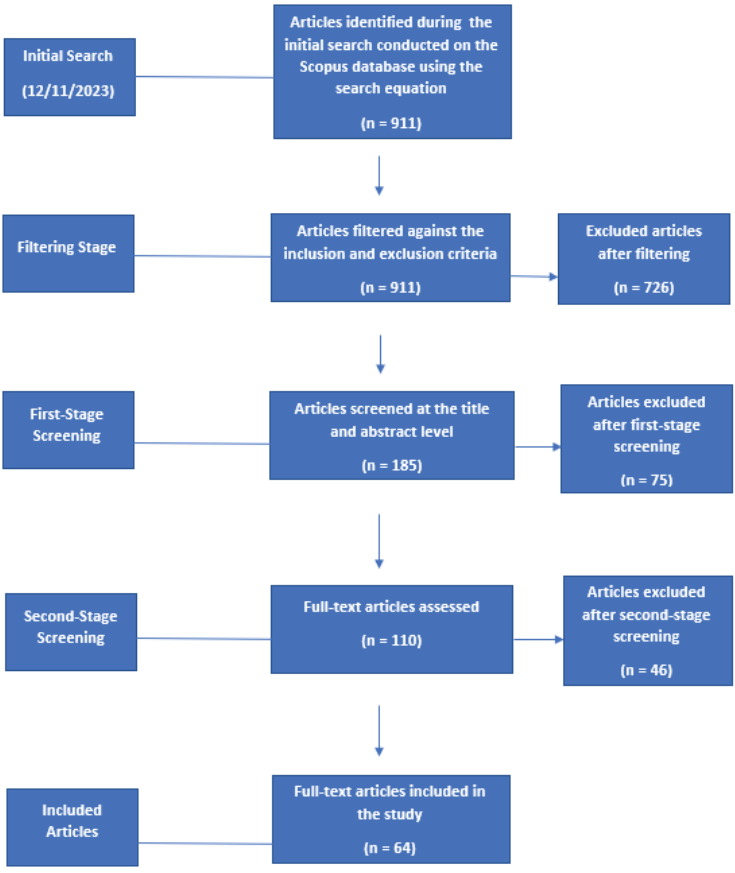

Figure 1. Systematic Literature Review Flow Chart

Data Extraction Results

This section presents the data extraction results, beginning with a descriptive analysis of the characteristics of the selected articles. Subsequently, the discussion unfolds with an analysis of the benefits and risks associated with decentralized finance (DeFi).

Descriptive Analysis of the Studies

The descriptive statistics of the included articles are presented in Table 2 as frequency distribution.

As indicated in Table 2, among the 64 articles exploring the benefits and risks of decentralized finance (DeFi), 52 incorporated secondary research, with an additional 6 articles not relying on any data. Additionally, 5 articles incorporated primary research, and 1 used both primary and secondary data. Notably, about 83% of the studies leaned heavily on secondary research, emphasizing its prevalence in this domain because of its cost effectiveness, time efficiency, and ability to draw from a diverse existing knowledge base.

Table 2

Descriptive Statistics of the Included Studies

Category	Item	Frequency Distribution
Research Approach	Primary	5
	Secondary	52
	Primary and secondary	1
	No Data Used	6
	TOTAL	**64**
Research Method	Qualitative	46
	Quantitative	12
	Mixed	6
	TOTAL	**64**
Publication Year	2023	23
	2022	27
	2021	7
	2020	5
	2019	2
	TOTAL	**64**

Regarding the research methods applied in the 64 articles, 46 carried out a qualitative study, 12 relied on a quantitative design, and 6 used both qualitative and quantitative methods (mixed approach). Unsurprisingly, more than 81% of the studies relied on qualitative methods because qualitative methods help researchers explore the complexities of DeFi and provide sufficient context.

97% of the studies were published in or after 2020. This is not surprising considering that cryptocurrencies and blockchain technology have gained mainstream acceptance and adop-

tion since 2020, leading to the concept of DeFi (Chen et al., 2022). Even more interestingly, more than 78% of the studies were published in just 2022 and 2023, indicating the growing body of research in this field.

Benefits of Decentralized Finance

From the 64 articles included in this study, the benefits of DeFi are presented in Table 3.

