Research paper / Оригинальная статья
https://doi.org/10.51176/1997-9967-2024-4-20-37
МРНТИ 44.01.11
JEL: G23, G28, O33

Sustaining Innovation and Regulation: The Eco-System of Decentralized and Centralized Finance

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For citation: Mergaliyeva, L.I. & Primbetova, S.C. (2024). Sustaining Innovation and Regulation: The Eco-System Of Decentralized And Centralized Finance. Economics: the strategy and practice, 19(4), 20-37, https://doi.org/10.51176/1997-9967-2024-4-20-37

ABSTRACT

This study examines the ongoing debate between Decentralized Finance (DeFi) and Centralized Finance (CeFi), analysing their unique advantages and challenges within the rapidly evolving financial landscape. The objective of this research is to argue for the convergence of DeFi and CeFi to create an innovative and secure financial ecosystem that balances accessibility with security, using Kazakhstan as a case study. The study employs comparative analysis and case-study methodology to explore Kazakhstan's regulatory approach to digital assets. The focus is on understanding how licensing, anti-money laundering (AML) protocols, and consumer protection measures can support the integration of DeFi and CeFi. Primary data includes an analysis of Kazakhstan's regulatory framework for digital assets, statistical data on AML implementation, and levels of consumer protection within the country. Findings indicate that a hybrid regulatory model effectively bridges the operational differences between DeFi and CeFi, fostering inclusivity and economic growth while safeguarding consumer interests. Kazakhstan's regulatory focus on licensing and AML protocols illustrates that a balanced regulatory approach can accommodate both technological progress and necessary protections for financial participants. The study concludes that a convergence of DeFi and CeFi through a hybrid regulatory model can lay the foundation for a sustainable digital financial environment that is accessible, innovative, and secure. Future studies are encouraged to explore the role of emerging technologies, such as quantum computing, and examine the socio-economic impacts of DeFi-CeFi integration on financial inclusivity for underserved populations.

KEYWORDS: Decentralized Finance, Centralized Finance, Blockchain Technology, Cryptocurrency Mining, Economic Sustainability, Regulatory Compliance, Financial Technology, Digital Economy

CONFLICT OF INTEREST: the authors declare that there is no conflict of interest

FINANCIAL SUPPORT: The study was not sponsored (own resources)

Article history:
Received 18 July 2024
Accepted 15 December 2024
Published 30 December 2024

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Устойчивые инновации и регулирование: эко-система децентрализованных и централизованных финансов

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Для цитирования: Мергалиева Л.И., Примбетова С.Ч. (2023). Устойчивые инновации и регулирование: эко-система децентрализованных и централизованных финансов. Экономика: стратегия и практика, 19(4), 20-37, https://doi.org/10.51176/1997-9967-2024-4-20-37

АННОТАЦИЯ

Данное исследование посвящено продолжающейся дискуссии между децентрализованными финансами (DeFi) и централизованными финансами (CeFi), с акцентом на анализ их уникальных преимуществ и вызовов в условиях стремительно меняющегося финансового ландшафта. Целью исследования является обоснование необходимостм конвергенции DeFi и CeFi для создания инновационной и безопасной финансовой экосистемы, которая сочетает доступность и безопасность, используя Казахстан в качестве примера. В исследовании используется метод сравнительного анализа и метод кейс-стади для изучения подхода Казахстана к регулированию цифровых активов. Основное внимание уделяется вопросам лицензирования, реализации протоколов противодействия отмыванию денег (AML) и защите прав потребителей как ключевым факторам интеграции DeFi и CeFi. В качестве первичных данных используется анализ регуляторной базы Казахстана в области цифровых активов, а также статистические показатели внедрения AML-протоколов и уровня защиты потребителей. Результаты исследования показывают, что гибридная регуляторная модель эффективно устраняет различия в операционной деятельности DeFi и CeFi, способствуя инклюзивности и экономическому росту при защите интересов потребителей. Регуляторный акцент Казахстана на лицензировании и протоколах AML демонстрирует, что сбалансированный подход к регулированию может учитывать как технологический прогресс, так и необходимость защиты финансовых участников. Исследование делает вывод, что конвергенция DeFi и CeFi через гибридную регуляторную модель может заложить основу для устойчивой цифровой финансовой среды, которая будет доступной, инновационной и безопасной. В качестве перспективных направлений для дальнейших исследований рекомендуется изучение роли передовых технологий, таких как квантовые вычисления, а также анализ социально-экономических последствий интеграции DeFi и CeFi в контексте повышения финансовой инклюзивности для недостаточно обслуживаемых групп населения.

КЛЮЧЕВЫЕ СЛОВА: стратегия, децентрализованные финансы, централизованные финансы, блокчейн-технологии, майнинг криптовалют, экономическая устойчивость, соблюдение нормативных требований, финансовые технологии, цифровая экономика

КОНФЛИКТ ИНТЕРЕСОВ: авторы заявляют об отсутствии конфликта интересов

ФИНАНСИРОВАНИЕ: Исследование не спонсировалось (собственные ресурсы).

История статьи:
Получено 18 июля 2024
Принято 15 декабря 2024
Опубликовано 30 декабря 20224

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INTRODUCTION

The global financial system is a more extensive regional system involving all financial institutions, borrowers, and lenders within the global economy. This includes the International Monetary Fund, central banks, government treasuries and monetary authorities, the World Bank, and significant private multinational banks globally (Casey et al., 2018; Ricks, 2019). Collectively, these organizations maintain systemic risk, financial stability, system frictions, interoperability, financial condition, openness or illicit activity. The regulation of money movement remains a critical concern for governments due to the need for transparency, and oversight in financial transactions. Kazakhstan as a part of the global financial system involved in the interplay of enduring development.

Money and finance have evolved with human history (Reinert, 2009; Goetzmann, 2016). Recently, according to authors, the monetary base comprises currency and commercial bank reserve deposits at the central bank (Miles et al., 2012). The critical feature of this type of money is that the central bank can only create it, giving the central bank a fundamental role in the monetary system. Cryptography is a new money that has evolved to address the increasing need for data security in an interconnected world. Michael Bordo stated that monetary transformations in history were motivated by changing technology, altering tastes, economic growth, and the need to satisfy the purposes of money effectively (Bordo & Levin, 2017). Thus, the transformation and development of new forms of money, cryptocurrencies (Bitcoin, Ethereum), stable coins (Libra, Diem), and central bank digital currencies (Bahamian sand dollar) are popular topics to discuss (Schuler et al., 2024; Park et al., 2022). Here, it is a definition of fundamental change to the financial system as the money has no longer been issued by the central bank but instead by a private company or a peer-to-peer network, such as Bitcoin.

A complex centralised global financial system today and its early forms in the past are supposed to ensure stability nationally and globally. However, the world has seen a wide variety of economic and financial crises in the last 180 years, including the crisis in Europe and Latin America in 1825, Argentina in 1890, Europe, North America, Latin America, and Asia in 1907, the Great Depression, and the Emerging markets crisis in 1981, Sovereign debt crisis s in the 1980s, Japanese problem in 1991, Mexican crisis in 1994, the Asian crisis in 1997, as well as Global financial crisis in 2008. Before the 2008 recession, popular thinking said globalization, better technology, and sophisticated monetary policy would prevent an economic collapse (Obstfeld & Rogoff, 2009). Recently, the world has gone through an economic crisis driven by the pandemic, the war in Ukraine, and inflation. The trust and credit for the banking system have been partially lost during crises.

