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RESEARCH PROGRESS ON DECENTRALIZED FINANCE

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Abstract: Decentralized Finance (DeFi) has emerged as one of the most transformative applications of blockchain technology, constructing a financial ecosystem that operates without traditional intermediaries through smart contracts and distributed protocols. This paper systematically reviews the research progress of DeFi in terms of technical architecture, core protocols, governance models, and application scenarios, with particular focus on analyzing key domains including lending platforms, decentralized exchanges, stablecoin mechanisms, and asset tokenization. Research indicates that although DeFi demonstrates revolutionary potential in enhancing financial inclusion and transaction efficiency, it still faces significant challenges in smart contract security, regulatory compliance, and systemic risk prevention. This paper further explores future research directions including the integration of DeFi with traditional finance, technological innovation, and real-world asset integration, providing reference for scholars, policymakers, and industry participants to understand this rapidly evolving field.
Keywords: Decentralized finance; Blockchain; Smart contracts

1 INTRODUCTION

Decentralized Finance, commonly abbreviated as DeFi, represents a revolutionary movement aimed at creating a financial system that operates independently of traditional intermediary institutions through code-based protocols on blockchain networks. DeFi can be defined as a financial service system constructed through blockchain and smart contract technology that operates without traditional financial intermediaries [1,2]. As of 2024, the DeFi sector has experienced significant growth, with Total Value Locked (TVL) reaching hundreds of billions of dollars, reflecting robust market demand for decentralized financial services.

The core innovation of DeFi lies in its ability to provide financial services free from centralized control, using blockchain-based protocols to automatically execute agreements between parties. These services span a wide range of domains, including lending, trading, asset management, insurance, and derivatives [3]. Unlike traditional finance, which relies on intermediaries such as banks, brokers, and clearinghouses, DeFi automates transaction execution through smart contracts deployed on blockchains, enabling asset transfers and contract fulfillment without third-party intervention when preset conditions are triggered [4,5].

Academic interest in DeFi has grown substantially, echoing the field's explosive market expansion. Academic attention to DeFi continues to increase, with related research growing from 2 publications in 2010 to 157 in 2024, covering multiple dimensions including technological innovation, economic impact, and regulatory policy [1,2]. This academic attention points to both technological innovation and the broader economic implications of this emerging financial paradigm.

Research on DeFi spans multiple levels of abstraction. Meyer et al. categorize it into micro, meso, and macro perspectives [1]. At the micro level, research focuses on specific protocols and their mechanisms; the meso level examines interactions between different DeFi components; while the macro level addresses systemic impacts, regulatory considerations, and integration with the broader financial ecosystem.

2 TECHNICAL FOUNDATIONS OF DEFI

2.1 Blockchain and Smart Contracts

The fundamental technological infrastructure of DeFi consists of blockchain networks and smart contracts. Blockchain technology provides a distributed, immutable ledger that records all transactions without requiring trusted intermediaries. Smart contracts—self-executing agreements with terms written directly into code—automate financial processes, eliminating dependence on traditional intermediaries [5].

Research has particularly focused on Ethereum as the primary blockchain platform for DeFi development. Meyer et al. found that Ethereum is the predominant blockchain focus in DeFi literature they reviewed [1]. This dominance stems from Ethereum's early support for complex smart contracts, enabling developers to create sophisticated financial applications that go beyond simple value transfers.

Smart contracts in DeFi enable core functions including financial process automation, intermediary removal, and asset self-custody [4,5]. Their immutability ensures deterministic execution of code logic, reducing counterparty risk.

2.2 DeFi Protocol Architecture

DeFi protocols employ a layered architectural design: the bottom layer consists of blockchain platforms providing immutable distributed ledgers; the middle layer comprises smart contracts encoding financial logic and transaction rules; and the application layer consists of decentralized applications (dApps) serving as interfaces for user interaction with protocols [5]. This modular architecture enhances system composability and scalability. Blockchain platforms store all transactions as decentralized and immutable digital ledgers. Decentralized applications serve as interfaces connecting users with underlying protocols, while smart contracts execute rules governing financial activities.

Research has identified several distinct categories of DeFi protocols based on functionality, including lending platforms, decentralized exchanges (DEXs), stablecoins, yield farming protocols, and insurance platforms [3,6]. Each protocol type implements specific mechanisms to address particular financial needs while maintaining the core DeFi principles of decentralization and transparency.