Table 3

Benefits of Decentralized Finance

Benefits	**Sources**
1. Disintermediation	Patel and Shrimali (2021), Han et al. (2023), Kaur et al. (2023), Saengchote et al. (2023), Bartoletti et al. (2022), Ziegler and Zehra (2023), Hassan et al. (2020), Zhao et al. (2022), Ozili (2022), Stepanova and Eriņš (2021), Zachariadis et al. (2019), Zetzsche et al. (2020), Kumari and Devi (2022), Jensen et al. (2021)
2. Decentralization	Song et al. (2023), Mnohoghitnei et al. (2022), De Collibus et al. (2022), Dodmane et al. (2023), Axelsen et al. (2023), Shahbazi and Byun (2022), Park and Youm (2022), Saengchote et al. (2023), Weingärtner et al. (2023), Barbereau and Bodó (2023), Zhao et al. (2022), Hameed (2019), Chen and Bellavitis (2020), Stepanova and Eriņš (2021), Al-Shaibani et al. (2020), Zetzsche et al. (2020)
3. Accessibility, Permissionlessness, and Democratization of Finance	Shokri et al. (2022), Mnohoghitnei et al. (2022), De Collibus et al. (2022), Dodmane et al. (2023), Kaur et al. (2023), Barbereau et al. (2023), Shahbazi and Byun (2022), Saengchote et al. (2023), Weingärtner et al. (2023), Barbereau and Bodó (2023), Bartoletti et al. (2022), Smith (2021), Vidal-Tomás et al. (2023), Ziegler and Zehra (2023), Salami (2021), Kumari and Devi (2022), Schär (2021), Hassan et al. (2020), Zhao et al. (2022), Schueffel (2021), Chen and Bellavitis (2020), Popescu (2020), Momtaz (2022), Stepanova and Eriņš (2021), Xu and Feng (2022), Bennett et al. (2023)
4. Financial Inclusion	Wu et al. (2023), Alsagheer et al. (2023), Kaur et al. (2023), Allen et al. (2022), Chiu et al. (2022), Alamsyah and Syahrir (2023), Weingärtner et al. (2023), Barbereau and Bodó (2023), Bartoletti et al. (2022), Vidal-Tomás et al. (2023), Salami (2021), Yang (2022), Zhao et al. (2022), Jensen et al. (2021), Schueffel (2021), Ozili (2022)
5. Transparency/Accountability (Traceability and Verifiability) / Trustlessness	Song et al. (2023), Patel and Shrimali (2021), Shokri et al. (2022), Wu et al. (2023), Mnohoghitnei et al. (2022), Dodmane et al. (2023), Burger and Weinmann (2022), Han et al. (2023), Xu et al. (2023b), Kaur et al. (2023), Lupaiescu et al. (2022), Xu et al. (2023a), Shahbazi and Byun (2022), Saengchote et al. (2023), Weingärtner et al. (2023), Seven et al. (2022), Smith (2021), Vidal-Tomás et al. (2023), Ziegler and Zehra (2023), Salami (2021), Kumari and Devi (2022), Schär (2021), Hassan et al. (2020), Zhao et al. (2022), Jensen et al. (2021), Schueffel (2021), Chen and Bellavitis (2020), Stepanova and Eriņš (2021), Al-Shaibani et al. (2020)
Security, Immutability, and Cryptography	Shokri et al. (2022), De Collibus et al. (2022), Dodmane et al. (2023), Han et al. (2023), Shahbazi and Byun (2022), Alamsyah and Syahrir (2023), Park and Youm (2022), Saengchote et al. (2023), Li and Shen (2022), Hassan et al. (2020), Yang (2022), Hameed (2019), Ozili (2022), Popescu (2020), Al-Shaibani et al. (2020)
Anonymity	Schueffel (2021)