This study aims to provide an introduction to the cryptocurrency system and present a comparative analysis of decentralized and centralized systems.

LITERATURE REVIEW

In parallel, over recent years, the banking sector has observed the influence of disruptive financial technologies (further – FinTech), yet it has been transforming significantly (Adrian & Mancini-Griffoli, 2019). The banking industry has witnessed a massive growth of new cryptocurrencies and the usage of blockchain technology. Unquestionably, DeFi is becoming the new edge with its potential to renovate global finance. Since Defi has the same functions as traditional money in contrast to Fintech, cryptocurrencies have an excellent chance to start taking a significant role. The Defi is a new power: transactions are direct, trustable, efficient, low-cost, and permissionless.

The root of the current cryptocurrencies is removing a central system and building a trust-free system, meaning the participants do not need to trust anyone. Not the people who made it, not the people who use it, and not those who abuse it (Dingle, 2018). However, this shift also brings significant challenges, particularly regarding security, accountability, and regulatory compliance.

CeFi operates within established regulatory frameworks designed to ensure market stability, protect consumers, and build trust. CeFi has licensed operators such as banks, pension funds, insurance companies, and other institutions. Each organization records, stores, manages client data and decides the security system and privacy policy. The traditional financial ecosystem is represented by financial regulators, institutions, instruments, participants, and markets: FX, derivatives, money, and capital. While CeFi institutions provide a sense of security and reliability, they often lag in adopting innovative technologies and struggle with issues of accessibility and transparency. The dichotomy between DeFi and CeFi presents a complex landscape where innovation must be balanced with the need for regulation and ethical considerations. There is a need for studies that explore how these two systems can coexist and interoperate efficiently. This includes understanding the technical, legal, and regulatory implications of

such integration and developing frameworks that facilitate seamless interaction between decentralized and centralized financial services (Park et al., 2022). The application of regulatory technology (RegTech) to monitor and enforce compliance in DeFi and CeFi is an emerging field that lacks sufficient research.

The rapid rise of cryptocurrency mining has had profound geopolitical and infrastructural impacts, particularly in regions like Kazakhstan. Estecahandy (2024) explores the geopolitical dynamics of cryptocurrency mining in Kazakhstan, linking a massive power blackout in January 2022 to the energy-intensive nature of mining activities. The study highlights the double territorial divide and the involvement of illicit networks, providing a comprehensive analysis of the political and infrastructural challenges.

Schuler et al. (2024) address the complexities of shock propagation in crypto-asset markets, particularly in the integration of conventional financial institutions (CeFi) and decentralized financial protocols (DeFi). They extend the well-established framework by Eisenberg and Noe (2001) to mixed DeFi/CeFi networks, providing a tool to understand potential contagion channels and loss redistribution. Their model helps regulators and policymakers comprehend the risks associated with the non-recourse nature of DeFi loans and the integration of CeFi and DeFi systems, emphasizing the need for comprehensive regulatory approaches to manage these risks effectively. Despite the significant advancements and potential benefits of DeFi financial systems, there remains a critical research gap in understanding how to effectively regulate them to ensure stability, security, and consumer protection.

One of the primary research gaps is the absence of comprehensive regulatory frameworks that can address the unique characteristics of DeFi and CeFi. DeFi, with its decentralized nature, operates without intermediaries, making traditional regulatory approaches less effective. Existing regulations are primarily designed for centralized entities, leaving a gap in managing decentralized protocols that operate globally and beyond any single jurisdiction's reach (Schuler et al., 2024). This paper aims to provide an introduction to the cryptocurrency system and presents a comparative analysis of decentralized and centralized systems. By examining the structural differences, regulatory environments, and implications for economic control, this research seeks to elucidate the potential impacts and future trajectory of cryptocurrencies in the global financial system.

There is an ongoing debate regarding the extent to which governments should be informed about personal transactions facilitated by cryptocurrencies. For example, a transaction between people might not be visible to the sovereign governments involved. This level of privacy is inherent to cryptocurrencies, which are designed to enable direct, straightforward, and instantaneous transactions (Dingle & Sidley, 2022). This raises important questions about the balance between privacy and regulatory oversight, as cryptocurrencies can ensure frictionless personal transactions while potentially circumventing traditional regulatory mechanisms. The challenge lies in determining whether and to what extent such private transactions should be subject to governmental scrutiny, considering both the benefits of privacy and the need for compliance with financial regulations.

In the future, quantum computing will push the human race to a new era of more advanced technologies (Mosca & Piani, 2021). The economic impact of cryptocurrencies extends beyond cybercrime to broader financial markets. Kumar et al. (2023) examine the interconnectedness of commodities, cryptocurrencies, and G20 capital markets during the COVID-19 pandemic and the Russian-Ukraine war. Their study reveals significant volatility spillovers, highlighting the multidimensional impacts of economic and political disorders on global markets. This research is crucial for understanding the broader economic implications and guiding investment and hedging strategies. Efficiency and security in cryptographic implementations are critical for practical applications. Alimzhanova et al. (2023) provide a comparative analysis of different AES block cypher modes. By investigating the periodicity and complexity of ciphertext properties, their study offers insights into the optimal use of AES in various scenarios. This research is essential for improving the practical security of AES implementations.

Beisembay and Ernazarov (2021) examined the foundational economic and organizational changes necessary to build a robust digital economy, emphasizing the need for investments in infrastructure, innovation, and collaborative policies among government, industry, and academia. Meanwhile, Moldabekova et al. (2021) focus specifically on the logistics sector, highlighting how digital technologies aligned with Industry 4.0 such as automation and data analytics—can enhance efficiency and integrate Kazakhstan more seamlessly into global supply chains. Together, these studies illustrate both the immense potential and the challenges of Kazakhstan's digital transformation, showing that while digital tools can drive competitiveness and economic growth, success will require addressing infrastructure gaps, skill shortages, and regulatory support. The study by Gumar et al. (2023) investi-

gated how digital technologies are transforming the banking sector. This research provides both quantitative and qualitative assessments of how digital advancements influence banking efficiency, specifically focusing on the Kazakhstan context. The authors highlight the dual benefits of digital technology in enhancing service quality and operational efficiency within banks, while also addressing challenges such as digital inequality and cybersecurity risks. This study underscores the importance of a balanced approach to digital transformation in finance, emphasizing both innovation and regulatory safeguards.

The research by Benarous et al. (2024) and Kaiyp et al. (2023), highlighted the dynamic shifts occurring in Kazakhstan's financial sector through the integration of advanced technologies like blockchain, data mining, and digital banking tools. Benarous et al. (2024) examined the macroeconomic effects of blockchain on the stock market, suggesting that blockchain's transparency and efficiency could significantly alter market operations and influence financial stability. This study opens up questions about the regulatory adjustments needed to accommodate blockchain's growing role in the economy. Complementing this, Kaiyp et al. (2023) focus on data mining methods in trade, emphasizing how these techniques can enhance decision-making and operational efficiency. Their work underscores the potential for data-driven insights to reshape commerce, pushing Kazakhstan's trade sector toward greater competitiveness.