3 KEY RESEARCH AREAS IN DEFI

3.1 Decentralized Lending Platforms

Decentralized lending is one of the most researched and developed areas in DeFi. Unlike traditional lending systems that rely on credit checks and borrower assessments, DeFi lending operates through over-collateralized loans managed by smart contracts [7]. This allows anonymous borrowers to access capital by pledging crypto assets as collateral, while lenders contribute to liquidity pools and earn interest from deposits.

Research indicates that DeFi lending protocols (such as Aave and Compound) exhibit the following characteristics [7]: First, both borrowers and lenders require no identity verification, with users interacting with liquidity pools rather than directly matching counterparties; second, they employ over-collateralization mechanisms to manage credit risk, requiring borrowers to provide crypto assets worth more than the loan amount as collateral; third, interest rates and liquidation processes are automatically executed by smart contracts according to preset algorithms.

However, DeFi lending systems exhibit structural vulnerabilities. Due to the rigid execution characteristics of smart contracts and information asymmetries among market participants, systems may exhibit multiple equilibrium states, triggering cascading liquidations and liquidity crises under extreme market conditions [7]. These findings emphasize the complex interactions between DeFi protocol design and market dynamics.

3.2 Decentralized Exchanges (DEXs)

Unlike the order book matching mechanisms of centralized exchanges, mainstream DEXs (such as Uniswap and Curve) employ Automated Market Maker (AMM) models that dynamically adjust asset prices through constant function formulas. Liquidity providers inject token pairs into pools, traders interact with pools to complete exchanges, and prices are automatically determined by the ratio of assets within the pool [4].

Research emphasizes the advantages of DEXs in eliminating intermediaries, enabling faster and more cost-effective trading through liquidity pools where users can contribute assets and earn fees from transactions [4]. DEXs also feature atomic settlement, ensuring that transactions either complete fully or not at all, reducing partial execution risk and enhancing security.

Pantera Capital notes that innovation in DEXs is concentrated on improving user experience, including developing better wallet interfaces, providing advanced features for sophisticated users, and mobile-first trading applications [8]. These improvements aim to address technical barriers that have historically limited DEX adoption relative to centralized alternatives.

3.3 Stablecoins in DeFi

Stablecoins—cryptocurrencies designed to maintain price stability—play a critical role in the DeFi ecosystem. Stablecoins can be categorized based on collateralization mechanisms into fiat-backed (such as USDT and USDC), crypto-collateralized (such as DAI), and algorithmic types. Fiat-backed stablecoins are custodied by centralized institutions holding fiat assets, while decentralized stablecoins manage on-chain collateral assets through smart contracts, achieving transparent operations [9,10].

Paxos research emphasizes the fundamental role of stablecoins in DeFi, noting that they provide the price stability necessary for trading, lending, and borrowing within DeFi platforms [10]. Stablecoins serve multiple functions in the DeFi ecosystem, including providing liquidity, stable value storage, facilitating lending, and enhancing smart contract execution through stable units of account [10].

The importance of stablecoins to DeFi stems from their ability to mitigate the inherent volatility of traditional cryptocurrencies, making them suitable for daily financial transactions and as a medium of exchange within DeFi protocols. Research indicates that integration between stablecoins and DeFi creates a powerful combination, leveraging their complementary strengths to create more robust financial ecosystems [10].

3.4 Asset Tokenization

On-chain tokenization of Real World Assets (RWA) provides new collateral types and investment targets for DeFi [3, 11]. Compared to traditional securities trading that requires settlement processes involving multiple parties such as

brokers and clearinghouses, tokenized assets achieve near-instantaneous clearing and settlement through smart contracts, with transparent on-chain disclosure of holdings and transaction information, reducing operational costs and counterparty risk [4].

4 GOVERNANCE MODELS IN DEFI

4.1 Decentralized Autonomous Organizations

Decentralized Autonomous Organizations (DAOs) have become the primary governance structure for DeFi projects. Research by Bacharach et al. describes DAOs as "organizations that utilize governance tokens to distribute power among community members, granting them voting rights over organizational management and decision-making" [2]. This governance model aims to align with DeFi's core principles of decentralization and community control.

Mainstream DeFi protocols (such as MakerDAO, Compound, and Uniswap) commonly employ token-weighted voting mechanisms: governance token holders can initiate proposals and vote on matters including protocol parameter adjustments, fund allocation, and technical upgrades, with voting weight typically proportional to token holdings [2]. This mechanism aims to decentralize decision-making authority to the community but also raises concerns about whale control and insufficient voting participation.