Innovation	Song et al. (2023), Wu et al. (2023), Burger and Weinmann (2022), Kaur et al. (2023), Hickey and Harrigan (2022), Aspembitova and Bentley (2022), Xu et al. (2023a), Allen et al. (2022), Axelsen et al. (2023), Chiu et al. (2022), Barbereau et al. (2023), Kitzler et al. (2023), Saengchote (2023), Alamsyah and Syahrir (2023), Bennett et al. (2023), Weingärtner et al. (2023), Barbereau and Bodó (2023), Bartoletti et al. (2022), Smith (2021), Ziegler and Zehra (2023), Kumari and Devi (2022), Yang (2022), Zhao et al. (2022), Hameed (2019), Jensen et al. (2021), Schueffel (2021), Chen and Bellavitis (2020), Ozili (2022), Momtaz (2022), Zachariadis et al. (2019), Zetzsche et al. (2020)
Efficiency/Speed	Shokri et al. (2022), Wu et al. (2023), Schuler et al. (2023), Mnohoghitnei et al. (2022), Dodmane et al. (2023), Han et al. (2023), Xu et al. (2023a), Chiu et al. (2022), Shahbazi and Byun (2022), Alamsyah and Syahrir (2023), Weingärtner et al. (2023), Barbereau and Bodó (2023), Andolfatto and Martin (2022), Seven et al. (2022), Yan and Zhou (2023), Li and Shen (2022), Smith (2021), Schär (2021), Hassan et al. (2020), Yang (2022), Zhao et al. (2022), Chen and Bellavitis (2020), Momtaz (2022), Stepanova and Eriņš (2021), Zachariadis et al. (2019), Al-Shaibani et al. (2020)
Cost Effectiveness	Shokri et al. (2022), Alsagheer et al. (2023), Burger and Weinmann (2022), Han et al. (2023), Kaur et al. (2023), Allen et al. (2022), Chiu et al. (2022), Alamsyah and Syahrir (2023), Grassi et al. (2022), Park and Youm (2022), Barbereau and Bodó (2023), Yan and Zhou (2023), Li and Shen (2022), Kumari and Devi (2022), Hassan et al. (2020), Yang (2022), Hameed (2019), Chen and Bellavitis (2020), Ozili (2022), Stepanova and Eriņš (2021), Al-Shaibani et al. (2020)
Automation/Programmability	Schuler et al. (2023), Mnohoghitnei et al. (2022), De Collibus et al. (2022), Han et al. (2023), Amini et al. (2023), Saengchote et al. (2023), Weingärtner et al. (2023), Bartoletti et al. (2022), Smith (2021), Hassan et al. (2020), Zhao et al. (2022)
Democratic governance/community engagement	Song et al. (2023), Shokri et al. (2022), Hickey and Harrigan (2022), Grassi et al. (2022), Rikken et al. (2023), Andolfatto and Martin (2022), Vidal-Tomás et al. (2023), Ziegler and Zehra (2023), Jensen et al. (2021), Zachariadis et al. (2019)
Diversification and risk management	Mnohoghitnei et al. (2022), Alsagheer et al. (2023), Hickey and Harrigan (2022), Aspembitova and Bentley (2022), Chen and Chang (2022), Grassi et al. (2022), Bennett et al. (2023), Weingärtner et al. (2023), Metelski and Sobieraj (2022), Salami (2021), Tetiana et al. (2022), Jensen et al. (2021), Song et al. (2023)
User Empowerment / Non-Custodial Finance	Wu et al. (2023), Vidal-Tomás et al. (2023), and Salami (2021)
Yield Generation, High Returns, and Passive Income	Schuler et al. (2023), Xu and Feng (2022), Smith (2021), Metelski and Sobieraj (2022), Tetiana et al. (2022), Jensen et al. (2021), Stepanova and Eriņš (2021)
Tokenization	Burger and Weinmann (2022), Han et al. (2023), Barbereau et al. (2023), Saengchote (2023), Rikken et al. (2023), Andolfatto and Martin (2022), Seven et al. (2022), and Smith (2021)
Global Funding Access	Han et al. (2023), Allen et al. (2022), Chiu et al. (2022), and Chen and Bellavitis (2020)
Composability/Interoperability	Kaur et al. (2023), Kitzler et al. (2023), Saengchote (2023), Park and Youm (2022), Seven et al. (2022), Chen and Bellavitis (2020), and Schär (2021)
Borderlessness	Chen and Bellavitis (2020), Ozili (2022), Popescu (2020), Stepanova and Eriņš (2021)
Liquidity Provision (Automated Market Makers (AMMs) and Liquidity Pools)	Grassi et al. (2022), Kim et al. (2022), Jensen et al. (2021)

Fewer Volatility/Stablecoins	Andolfatto and Martin (2022)
Financial Autonomy and Flexibility	Tetiana et al. (2022), and Schueffel (2021)
Less defaults/overcollateralization	Schuler et al. (2023), and Li and Shen (2022)
Alternative Financial Ecosystems	Salami (2021), Kumari and Devi (2022), and Zetzsche et al. (2020)
Increased Competition	Kumari and Devi (2022)
Data Consistency	Al-Shaibani et al. (2020)
Censorship Resistance	Ozili (2022) and Popescu (2020)
Reduced Information Asymmetry	Dodmane et al. (2023), Grassi et al. (2022), and Li and Shen (2022)
Herding Prevention	Yan and Zhou (2023)
Less Counterparty Risk	Schueffel (2021)
Wide Acceptance and Adoption/Market Significance	Aspembitova and Bentley (2022), Kitzler et al. (2023), Bennett et al. (2023)
Financial Stability	Amini et al. (2023)
Economic Growth	Kaur et al. (2023), Axelsen et al. (2023)
Applications beyond Finance	Hameed (2019)

As shown in Table 3, numerous benefits of decentralized finance (DeFi) have been identified in the existing literature. First and foremost, DeFi eliminates the need for traditional financial intermediaries. This disintermediation reduces user transaction costs. As a result, financial services are becoming more affordable. In addition, through the absence of intermediaries, DeFi eliminates bureaucratic delays, improves transaction speed, and enhances efficiency. Again, efficiency is enhanced by smart contracts that automate DeFi processes. In addition, due to smart contracts, reliance on counterparty trust is reduced. This mitigates counterparty risk.