Thus, regarding our above review, the recent research into decentralized finance (DeFi) and centralized finance (CeFi) has uncovered significant insights into these systems' technological, regulatory, and security dimensions. Despite intense research in the area, there are gaps, particularly in the realm of regulatory frameworks. Existing regulations, primarily designed for centralized financial systems, are inadequate for addressing the unique characteristics of decentralized protocols that operate without intermediaries and often cross jurisdictional boundaries. Furthermore, the dual role of cryptocurrencies as both economic tools and instruments for illegal activities underscores the urgent need for robust regulatory frameworks and consumer protection mechanisms, which are currently underdeveloped. These gaps hinder effective management and oversight of DeFi systems and contribute to vulnerabilities in consumer protection. Additionally, integrating DeFi and CeFi systems presents complex challenges requiring further exploration. There is a need to extend existing frameworks to understand shock propagation and risk dynamics in mixed DeFi/CeFi networks, emphasizing the need for sophisticated regulatory approaches. The ongoing debate surrounding privacy versus regulatory oversight complicates the regulatory landscape. Future research must address these gaps by developing comprehensive regulatory frameworks, enhancing consumer protection, and improving the integration of decentralized and centralized financial systems to ensure a balanced and stable financial ecosystem.

The literature review reveals substantial progress in DeFi and CeFi research, particularly concerning their technological, regulatory, and security aspects. However, it identifies a key research gap: existing regulatory frameworks largely fail to address the unique demands of DeFi, which operates without centralized intermediaries. This gap underscores the need for a hybrid regulatory approach that can balance the transparency and accessibility of DeFi with the stability and consumer protection offered by CeFi. Accordingly, this study aims to explore how such an integrated regulatory model can function effectively, using Kazakhstan's evolving regulatory environment as a case study.

METHODOLOGY

This study adopts a qualitative research design, combining literature synthesis, case study analysis, and secondary data examination to explore the integration of DeFi and CeFi within a hybrid regulatory framework (Merriam & Tisdell, 2015). By focusing on Kazakhstan as a primary case, this research provides insights into how emerging economies can balance technological advancements with regulatory requirements (Stake, 1995; Eisenhardt, 1989). The research utilizes a qualitative methodology to capture nuanced insights into the regulatory environment for DeFi and CeFi. This approach is particularly well-suited for examining social and economic variables in dynamic contexts, where regulatory frameworks are still evolving (Creswell & Poth, 2013; Bryman, 2016). It allows for an in-depth exploration of complex socio-economic factors, regulatory structures, and technological impacts within the financial sector, which quantitative approaches might fail to capture effectively (Denzin, 2017).

The methodology framework for this research is represented in a flowchart that visually outlines the sequential steps undertaken to analyze the integration of Decentralized Finance (DeFi) and Centralized Finance (CeFi) within Kazakhstan. The flowchart starts with defining the Research Objective, which sets the foundation for the entire study. The main aim here is to determine how DeFi and CeFi can be effectively integrated within Kazakhstan's financial system. This objective serves as the anchor for all subsequent steps, ensuring that every methodological decision is aligned with the study's core purpose.

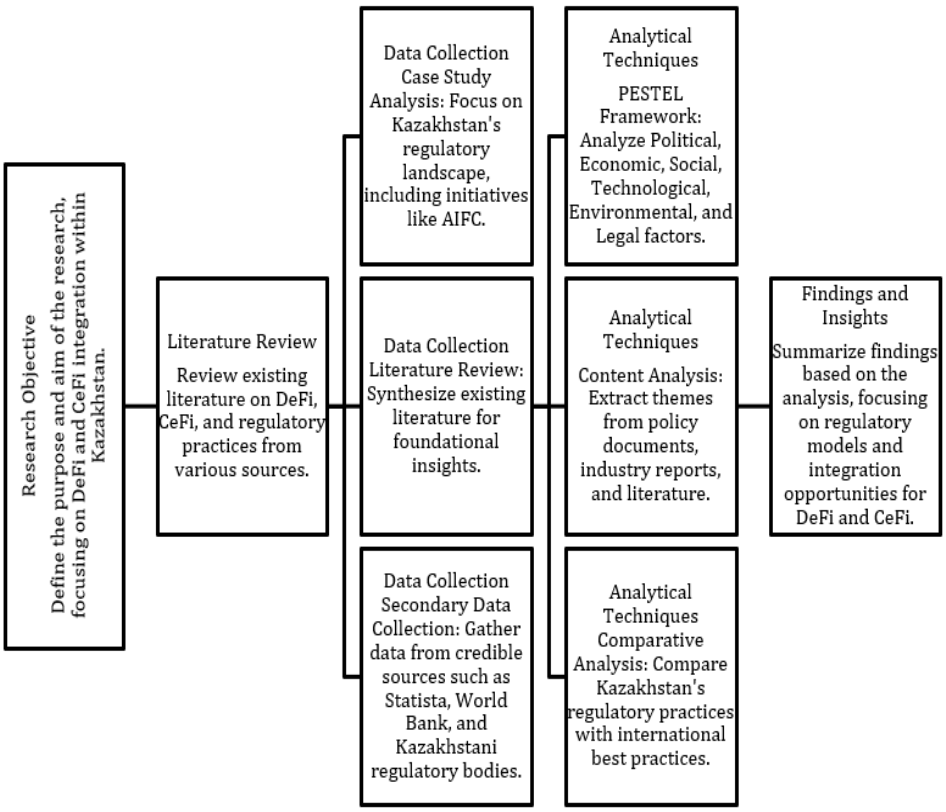

Figure 1. Research Design and Methodology for DeFi-CeFi Convergence

Note: complied by authors

Following the establishment of the research objective, a Literature Review is conducted to build a theoretical basis (Tranfield et al., 2003). This involves examining existing academic work and industry reports on DeFi, CeFi, and regulatory practices. The literature review helps to identify the current trends, opportunities, and challenges associated with these financial technologies. This stage is crucial for providing context, understanding previous research, and revealing any existing gaps that this study can address.

The Data Collection process is divided into three complementary aspects. First, Case Study Analysis focuses specifically on Kazakhstan's financial regulatory environment, including initiatives like the Astana International Financial Centre (AIFC). This localized approach provides depth, enabling a nuanced understanding of how Kazakhstan is attempting to navigate the integration of DeFi and CeFi. The second aspect, Secondary Data Collection, involves gathering information from credible sources such as Statista, the World Bank, and Kazakhstan's regulatory bodies. This ensures the study is grounded in up-to-date and reliable data. The third aspect, Literature Review for Data Synthesis, involves synthesizing existing literature to extract key insights that support the empirical findings. Together, these components provide a comprehensive data collection approach that encompasses both qualitative and quantitative elements.

The next phase involves applying Analytical Techniques to interpret the collected data. The PESTEL Framework is employed to analyze the macro-environmental factors that influence DeFi and CeFi in Kazakhstan. Specifically, it considers Political, Economic, Social, Technological, Environmental, and Legal aspects, which collectively provide a holistic view of the opportunities and challenges faced in integrating these financial systems. Comparative Analysis is also conducted to benchmark Kazakhstan's regulatory practices against international standards, highlighting both strengths and areas for improvement. Additionally, Content Analysis is performed on policy documents, industry reports, and literature, which allows the extraction of relevant themes related to regulatory challenges, consumer protection, and technological adoption (Krippendorff, 2018). These analytical techniques

help to draw out meaningful conclusions from the collected data, ensuring a multi-dimensional understanding of the research problem.