5 CHALLENGES AND RISKS IN DEFI

5.1 Security Vulnerabilities

Security represents one of the most significant challenges in DeFi research. While smart contracts provide automation and transparency, they are vulnerable to exploits and attacks that can result in substantial financial losses. Security incidents including smart contract vulnerabilities, cross-chain bridge attacks, and private key leaks occur frequently. Research documents multiple major security incidents, such as Poly Network losing over 600million in 2021 due to cross−chain contract vulnerabilities, and DeFi sector losses reaching 1.5 billion in 2024 due to security vulnerabilities and fraud [4].

Academic research emphasizes the importance of comprehensive security audits and multiple intervention mechanisms to reduce single points of failure in DeFi protocols [4]. However, the immutability of blockchain-based smart contracts creates unique security challenges, as deployed code typically cannot be modified even when vulnerabilities are discovered.

5.2 Regulatory Challenges

Regulatory uncertainty represents a significant challenge to DeFi development and adoption. Research in the World Journal of Advanced Research and Reviews emphasizes that DeFi faces challenges including "regulatory uncertainty, security issues, and scalability problems" [12]. This regulatory ambiguity affects how DeFi protocols operate and develop within existing legal frameworks.

The cross-border, anonymous, and disintermediated characteristics of DeFi pose challenges to traditional regulatory frameworks. Major regulatory difficulties include: difficulty identifying responsible parties, Anti-Money Laundering/Counter-Terrorist Financing (AML/CFT) compliance difficulties, absence of investor protection mechanisms, and cross-jurisdictional coordination issues [12,13]. Regulators need to strike a balance between preventing systemic risks and maintaining technological innovation vitality.

5.3 Scalability and Interoperability

Scalability limitations and interoperability challenges represent significant technical barriers to DeFi adoption. Pantera Capital's research identifies advances in Layer 2 solutions, such as Optimistic Rollups and zk-Rollups, as key developments addressing DeFi scalability issues [3]. These solutions aim to improve transaction efficiency and reduce costs, thereby expanding DeFi's appeal.

Cross-chain functionality has become an important research direction for addressing interoperability challenges. Pantera Capital notes that "the development of cross-chain technology is enabling users to interact seamlessly across various blockchain platforms, enhancing liquidity and overall system efficiency" [3]. This research suggests that interoperability is critical for DeFi's continued growth and integration with the broader financial system.

6 FUTURE RESEARCH DIRECTIONS

6.1 Integration with Traditional Finance

Research indicates significant potential for integration between DeFi and traditional financial systems. Research shows that the convergence of DeFi and Traditional Finance (TradFi) is accelerating, with hybrid financial products (such as compliant tokenized securities and permissioned DeFi protocols) combining DeFi's transparency with traditional finance's regulatory compliance [3,11]. Institutional investor participation in DeFi has increased significantly, bringing

more abundant liquidity and more mature risk management practices to the market. This institutional participation may significantly increase liquidity in DeFi markets and accelerate integration with traditional finance.

6.2 Technological Innovation

Research highlights several technological innovations that may shape the future of DeFi. Emerging technological directions include: Zero-Knowledge Proofs for enhanced privacy protection, AI-assisted on-chain risk assessment, and Account Abstraction for improved user experience [4]. The maturation of Layer 2 scaling solutions (such as Optimistic Rollups and zk-Rollups) is expected to significantly reduce transaction costs and increase throughput [3].

6.3 Real World Asset Integration

Tokenization of RWAs has become an important research direction for DeFi. Pantera Capital identifies this trend as a factor enabling more sustainable yields in DeFi applications [8]. This research suggests that RWA integration may help DeFi evolve beyond purely cryptocurrency-based applications toward broader financial use cases.

RWA tokenization is a critical bridge connecting traditional finance with DeFi but faces challenges including legal property rights definition, asset valuation, and oracle reliability [1,8]. Core research questions in this field include: how to reliably introduce off-chain real asset data into smart contracts through oracles, and how to achieve compliant asset custody in decentralized environments.

7 CONCLUSION

This paper systematically reviews the technical architecture, core protocols, governance mechanisms, and application practices of decentralized finance, revealing DeFi's innovative value in reconstructing financial service paradigms. Research indicates that DeFi achieves the removal of financial intermediaries, automation of transaction processes, and transparency in asset management through smart contracts, forming a rich application ecosystem in lending, trading, stablecoins, and asset tokenization. However, smart contract security, regulatory compliance, and systemic risk remain key bottlenecks constraining DeFi's scaled development. Future research needs to focus on cross-chain interoperability, privacy-preserving technologies, Regulatory Technology (RegTech) adaptation, and deep integration of DeFi with traditional finance to promote decentralized finance toward maturity and sustainable development.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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