DeFi reduces the dependence on central authorities by operating on decentralized networks. Decentralized mechanisms in DeFi contribute to financial stability. This ensures robustness against system failures. In addition, decentralization in DeFi discourages herding behavior. This reduces market bubbles. Again, decentralization enhances financial system security. In security, DeFi employs cryptographic techniques and leverages the immutability of blockchain records. This ensures the security of DeFi transactions. Due to the immutability of blockchain records, data are consistent in DeFi. This enhances data integrity. Anonymity is another DeFi factor that secures users' data and protects their privacy. Users can transact on DeFi platforms without disclosing personal information.

In addition, DeFi enhances transparency and accountability. This is due to its ability to limit asymmetric information and to the blockchain network, where all DeFi transactions are traceable and verifiable.

In addition, by extending financial services to unserved and underserved populations, DeFi enhances financial inclusion. By increasing accessibility to financial services and due to the borderless nature of DeFi, international trade (and, hence, economic growth) increases, and it becomes relatively easier for financial institutions and the general public to raise funds.

DeFi drives innovation as well. Thanks to DeFi, and especially due to the composability and interoperability of its protocols, users can enjoy various innovative financial products and services.

DeFi allows for community participation and engagement on its platforms (decentralized autonomous organizations – DAOs), since users can have a say in governance by holding voting tokens.

Furthermore, DeFi offers investment opportunities for users, promising relatively high returns. In addition to cryptoassets, users can stake in digital tokens of physical assets, even without fully owning the physical assets. Due to the numerous investment options, users can easily diversify their portfolios. The non-custodial nature of DeFi gives investors total control over their assets, mitigating the risk of asset loss.

Unlike traditional finance, which relies on traditional market makers for liquidity, this is less of a problem in DeFi, where liquidity is enhanced by automated market makers (AMMs). In addition, by encouraging fractional ownership of assets via tokenization, liquidity in DeFi is further enhanced.

In DeFi, users are free to be flexible and make whatever financial decisions they want; there is no censoring of user transactions, and the risk of default is low due to the requirement of overcollateralization.

Finally, by providing alternative financial services, DeFi increases competition for conventional finance and; hence , improves the quality of the services it provides to customers.

DeFi has applications beyond financial realms. It also has real estate, supply chain management, and healthcare applications. This encourages cross-industry innovation.

Thanks to the numerous benefits of DeFi, it has gained acceptance and adoption in mainstream markets, thereby enhancing its legitimacy.

Risks and Challenges of Decentralized Finance and Risk Mitigation Strategies

Based on the 64 articles included in this study, the risks and challenges associated with DeFi are presented in Table 4. As Table 4 shows, there are numerous risks and challenges associated with decentralized finance (DeFi), as indicated in the existing literature. The most common risks and challenges of decentralized finance in Research by De-Fi systems are summarized in Table 5.

To begin with, there could be security issues related to vulnerabilities in smart contracts. If hackers exploit these vulnerabilities, users of DeFi platforms may lose both their money