The final step is Findings and Insights, which involves synthesizing all the information gathered and analyzed to provide a comprehensive summary of the research findings. This step focuses on articulating the regulatory models and potential opportunities for DeFi and CeFi integration within Kazakhstan. The insights derived from this stage offer valuable recommendations for stakeholders, suggesting pathways that could facilitate a hybrid financial ecosystem that blends the innovation of DeFi with the regulatory oversight of CeFi.

The flowchart serves as a visual representation of the research methodology, guiding the reader through the logical progression of the study. Starting from defining the research objective to conducting a literature review, gathering data, applying analytical techniques, and finally summarizing the findings, each step is systematically connected. Limitations of the research design include reliance on secondary data and the rapidly evolving nature of DeFi and CeFi regulations. Future research could expand to primary data collection, such as interviews with Kazakhstani regulators, and explore emerging technologies like quantum computing in DeFi-CeFi integration.

RESULTS

The landscape. Understanding the ongoing changes in the global financial system is increasingly complex and critical. The perception of cryptocurrencies is highly volatile due to persistent uncertainty, rampant speculation, and frequent fraudulent activities. The collapse of FTX was a monumental setback for the cryptocurrency industry, starkly highlighting the urgent and immediate need for robust regulatory measures to protect investors and ensure financial stability. This incident has dramatically intensified the urgency of regulatory discussions. However, regulatory development is lagging significantly behind the industry's rapid evolution. Furthermore, regulatory approaches differ drastically between countries, and no single, globally accepted regulation for cryptocurrencies exists. This fragmented regulatory landscape severely hampers efforts to establish a stable and secure global financial ecosystem, posing significant risks to global economic stability.

The United Nations (UN) comprises 193 Member States, representing most of the global population. Within this international community, more than 50 countries have imposed sanctions on cryptocurrencies, according to the Global Legal Research Directorate of the Law Library of Congress. As of 2021, nine countries had implemented an absolute prohibition, rendering cryptocurrencies illegal, while 42 countries had enacted implicit bans, preventing financial institutions from engaging with cryptocurrencies. Consequently, the total number of countries with some form of cryptocurrency ban is 51 (Dailay, 2022). Notably, China and Kazakhstan are among the countries that have prohibited cryptocurrencies. Interestingly, despite Kazakhstan's ban, it accounted for an estimated 27.3 per cent of the global Bitcoin hash rate at its peak in October 2021, temporarily making it the second-largest Bitcoin mining nation after China. This paradox highlights the complexities and contradictions in cryptocurrency regulation and enforcement, revealing how economic incentives can lead to unexpected outcomes even in restrictive regulatory environments.

For example, Figure 2 illustrates the global growth in the number of Bitcoin ATMs from October 2013 to April 2024, displaying both the raw number of ATMs and the year-over-year percentage change. The number of Bitcoin ATMs shows a steady increase from late 2017 onwards, peaking around 2023 with nearly 40,000 units. However, the year-over-year percentage change (shown by the black line) reveals a volatile trend, initially peaking dramatically around 2014 but stabilizing close to zero percent from 2017 onwards. This suggests that while the absolute number of ATMs has grown substantially, the rate of growth has leveled off, indicating market saturation or slowed expansion in recent years.

Building on the previous analysis of cryptocurrency infrastructure across countries, Figure 3 illustrates a significant increase of cryptocurrency users from 2016 to June 2024 in global adoption. Starting from a modest user base of approximately 5 million in 2016, the number of verified crypto users has grown dramatically, reaching over 600 million by mid-2024. This rapid expansion is particularly noticeable from early 2021, when user numbers accelerated from around 100 million to 617 million by June 2024. The substantial jumps observed around early 2021 and subsequent consistent growth suggest increasing mainstream acceptance of cryptocurrencies, possibly driven by greater institutional involvement, improved regulatory clarity, and advancements in blockchain technology. As a result, the cryptocurrency market has evolved from a niche interest to a major financial sector with widespread user engagement. This trend highlights the role of identity verification and regulatory compliance in the sector's maturation, as well as the potential for future growth as more individuals worldwide adopt digital assets..

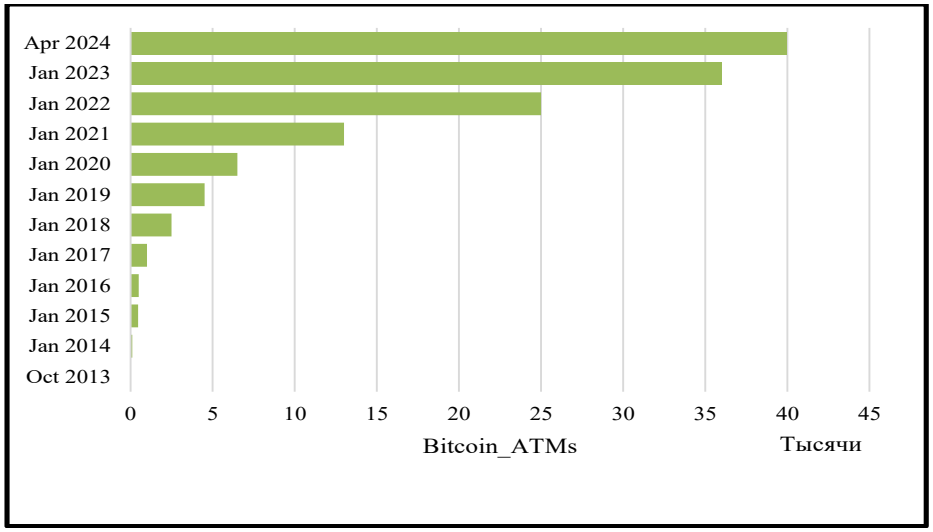

Figure 2. Global Adoption and Market Saturation of Bitcoin ATMs: A Decade-Long Analysis (2013-2024)

Note: complied by authors based on Coin ATM Radar (2024)

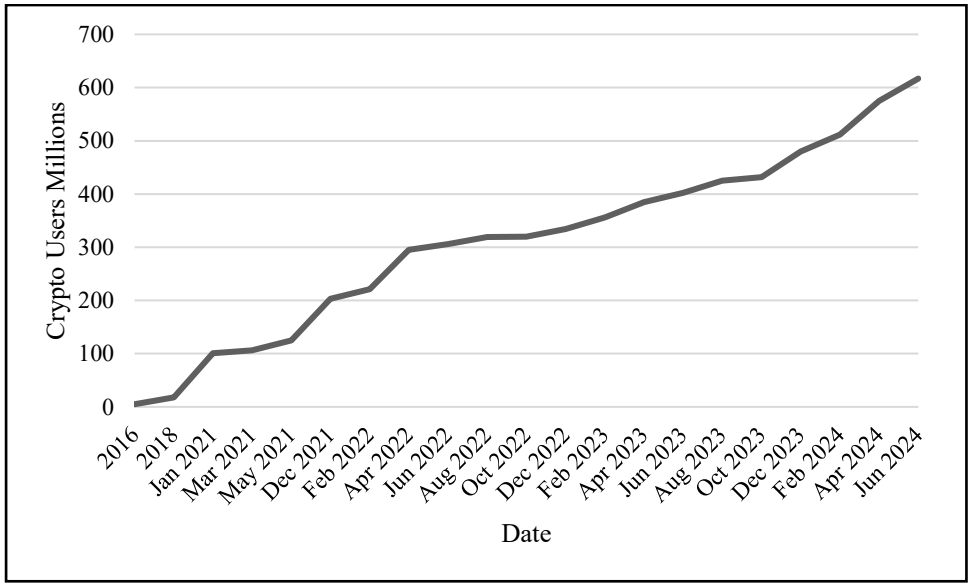

Figure 3. Global Growth of Identity-Verified Cryptocurrency Users: An Analysis from 2016 to 2024 (in millions)

Note: complied by authors based on Statista (2024a)

Connecting this perspective on global stock exchanges with the previous analysis of cryptocurrency adoption by industry and region, it's clear that blockchain technology is driving transformative changes across both traditional finance and emerging decentralized ecosystems. Concurrently, the London Stock Exchange is exploring transformative opportunities through a cross-industry alliance to enhance securities trading in Europe (Bajpai, 2024). Similarly, other major exchanges, such as the South Korean Stock Exchange, the Tokyo Stock Exchange, and the National Stock Exchange of India, are also investigating the potential benefits of blockchain technology. The market is becoming more extensive and more complicated by the day. With operation time and operational costs being a top matter, major stock exchanges are searching blockchain for its capacity to allow almost immediate settlements and

automate compliance through intelligent contracts with greater security and transparency.

The further pace of BT adoption will depend on how regulatory bodies across the globe support the ongoing changes. Some policies connected to blockchain are already in power, as listed below:

- The United States of Delaware approved a law that acknowledges stock trading using blockchain;
- Commodity Futures Trading Commission (US regulator) has founded a blockchain panel to investigate how the technology can be applied in the market for derivatives;
- The European Securities Market Authority has delivered legislation that scrutinises the risks and benefits of blockchain on the securities markets;
- The Financial Conduct Authority in the UK has issued documents that examine the risks and benefits of blockchain on the securities markets;
- The Australian Securities and Investment Commission governing framework requires financial services companies employing distributed ledger technology to have appropriate infrastructure and risk management systems in place to operate;
- Switzerland's Zug region is now famous as 'Crypto Valley' for its cryptocurrency-friendly control. Switzerland is promoting itself as an epicentre for Initial Coin Offerings ICOs.

In 2024, Kazakhstan made significant strides in regulating cryptocurrency and digital assets, establishing a comprehensive legal framework that balances innovation with financial stability and consumer protection. Key Aspects of Kazakhstan's Cryptocurrency Regulation: Comprehensive Licensing System, Anti-Money Laundering (AML), Consumer Protection, Taxation and Energy Consumption, Role of the Astana International Financial Centre (AIFC).

It is important to state that the circulation of so-called unsecured digital assets is banned in Kazakhstan. These are broadly akin to unbacked crypto assets (Bitcoin, Ether etc.), stablecoins (USDT, USDC etc.) and security tokens. The circulation of so-called secured digital assets is allowed in Kazakhstan, although as of April 2023, there is currently no underpinning regulation, active market, and little demand.

Despite the prohibition of cryptocurrencies, the Astana International Financial Centre regarding its unique status has launched a pilot project aimed at attracting foreign capital and developing domestic financial markets. The Astana Financial Services Authority (AFSA) holds regulatory authority within the AIFC. This pilot project allows for the circulation of unsecured digital assets, albeit with significant restrictions, primarily serving residents of Kazakhstan and utilizing the fiat settlement systems of commercial banks domiciled and registered in Kazakhstan. As of April 2023, the project has seen limited uptake, with approximately 6,000 users and $6 million in transactions. Participants face restrictions on the amount they can invest, the types of crypto assets they can trade, and the activities they can conduct. It is anticipated that the transition from the pilot phase to a live launch will involve changes to some regulatory requirements and restrictions.

The convergence context. Changing global scenarios and unstable financial markets of BT are the main characteristics of the current landscape. DiFi is an innovation that can modernise the existing system and make it more secure and efficient, and businesses globally might be exploring more and investing actively in this technology to compete, which will create a disruptive environment. A comprehensive framework has been generated to display the pros and cons of both Decentralized Finance (DeFi) and Centralized Finance (CeFi). This framework aims to provide a detailed comparison, highlighting the unique benefits and challenges associated with each system. By examining key factors such as security, accessibility, transparency, innovation, regulatory compliance, and user trust, our framework offers valuable insights for stakeholders. It helps in understanding how DeFi and CeFi can complement each other and where improvements or integrations might be necessary to create a more robust and inclusive financial ecosystem. This tool is designed to facilitate informed decision-making for investors, policymakers, and financial institutions as they navigate the evolving landscape of modern finance. The lack of central control in cryptocurrency systems can be seen as both an advantage and a drawback. On one hand, it provides a level of transparency and security against inflationary policies that can devalue fiat currencies. On the other hand, it poses challenges for governments attempting to implement monetary policies or respond to economic crises.

The further step of convergence implementation will depend on how the main challenges might be addressed:

1. *Resistance to manipulation.* Traditional fiat currencies are subject to governmental control, allowing authorities to adjust monetary policies, such as altering interest rates and controlling the money supply, to respond to various economic pressures. In contrast, the decentralized nature of cryptocurrencies means that such control is not possible. The supply and generation of new coins or tokens are governed by predefined algorithms and indepen-

dent mining operations, rather than by centralized authorities.

2. *Compromise to UN SDGs*. DeFi comes at costs as governments are struggling to decrease energy consumption to mitigate future climate change and achieve the UN agenda regarding SDGs. As governments strive to reduce energy consumption to address climate change, the high energy demands of Bitcoin mining contrast sharply with these global sustainability goals, highlighting a key challenge in aligning cryptocurrency practices with environmental priorities.

Table 1. Bitcoin energy consumption relative to several countries worldwide in 2024

Category	Energy Use (%)
Bitcoin	*100*
United States	4.1
Russian Federation	17.6
Canada	30.7
Germany	31
France	36.6
United Kingdom	54
Italy	55.7
Australia	71
Netherlands	150.2
Czech Republic	251.6

Note: complied by authors based on (Statista, 2024b)

Bitcoin mining consumes a substantial amount of energy globally. The figures underscore the sheer scale of Bitcoin's energy demands (100%) – equivalent to an entire nation (Table 1). The data reveals significant variations, with the Czech Republic leading at 251.6%, followed by the Netherlands at 150.2%, and Australia at 71%. Developed countries like Italy (55.7%) and the United Kingdom (54%) report high levels, highlighting the substantial environmental footprint of cryptocurrency operations. This level of energy use raises questions about the sustainability and environmental impact of Bitcoin mining, especially given its limited practical applications outside of decentralized finance (DeFi).