Table 4

Risks and Challenges of Decentralized Finance

Risks and Challenges	**Sources**
1. Security Concerns, Smart Contract Vulnerabilities, Bugs, and Oracle Challenges	Patel and Shrimali (2021), Wu et al. (2023), Alsagheer et al. (2023), Kaur et al. (2023), Aspembitova and Bentley (2022), Xu et al. (2023a), Allen et al. (2022), Chiu et al. (2022), Shahbazi and Byun (2022), Grassi et al. (2022), Saengchote et al. (2023), Weingärtner et al. (2023), Barbereau and Bodó (2023), Andolfatto and Martin (2022), Bartoletti et al. (2022), Li and Shen (2022), Smith (2021), Vidal-Tomás et al. (2023), Ziegler and Zehra (2023), Kumari and Devi (2022), Schär (2021), Hassan et al. (2020), Tetiana et al. (2022), Zhao et al. (2022), Hameed (2019), Jensen et al. (2021), Schueffel (2021), Chen and Bellavitis (2020), Ozili (2022), Popescu (2020), Stepanova and Eriņš (2021), Zachariadis et al. (2019), Zetzsche et al. (2020), Xu and Feng (2022)
2. Regulatory Challenges and Uncertainties	Patel and Shrimali (2021), Wu et al. (2023), Mnohoghitnei et al. (2022), Dodmane et al. (2023), Burger and Weinmann (2022), Han et al. (2023), Kaur et al. (2023), Hickey and Harrigan (2022), Xu et al. (2023a), Allen et al. (2022), Axelsen et al. (2023), Saengchote (2023), Alamsyah and Syahrir (2023), Grassi et al. (2022), Weingärtner et al. (2023), Barbereau and Bodó (2023), Andolfatto and Martin (2022), Bartoletti et al. (2022), Smith (2021), Vidal-Tomás et al. (2023), Salami (2021), Kumari and Devi (2022), Yang (2022), Hameed (2019), Schueffel (2021), Chen and Bellavitis (2020), Ozili (2022), Popescu (2020), Momtaz (2022), Stepanova and Eriņš (2021)
3. Market Volatility	Song et al. (2023), Mnohoghitnei et al. (2022), Chiu et al. (2022), Bennett et al. (2023), Weingärtner et al. (2023), Smith (2021), Tetiana et al. (2022), Hameed (2019), Chen and Bellavitis (2020), Ozili (2022), Xu and Feng (2022), Kaur et al. (2023), Allen et al. (2022)
4. Scalability Issues and Low Transaction Throughput	Tsepeleva and Korkhov (2022), Alamsyah and Syahrir (2023), Yan and Zhou (2023), Kumari and Devi (2022), Schär (2021), Hameed (2019), Schueffel (2021), Zachariadis et al. (2019), Li and Shen (2022), Popescu (2020)
5. Privacy concerns/consumer protection risks	Wu et al. (2023), Alsagheer et al. (2023), Hickey and Harrigan (2022), Xu et al. (2023a), Allen et al. (2022), Chen and Bellavitis (2020), Zachariadis et al. (2019), Al-Shaibani et al. (2020)
6. Absence of Know Your Customer (KYC) Requirements /Ilicit Activities (Money Laundering, Tax Avoidance)	Wu et al. (2023), Allen et al. (2022), Barbereau and Bodó (2023), Salami (2021), and Schär (2021)
7. Composability Risks, Systemic Risks, and Single Point of Failure	Xu and Feng (2022), Kitzler et al. (2023), Saengchote (2023), Grassi et al. (2022), Saengchote et al. (2023), Weingärtner et al. (2023), Schär (2021), and Jensen et al. (2021)
8. Spillover and Contagion Risks	Schuler et al. (2023), Mnohoghitnei et al. (2022), Bennett et al. (2023)
9. Operational Risks	Mnohoghitnei et al. (2022), Kaur et al. (2023), Allen et al. (2022), Weingärtner et al. (2023), Tetiana et al. (2022)
10. Technological Complexity /UI Challenges	Song et al. (2023), Popescu (2020), Hassan et al. (2020), and Burger and Weinmann (2022)
11.	
12. Technological Constraints	Burger and Weinmann (2022), Kaur et al. (2023), Grassi et al. (2022), Weingärtner et al. (2023), Ozili (2022)
13. Immutability, Rigidity, and Inflexibility	Chen and Bellavitis (2020)

14. Governance Concentration/Low Voting Participation	Barbereau et al. (2023), Vidal-Tomás et al. (2023), Schär (2021), Jensen et al. (2021)
15. Concentration Risk/Reliance on Ethereum	Grassi et al. (2022)
16. Slippage and Impermanent Loss	Dodmane et al. (2023), Kaur et al. (2023), Xu et al. (2023a), Bartoletti et al. (2022), Kim et al. (2022)
17. High gas prices/fees	Dodmane et al. (2023), and Saengchote (2023)
18. Integration Challenges	Dodmane et al. (2023)
19. Adaptability Challenges	Hassan et al. (2020) and Song et al. (2023)
20. Network Congestion	Schuler et al. (2023), Jensen et al. (2021), Ozili (2022)
21. Property Rights Challenges	Andolfatto and Martin (2022)
22. Financial Illiteracy Risk, User Education, and Challenges in Widespread Adoption	Kaur et al. (2023), Stepanova and Eriņš (2021), Hameed (2019)
23. Liquidity Risk	Kaur et al. (2023), Allen et al. (2022), and Andolfatto and Martin (2022)
24. Lack of Shock Absorbers	Saengchote et al. (2023)
25. Strategic defaults and credit risk	Schuler et al. (2023), Kaur et al. (2023), and Allen et al. (2022)
26. Liquidation Risk	Tetiana et al. (2022)
27. Leverage Risk	Mnohoghitnei et al. (2022)
28. Reputational Risk	Weingärtner et al. (2023)
29. Inter-Platform Competition	Burger and Weinmann (2022)
Dependence on Large Network Size	Yan and Zhou (2023)
Algorithm-Human Balance Challenge	Grassi et al. (2022)
Risk of Insufficient Reserves for Back Stablecoins	Salami (2021)
Dependence on network monitoring	Li and Shen (2022)
Job Loss (Unemployment)	Ozili (2022)
Environmental Degradation (Energy Consumption and Carbon Emissions)	Han et al. (2023)