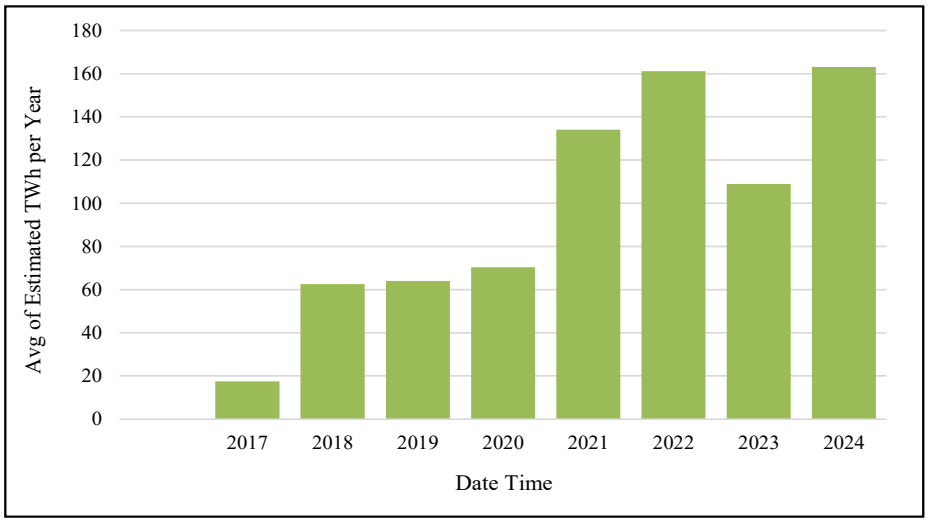

Figure 4. Annual Average Estimated Energy Consumption for Bitcoin Mining (2017-2024, TWh)

Note: complied by authors based on Digiconomist (2024)

The Figure 4 illustrates the estimated annual average energy consumption (in TWh) for Bitcoin mining from 2017 to 2024, showing a steady increase over time. Starting from a modest level in 2017, Bitcoin mining energy consumption sharply rises by 2021, reaching over 120 TWh. The peak occurs in 2022 at nearly 150 TWh, with a slight dip in 2023, followed by a return to near-peak levels in 2024. This trend reflects the growing computational power required for Bitcoin mining and highlights the escalating energy demands of the cryptocurrency sector over recent years.

Thus, cryptocurrency mining and transactions employ an ineffective use of limited energy resources (Figure 5), adding to the point, the energy consumption of 1 bitcoin transaction consumes 703.25 KWh compared to 100K visa transactions that consume 148KWh (Statista, 2024b). In other words, the execution time of 1 Bitcoin transaction is equivalent to 1.47 million transactions of Visa based on centralized systems.

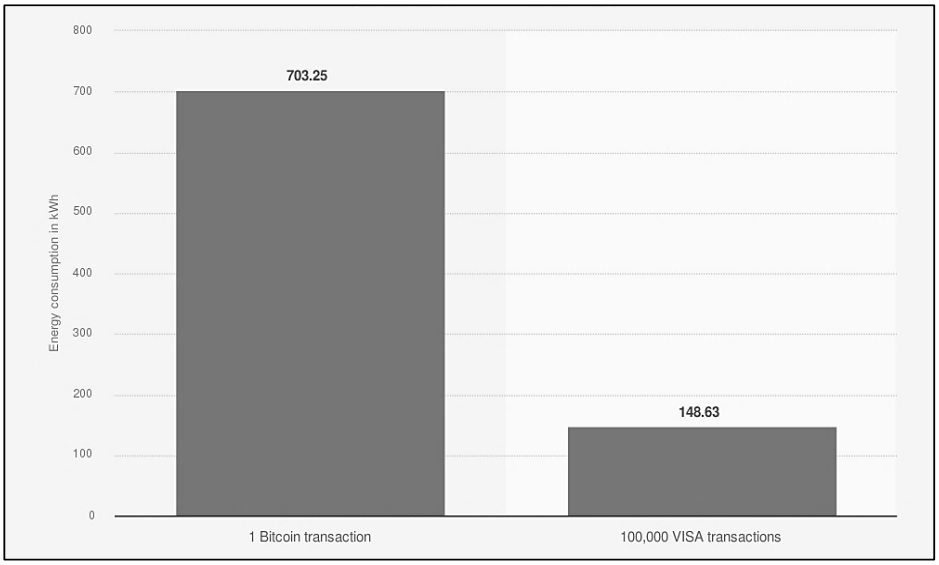

Figure 5. Energy consumption per transaction Visa vs Bitcoin, kWh

Note: complied by authors based Digiconomist (2023)

Underlying concern: the entire energy system would collapse if our financial system migrated to a decentralized mechanism like Bitcoin follows. Thus, in Kazakhstan, there was a massive power blackout in January 2022 due to the energy-intensive nature of mining activities. At the time Kazakhstan was considered an attractive place to develop mining firms due to the chip energy cost and absence of legislation. Following the high energy consumption the creator and author of Ethereum, has suggested that existing blockchains cannot achieve scalability – overcome the capacity constraints described above – without sacrificing decentralization or security (Casey et al., 2018). The capacity constraints, and associated latency, of decentralized blockchains – in particular those employing proof-of-work consensus – make using them directly untenable for specific applications (Casey et al., 2018; Gramlich et al., 2023). The scalability of cryptocurrencies might be doubtful regarding the scarcity of the resource, as was mentioned earlier.

3. *Illegal financial activities*. The financial system has adopted control to check financial stability and avoid illegal activity, such as know-your-customer (KYC) and anti-money laundering (AML) frameworks introduced in early 2000. However, it does not work with DeFi. Anonymous transactions might shake users' trust as the purpose of the transactions is unknown. In 2019, criminal activity represented USD 11.5 bn of all cryptocurrency transaction volume, in 2024 it achieved USD 24.2 bn (Chaianalysis, 2020, 2024). The use of privacy coins, which shield customer information, has been a source of money laundering.

4. *Quantum computing.* The invention of quantum computing and post-quantum encryption might fundamentally disrupt the security foundations of current cryptocurrencies (Fernandez-Carames &

Fraga-Lamas, 2020). The Global Risk Institute estimates that quantum computers could break encryption within the next 10-15 years, posing a significant risk to blockchain security and the roughly USD 150 billion market cap of Bitcoin alone (Mosca & Piani, 2020). Research indicates that about 90% of existing blockchain protocols rely on cryptographic algorithms like ECC, which are vulnerable to quantum attacks (Fernandez-Carames & Fraga-Lamas, 2020). Deloitte projects that the financial industry could face losses in the hundreds of billions USD if quantum technology disrupts public-key cryptographic standards, endangering up to 5-10% of the total cryptocurrency market (Deloitte, 2020)

Table 2. Comparison of advantages and disadvantages of decentralized finance (DeFi) and centralized finance (CeFi)