and trust in the system. To mitigate this risk, there should be improvements in smart contract coding, and the contracts' security should be audited at regular intervals. In addition, depending on oracles for data, there is always a risk that data inputs may be tampered with. This risk can be reduced by transitioning from centralized to decentralized oracles.

Second, the uncertainty surrounding the regulatory landscape of DeFi has impeded its growth and adoption. Regulatory arbitrage may also be encouraged due to heterogeneity in cross-country regulations. To address this problem, developers of DeFi platforms should engage with regulators, and regulators in different countries should collaborate to ensure homogeneity in DeFi regulations.

Third, reliance on the Ethereum blockchain introduces the problem of scalability for DeFi. DeFi platforms struggle to deal with too many transactions at a time, leading to network congestion and slowing transactions. To address these problems, DeFi platforms should transition to the Ethereum 2.0 blockchain, employ layer 2 scaling solutions, and/or leverage cross-chain solutions.

Table 5

Common Risks and Challenges in Decentralized Finance

Security risks
Due to their decentralized structure, questions arise about how DeFi organizations can properly manage and control customer data. It can lead to data leaks and fraud (Stein Smith, 2021). This increases the risk of potential exploitation of vulnerabilities, even if transparency is provided (Zatonatska et al., 2022). The security of DeFi systems depends on the secure programing and execution of smart contracts. Smart contracts are automated agreements executed on a blockchain, enabling secure transactions without the need for third parties. However, coding errors or vulnerabilities in such contracts can lead to significant losses. For example, smart contracts running on platforms like Ethereum can be vulnerable to attacks that could compromise user funds. Structures like decentralized autonomous organizations (DAOs) also face these risks (Andolfatto & Martin, 2022; Alsagheer, Xu & Shi, 2023). There are also re-entry vulnerabilities, block randomness, and overcharging vulnerabilities (Weingärtner et al., 2023). Analyzing transaction data and addresses can expose users' identities and transaction activities, jeopardizing individuals' privacy (Hickey & Harrigan, 2022). Patel and Shrimali (2023) mentioned security risks related to their developed systems and other systems. They suggested that to achieve security goals, such as integrity, non-repudiation, confidentiality, and authentication, integrity can be provided with hash functions, such as SHA-256, to ensure that data have not been altered, that an authorized entity has performed transactions by signing them with the sender's private key to ensure non-repudiation, that symmetric key encryption, such as AES, should be applied to protect confidentiality, and that the concept of digital signature should be implemented using algorithms, such as RSA, for authentication. Researchers have stated in their studies that by implementing these measures, these security goals have been achieved and maintained in both the shipment and insurance claim processes (Patel & Shrimali, 2023).
Price Volatility
DeFi often uses digital assets such as cryptocurrencies and tokens; thus, the financial services offered are highly volatile and subject to significant price fluctuations. Mnohoghitnei and colleagues also stated that the risks associated with DeFi are moderate. DeFi users may be exposed to significant financial risks, such as the possibility of losing investments or the value of their assets (Weingärtner et al., 2023). Many authorities warn consumers that the funds they invest in cryptocurrency may be lost. However, it has been noted that institutional investors' interest in cryptocurrency, including leverage use, has increased throughout 2021 (Mnohoghitnei, Horobet & Belascu, 2022) Price volatility is a significant risk factor in DeFi systems. In particular, cryptoassets often exhibit high price volatility (Stein Smith, 2021; Zatonatska et al., 2022). For example, stablecoins can be sensitive to sudden market changes and lose value. The value of a token can fluctuate depending on trading volume, supply, and demand, which pose significant risks for investors (Hickey & Harrigan, 2022). In collateralized debt cases, the collateral's value can be subject to sudden fluctuations, increasing liquidation risk. Fluctuations in prices also affect investors' and users' investment decisions (Andolfatto & Martin, 2022).
Regulatory Ambiguities
The decentralization of DeFi poses different challenges for regulators. The absence of a central authority makes it difficult to regulate and determine which laws apply in different cases. Additionally, regulatory uncertainties, such as KYC (Know Your Customer) and AML (Anti-Money Laundering) are difficult to enforce (Zatonatska et al., 2022; Stein Smith, 2021). DeFi protocols operate without being subject to traditional financial regulations; thus, there is a risk that their regulations are often not updated to suit these technologies. Products such as stablecoins lead to uncertainty about what standards regulators will apply and how these products will be audited (Andolfatto & Martin, 2022). It is difficult for regulators to monitor such systems. Lack of regulation or uncertainty makes the prevention of illegal activities and fraud difficult. Decentralized financial transactions like those experienced with the DAO and BSQ tokens, can allow users and projects to evade regulatory oversight, increasing legal risks (Hickey & Harrigan, 2022).
Scalability Issues and Low Transaction Throughput
An increase in the number of transactions in the Defi systems both prolongs the time required for transactions to be performed and slows down the network (Alamsyah & Syahrir, 2023). During periods of intense transactions, efficiency may decrease, and the network may slow down (Tsepeleva & Korkhov, 2022; Kumari & Devi, 2022; Alamsyah & Syahrir, 2023). Developers are researching expanding network connections and optimizing gas costs using multiple back-end nodes. If this is achieved, the efficiency of the blockchain may increase (Tsepeleva & Korkhov, 2022; Kumari & Devi, 2022).

Fourth, the high volatility of DeFi assets could cause investors to incur significant financial losses. Diversification and use of stablecoins could help mitigate this risk.

However, stablecoins are not without risks. There is always a risk of insufficient reserves to support stablecoins. If the stability of stablecoins is compromised, volatility may arise, potentially resulting in significant financial losses for investors. This concern can be addressed by regularly auditing and reporting reserves holdings, and audits and reports should be transparent.

Another disturbing issue with DeFi is privacy. The transparency of blockchain networks may compromise user privacy by exposing their information to other users. To tackle this challenge, users should be cautioned about the type of private information to provide. Very sensitive user information should not be required or requested on DeFi platforms, and new technologies should be geared toward protecting user privacy.

Again, illicit activities such as money laundering and tax evasion, have been predominant on DeFi platforms. This is because Know Your Customer (KYC) procedures are not required on DeFi platforms. This problem can be solved by incorporating ways to identify customers without compromising their privacy.

In addition, the composability of DeFi protocols introduces the risk of systemic failure, as vulnerabilities in one protocol may affect other protocols. Regular stress testing can help control this risk. Likewise, volatility spillovers could occur between DeFi markets due to their connectedness. Portfolio optimization can help investors construct optimal portfolios when investing across DeFi markets.

In addition, non-technical users may not feel comfortable navigating the complex interfaces of DeFi platforms, thereby preventing their adoption of DeFi. To prevent this from happening, platform developers should ensure that the interfaces are user-friendly and should provide user guides.

Blockchain immutability prevents the rectification of transactions errors. This rigidity and inflexibility may make it difficult to adapt to changing circumstances or correct any financial mistakes. To address this challenge, upgradable smart contracts could be employed, and the community (users) should be more involved in DeFi governance.

In terms of governance, there is the risk that power may be concentrated in a few wealthy token holders (voters). Although governance concentration may speed up the decision-making process, it may lead to centralized control, resulting in limited decision-making representation. Potential solutions include improved governance mechanisms, broad community participation, and unconcentrated voting power.

Furthermore, many DeFi platforms are built on the Ethereum blockchain, and overreliance on a single blockchain poses concentration risks, particularly posing challenges during network disruptions. In addition, any security vulnerabilities in the Ethereum blockchain will compromise the security of DeFi platforms. Other blockchain networks should also be employed to reduce dependence on the Ethereum blockchain.

In addition, over-competition between DeFi platforms may lead to aggressive strategies that may harm the ecosystem. To avoid this, DeFi platforms should be encouraged to collaborate and cooperate more; even when competing against each other, they should adhere to sustainable practices.

In addition, it is difficult to balance the use of algorithms and humans in DeFi. Suboptimal decisions may be made if human intervention is not sufficient. While relying significantly on algorithms to make decisions, this should be supplemented with human judgment, especially for critical issues.