Issue	DEFI	CEFI
Advantage	- Minimal transaction fees - Enhance 4D data privacy Efficient and immediate transactions - High availability and accessibility - Open-source platforms - Permissionless operation - Global reach without borders - Increased transparency through public ledgers	- Subject to regulatory oversight - Strong regulatory frameworks in developed countries - Consumer protection mechanisms - Established financial infrastructure - Stability and lower volatility due to central oversight
Disadvantage	- Anonymity may facilitate illicit activities such as terrorism and crime - Lack of traditional market metrics (e.g., risk-free rate, pricing, exchange volatility) - High energy consumption - Potential exclusion due to digital illiteracy - High volatility - Vulnerability to quantum computing threats - Regulatory uncertainty and evolving legal frameworks - Scalability issues with current blockchain technology	- High service fees - Risk of fraudulent activities, deception, and corruption - Inefficient and time-consuming processes - A significant portion of the population lacks access to banking services - General mistrust in financial institutions - Issues with remoteness and accessibility - Potential for government interference and manipulation

Note: complied by authors

The table 2 provides a comparison of the advantages and disadvantages of Decentralized Finance (DeFi) and Centralized Finance (CeFi). DeFi offers benefits like minimal transaction fees, high accessibility, open-source platforms, and global reach without borders, enhanced by transparency and privacy through blockchain technology. However, it faces challenges such as high energy consumption, lack of regulatory clarity, and susceptibility to volatility and quantum threats. Conversely, CeFi benefits from regulatory oversight, consumer protection, and a stable financial infrastructure, making it more resilient to volatility. Yet, it is also hindered by high fees, inefficiency, potential government interference, and limited accessibility in remote or underserved areas. This comparison highlights the strengths and limitations of both systems, underscoring the trade-offs between decentralization and regulatory stability.

Beyond DeFi. Every national economy globally is always associated with centralization. Politic and economic power is based on centralization (governments, central banks), and even supranational organizations centralize assets (IMF, World Bank). These official bodies are not ready to accept the idea of decentralization because it might question their power and existence. A significant portion of the population lacks access to banking services (Demirgüç-Kunt et al., 2018). Central bank digital currencies (CBDCs) guarantee cash-like safety and convenience for peer-to-peer payments. Thus, they must be robust and accessible. They should also protect the user's privacy while allowing effective law prosecution. Various technical designs satisfy these attributes to varying degrees, referring to whether they feature intermediaries, a conventional or distributed infrastructure, account- or token-based access, and retail interlinkages across boundaries. The underlying trade-offs and the related hierarchy of design choices have been set.

CBDC would satisfy the essential functions of money: a unit of bank account, a standard of exchange, and a store of value (Bordo and Levin

2017). CBDC might head off the risk to monetary sovereignty from stablecoins released by global digital services companies like Facebook, threatening central banks' capability to conduct monetary policy. CBDC would provide a secure, reliable currency, free from the dangers of fraud, hacking, money laundering and financing terrorism (Pomfret, 2009). Some digital assets that operate on their native blockchains are called coins, whereas tokens are built on other non-native blockchains. But CBDCs have different natures; they are not encrypted as cryptocurrencies and represent a centralized financial system.

The following middleman has the potential to be eradicated because they promote information asymmetry and access that cryptocurrencies and blockchain technology could solve. The middlemen are banks and card companies for services and goods transactions; sales agents for materials; real estate agents; brokers on exchanges and insurance companies; agents for talents; deposits and loans; and sellers and resellers of goods (Crosby et al., 2016).

External factors are influences originating outside of a system or organization that impact its performance, trends, and behaviours. This framework categorizes and illustrates the key external factors affecting Centralized Finance (CeFi) and Decentralized Finance (DeFi) platforms (Table 3).

Table 3. External factors influencing CeFi and DeFi based on PESTEL framework

Factor	Description		Impact on CeFi/DeFi	Examples
Political	Regulatory Changes	Government regulations or policy changes affecting CeFi and DeFi operations.	CeFi platforms comply with regulations (KYC, AML), potentially deterring DeFi users in regulated regions.	In 2021, FATF's implementation of KYC and AML guidelines led to increased compliance costs for CeFi platforms, with the global cost of AML compliance reaching approximately USD 180 billion (FATF, 2021).
Economical	Economic Conditions	Macroeconomic factors such as inflation, interest rates, and currency fluctuations.	Inflation can push users toward DeFi as a store of value, while high interest rates may favour secure CeFi options.	During Argentina's inflation surge in 2021, cryptocurrency adoption increased by 20%, as citizens sought stable assets through DeFi (Chainalysis, 2021).
	Market Sentiment and Trends	Investor perceptions and global financial trends impacting CeFi and DeFi demand.	Bear markets may lower DeFi participation, whereas centralization concerns might increase DeFi's appeal over CeFi.	In the 2022 crypto bear market, DeFi participation dropped by 25%, illustrating the volatility-sensitive nature of the sector (Glassnode, 2022).
	Competitive Landscape	Competition from other financial technologies or new entrants within CeFi and DeFi.	New DeFi platforms with low fees or unique features may draw users from CeFi, while CeFi's broader offerings may strengthen its market position.	A new DeFi platform with 50% lower transaction fees gained 10% user adoption growth in six months, highlighting the competition's impact on the CeFi and DeFi market.
Social	Social and Cultural Trends	Changing public attitudes toward financial decentralization and data privacy.	Privacy and decentralization interest boost DeFi, whereas risk aversion towards unregulated assets favours CeFi.	A survey by Statista found that 30% of crypto users prioritize privacy and decentralization, making DeFi platforms their preferred choice (Statista, 2024a).
Technological	Technological Advancements	Innovations that enhance efficiency, security, and scalability for CeFi and DeFi. The invention of quantum computing and post-quantum encryption might fundamentally disrupt the security foundations of current cryptocurrencies.	Blockchain improvements encourage DeFi growth; new fintech solutions benefit CeFi platforms.	Ethereum's upgrade to proof of stake in 2022 reduced energy consumption by 99.95%, significantly lowering operational costs for DeFi users (Ethereum Foundation, 2022).

Environmental	Energy Costs and Environmental Factors	Energy demands and environmental considerations impacting blockchain activities.	High energy costs may limit DeFi operations, while eco-conscious regulations could restrict energy-intensive crypto activities.	Bitcoin mining's annual energy consumption reached 91 TWh in 2022, equivalent to the energy consumption of a small country, raising sustainability concerns (Cambridge Centre for Alternative Finance, 2019).
Legal	Data Privacy Laws (GDPR and CCPA	DeFi platforms encounter difficulties in fully complying without compromising decentralization.	Regulations like the EU's General Data Protection Regulation (GDPR) and California's Consumer Privacy Act (CCPA) require user data protection and privacy. CeFi platforms that collect user data must comply, while DeFi platforms, designed for pseudonymity, face challenges in adapting to these laws.	If a CeFi platform fails to comply, it may face fines of up to 4% of its global revenue or €20 million (whichever is higher), illustrating the financial implications of data privacy laws (EPCEU, 2016).

Note: complied by authors

The five Elements of DeFi and CeFi ecosystems (Figure 6) represent the foundational components necessary for a structured and compliant decentralized finance (DeFi) ecosystem. This diagram illustrates that a robust DeFi ecosystem requires alignment with regulatory standards, a focus on consumer rights, and an environmentally conscious approach. Each element addresses a distinct challenge in DeFi, reflecting the need for a balanced approach that considers both innovation and compliance. By including these components, the DeFi ecosystem can potentially gain wider acceptance and improve its reliability, ensuring its sustainability and scalability.

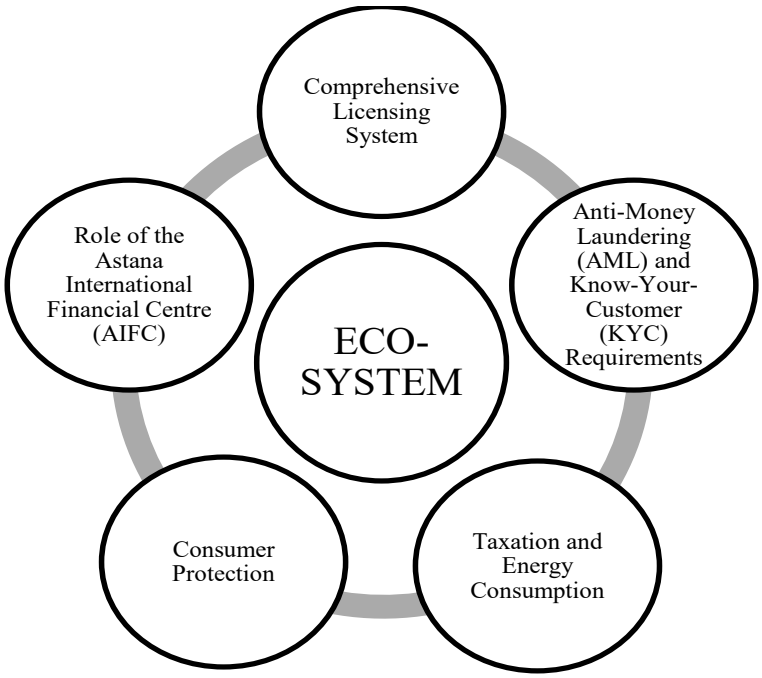

Figure 6. DeFi and CeFi ecosystems adaptation framework

Note: complied by authors

Comprehensive Licensing System: Kazakhstan has implemented a robust licensing system for cryptocurrency exchanges and digital asset service providers. This system ensures that all crypto-related businesses secure licenses and adhere to strict operational standards designed to enhance transparency and protect investors' assets.

Anti-Money Laundering (AML) and Know-Your-Customer (KYC) Requirements: The regulatory framework emphasizes stringent AML and KYC procedures for all cryptocurrency transactions. These measures are critical for preventing the misuse of digital assets for illegal activities and safeguarding the financial system's integrity (IMF, 2024).

Consumer Protection: Kazakhstan has put in place comprehensive guidelines to address fraud, market manipulation, and operational disruptions. These measures are crucial for building trust among consumers and ensuring the stable growth of the digital asset sector.

Taxation and Energy Consumption: The new regulations include provisions for taxing gains from cryptocurrency investments, ensuring they are treated consistently with other financial instruments. Additionally, digital miners are subject to specific energy consumption quotas and are required to purchase electricity from approved sources, including renewable energy.

Role of the Astana International Financial Centre (AIFC): The AIFC plays a pivotal role in regulating digital asset exchanges. Only exchanges licensed by the AIFC are permitted to operate, providing a controlled environment for cryptocurrency trading. This special legal regime helps maintain regulatory oversight while fostering a secure marketplace for digital assets.

Establishing a regulatory framework involves creating clear guidelines on how cryptocurrencies should be reported in banking accounts and developing a classification system that recognizes the different types of cryptocurrencies, such as stablecoins versus volatile cryptocurrencies, and their roles in the financial system. Additionally, standardized accounting practices for reporting cryptocurrency holdings and transactions need to be created to ensure transparency and consistency in how banks report cryptocurrency-related activities.

By addressing these points, the National Bank can develop a comprehensive approach to incorporating cryptocurrencies into banking reports and accounts, ensuring that the financial system remains robust and adaptable to emerging financial technologies. Kazakhstan's regulatory approach aligns with global standards and involves active participation in international forums. The government also focuses on educational initiatives to raise public awareness about the opportunities and risks associated with cryptocurrencies, fostering a more informed and engaged citizenry.

The results highlight that DeFi and CeFi each offer distinct advantages that, if effectively combined, could transform financial systems. DeFi enables accessibility, innovation, and low-cost transactions, while CeFi provides trust, consumer protection, and system stability. Kazakhstan's regulatory approach demonstrates that a hybrid model could address the challenges of each system, suggesting that emerging economies can lead to developing inclusive, secure financial systems. This convergence approach not only enhances regulatory flexibility but also strengthens the foundation for sustainable digital finance ecosystems.

CONCLUSION

This study underscores the potential for a hybrid regulatory framework that balances Decentralized Finance (DeFi) and Centralized Finance (CeFi) within the context of Kazakhstan's financial environment. By examining the strengths and limitations of both systems, we propose a three-framework model to guide future development and ensure an inclusive, innovative, and secure digital finance landscape.

Firstly, the Regulatory Convergence Framework with a focus on weakneess and strenthes serves as a foundational model for a regulatory framework. This model leverages CeFi's structured oversight to address DeFi's security and compliance gaps, creating a stable environment that supports both technological advancement and economic inclusivity. A convergence framework that bridges regulatory differences can foster a resilient financial ecosystem adaptable to emerging economies.

Secondly, the convergence of DeFi and CeFi in regard to the external factor offers the view of future expantion and financial accessibility within the strategy PESTEL framework. By integrating DeFi's decentralized, accessible model with CeFi's secure, regulated environment, this framework aims to create a more inclusive financial infrastructure. This would support underserved populations, provide new financial opportunities, and drive economic growth through sustainable innovation.

To sustain and secure a hybrid DeFi-CeFi ecosystem, the DeFi and CeFi ecosystems adaptation framework emphasizes the need to adapt to emerging technologies, such as quantum computing and advanced data protection standards. Preparing for

future technological advancements is essential to maintaining the security, scalability, and efficiency of digital finance. This framework encourages ongoing research and collaboration to keep pace with technological changes while ensuring long-term financial stability. By implementing these three frameworks, Kazakhstan and similar emerging economies can harness the strengths of both DeFi and CeFi. This approach balances regulatory stability with innovation, offering a pathway toward a secure, inclusive, and adaptable digital finance ecosystem. Future research should continue to refine these frameworks, assess emerging technologies, and examine socio-economic impacts to further strengthen financial inclusivity.

In conclusion, this research successfully met its aim of providing a comprehensive evaluation of Kazakhstan's hybrid regulatory model by assessing its potential applicability as a framework for other emerging economies. Through an in-depth exploration of the convergence between Decentralized Finance (DeFi) and Centralized Finance (CeFi), the study identified key strengths and weaknesses of each system within a hybrid regulatory context. By utilizing Kazakhstan as a case study, the research illustrated how a balanced approach can foster financial inclusivity, promote innovation, and ensure consumer protection. The findings demonstrated that, with an appropriate regulatory framework, emerging economies can effectively navigate challenges posed by the digital finance era while enhancing economic growth and financial stability, offering a potential blueprint for other nations aiming to adapt to evolving financial ecosystems.

AUTHOR CONTRIBUTIONS

Conceptualization and theory: LM; research design: LM and SP; data collection: LM; analysis and interpretation: LM; writing draft preparation: LM and SP; supervision: LM; correction of article: LM and SP; proofread and final approval of article: LM and SP. All authors have read and agreed to the published version of the manuscript.

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