Again, market fluctuations may result in slippage and impermanent losses for liquidity providers on DeFi platforms. Losses reduce returns for liquidity providers and may discourage liquidity provision in times of high volatility. To address these liquidity challenges, dynamic liquidity strategies should be employed, liquidity providers should be incentivized, and liquidity pools should be fostered across various assets.

Another DeFi risk is credit risk. DeFi loans are non-recourse , and there are limited means of enforcing loan repayments. This may cause users to strategically default on their loans (credit risk), resulting in financial losses for lenders. As a result, confidence levels drop, impacting the creditworthiness of decentralized lending platforms. Reputation-based lending systems, collateral management solutions, and responsible lending practices can help mitigate this risk.

Other risks in DeFi include leverage and liquidation risks. It is possible to take high leverage positions in DeFi. Excessive leverage may result in margin calls, and DeFi participants may face the risk of liquidating their collaterals in decentralized lending protocols if the collateral values fall below specified levels. This may result in users' financial or asset losses in volatile markets or during market downturns. Potential solutions include dynamic collateral management, clear risk disclosures, conservative leverage limits, conservative liquidation thresholds, and user education on responsible leveraging.

Finally, from a social perspective, the growth and widespread adoption of DeFi may lead to job losses in the traditional finance sector, raising unemployment concerns. Disintermediation in financial services could lead to a loss of traditional intermediary jobs, leading to financial difficulties. It would be helpful to encourage workers in the traditional finance sector to acquire digital finance skills.

Conclusion

While DeFi has revolutionized the traditional financial landscape, it offers a balance between benefits and risks. Regarding its advantages, DeFi increases accessibility to financial services and enhances financial inclusion. It ensures the transparency and accountability of financial transactions, drives innovation and economic growth, and ensures transaction security by leveraging the immutability of the blockchain network. On the other hand, DeFi faces various risks and challenges, such as smart contract vulnerabilities, regulatory uncertainties, market volatility, scalability limitations, and privacy concerns.

This balance of advantages and challenges means that policymakers and regulators must strike equilibrium in regulating the DeFi ecosystem in such a way that minimizes risks without stifling innovation. Proper risk minimization will reduce stakeholders' financial losses and regulatory backlash, while continuous innovation will ensure the sustainable growth and progress of DeFi.

Based on the findings, recommendations for developers, regulators, and investors were developed:

Developers: One of the important roles of developers is to minimize security risks in DeFi systems. Developers must constantly follow new technologies and implement the most secure and up-to-date encryption techniques. In addition, updates should be made continuously according to user feedback to identify security vulnerabilities in the system. Developers can prepare seminars and educational videos that contain detailed information about smart contract security to investors and regulators.

Regulators: To develop laws and standards, regulators must first understand the logic and execution of DeFi systems. Regulators can learn the process and system in detail by collaborating with DeFi technology experts. International laws and protocols should be considered when developing laws and standards, and joint work should be carried out if necessary.

Investors: There are a few important points that investors should pay attention to in order to reduce security risks. First, they should undergo a detailed evaluation process for their investment projects. Who are the project supporters? How long has the project been in operation? They should answer such questions and conduct an analysis. Investors should constantly conduct security assessments to secure their DeFi systems. In addition, encryption technologies change constantly. The most innovative encryption techniques should be followed, and secure ones should be used.

Researchers can follow new technologies related to encryption techniques and conduct studies to determine their strengths and weaknesses. In addition, stress tests can be designed to determine the level of liquidity concerns of investors and guide other stakeholders. To add-

ress scaling challenges, research can be conducted to create technological solutions that will increase network speed and balance gas costs.

This study is not without limitations. First, only the Scopus database was used to search for relevant articles. Although the comprehensive coverage of the Scopus database is appreciated, the comprehensiveness of the Scopus database could be enhanced by searching for articles from other reliable databases. Second, this study's findings were obtained from only the 64 articles selected after the final screening stage. There is a risk of bias because the findings may reflect only the views presented in the 64 selected articles. Moreover, not all potential risks and challenges associated with DeFi have been identified. As the DeFi space evolves at a very rapid pace, new risks and challenges that are beyond the analyses conducted in this study will emerge.

To address the identified limitations of our study, we propose that future researchers try answering the research questions by searching for relevant articles from a wide range of databases to ensure comprehensiveness and possibly capture all the benefits and risks of DeFi discussed in the literature. Also, data sources should extend beyond scholarly articles to include industry reports, interviews, other primary sources, and real-world data. Practically, we recommend that practitioners integrate the risk-mitigation insights we have presented in this study and have comprehensive and effective risk management frameworks to deal with the numerous risks associated with DeFi.

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