KWARTALNIK NAUK O PRZEDSIĘBIORSTWIE

DOI: 10.33119/KNOP.2025.75.1.2 1/2025

Cryptocurrency exchanges in the decentralized finance system

Giełdy kryptowalutowe w systemie finansów zdecentralizowanych

prof. SGH, dr hab. Dorota Ciesielska-Maciągowska
SGH Warsaw School of Economics
Collegium of Business Administration
Institute of Markets and Competition
e-mail: dorota.ciesielska@sgh.waw.pl
ORCID: 0000-0002-6393-9491

MSc Łukasz Spyra
SGH Warsaw School of Economics
e-mail: ukasz.spyra@gmail.com
ORCID: 0009-0006-8820-5060

Keywords:
blockchain, cryptocurrencies, cryptocurrency exchanges, cryptocurrency wallets, CEX (centralised exchange), DEX (decentralised exchange), DeFi (decentralised finance)

Abstract: The purpose of this article is to explore the key aspects of cryptocurrency exchange systems, including their role in storage, exchange, and token staking. By examining the characteristics and features of these exchanges, cryptocurrency users can make informed decisions about how to allocate and store their funds effectively.

There are two main types of cryptocurrency exchanges: centralized exchanges (CEX) and decentralized exchanges (DEX). Centralized exchanges are governed by a central authority that manages user funds, providing a more streamlined and user-friendly experience. However, this centralization creates security risks, as users must trust the exchange with their assets. If the platform is compromised or experiences technical failures, users may suffer significant losses. Moreover, centralized exchanges often require identity verification and other regulatory procedures, which can be a barrier for those who prioritize privacy or anonymity in their transactions. On the other hand, decentralized exchanges (DEXs) operate without a central governing body, allowing users to retain control over their funds and trade directly with each other using smart contracts on a blockchain. This decentralization reduces reliance on intermediaries and enhances privacy, but it also presents challenges. DEXs tend to be more complex to use and may require greater technical expertise.

Future research should examine how various groups – ranging from individual investors to large financial institutions – are incorporating cryptocurrency exchanges into their financial strategies.

Słowa kluczowe:
łańcuch bloków, kryptowaluty, giełdy kryptowalutowe, portfele kryptowalutowe, CEX (scentralizowana giełda), DEX (zdecentralizowana giełda), DeFi (zdecentralizowane finanse)

JEL:
E42, E44, E49, F31, F32, F38, G11, G14, G15, G18, G21, O16

Streszczenie: Celem artykułu jest przedstawienie kluczowych aspektów związanych z systemem giełd kryptowalutowych. Wyróżnia się dwa główne typy giełd kryptowalutowych: giełdy scentralizowane (CEX) oraz giełdy zdecentralizowane (DEX). Giełdy scentralizowane są zarządzane przez centralny organ, który kontroluje środki użytkowników, oferując bardziej uproszczone i przyjazne dla użytkownika doświadczenie. Jednak ta centralizacja wiąże się z ryzykiem, zwłaszcza związanym z bezpieczeństwem, ponieważ użytkownicy muszą powierzyć swoje aktywa giełdzie. Z kolei giełdy zdecentralizowane (DEX) działają bez centralnego organu, pozwalając użytkownikom na zachowanie pełnej kontroli nad swoimi środkami oraz bezpośrednią wymianę kryptowalut za pomocą smart kontraktów na blockchainie. Ta decentralizacja redukuje zależność od pośredników i zwiększa prywatność, ale wiąże się również z wyzwaniami. Giełdy DEX są zazwyczaj bardziej skomplikowane w obsłudze i mogą wymagać większej wiedzy technicznej. Przyszłe badania w obszarze zdecentralizowanych finansów powinny się skupić na analizie tego, w jaki sposób różne grupy inwestorów – od indywidualnych po duże instytucje finansowe – zaczynają wykorzystywać giełdy kryptowalutowe w swoich strategiach finansowych.

Introduction

The crypto ecosystem is based on the concept of decentralization. Instead of depending on central bank currencies and trusted intermediaries, it envisions transfer recordkeeping handled by a network of anonymous validators. Decentralized finance (DeFi) aims to mirror traditional financial services within the crypto world, typically supported by the role of stablecoins as a medium of exchange. DeFi also integrates innovations like programmability and composability on blockchains [Bank for International Settlements, 2023].

Cryptocurrencies are defined in various ways, with one definition provided by the Act of March 1, 2018, on counteracting money laundering and terrorist financing. According to this definition, cryptocurrencies are described as "virtual currency, i.e., a digital representation of value that is not:

- a legal tender issued by the NBP, foreign central banks, or other public administrative bodies,
- an international settlement unit established by an international organization and accepted by individual countries belonging to or cooperating with that organization,
- electronic money under the act on payment services,
- a financial instrument under the act on trading in financial instruments,
- a bill of exchange or check,

- and can be exchanged in economic circulation for legal tender, accepted as a medium of exchange, and may be stored, transferred, or traded electronically" [Ustawa z dnia 1 marca 2018 r.].

It is important to note that in 2025, new legislation concerning cryptocurrencies is expected, with ongoing work on this project currently being conducted [Chancellery of the Prime Minister, 2024]. Moreover, recent reinforcement of European legislative landscape through implementation of the Regulation on the Markets in Crypto-Assets (MiCA) was adopted in June 2023 [*Crypto-assets*…, 2023]. Regulation covers crypto-assets and services not already regulated by existing EU financial services legislation and in February 2025 was additionally extended over stablecoins, to ensure the intrinsic coverage of their value [*Markets in Crypto-Assets*…, 2025].

Cryptocurrency should not be considered synonymous with virtual currency, as there are virtual currencies that do not all use blockchain technology and associated cryptographic methods for recording transactions [UKNF, 2021].

The development of cryptocurrencies has initiated the creation of exchange systems that act as intermediaries in the trading of digital assets and cryptocurrency wallets that allow for the storage of tokens with varying levels of security and the required level of user experience and knowledge [Taylor et al., 2022].

The purpose of this article is to present the key aspects related to the system of exchanges that enable the storage, exchange, and token staking. The characteristics and analysis of the significant features of cryptocurrency exchanges allow cryptocurrency users to make the most optimal choices related to the allocation and storage of their funds. Furthermore, analyzing factors related to the security, anonymity, costs, and risks of individual methods of storing and exchanging cryptocurrencies is crucial for cryptocurrency users.

Characteristics of Cryptocurrency Exchanges

The cryptocurrency trading system operates in many different forms. There are cryptocurrency exchanges, currency exchange offices, virtual currency wallets, exchanges, and cryptocurrency ATMs. This article focuses on the unique aspects of cryptocurrency exchanges. It should be emphasized that the essence of the operation of cryptocurrency exchanges and wallets lies in the process related to cash flow and cryptocurrencies [You-Ping Chen, 2019].

As cryptoassets gained wider attention from potential investors, centralized entities took on a larger role in directing funds into cryptocurrencies. Centralized exchanges, in particular, which enabled the conversion between Bitcoin, other cryptoassets, and fiat currencies, helped drive rising crypto prices by attracting new participants in

a self-reinforcing cycle. Centralized intermediaries, including platforms like Mt. Gox in the early days and more recently Binance, Coinbase, Kraken, and FTX until its sudden collapse in late 2022, have consistently reaffirmed their crucial role in the crypto ecosystem. However each crash or failure of well know CEX leads to further reinforcement of the regulatory landscape of cryptocurrency market and surveillance over institutions entrusted with safekeeping of assets (McDevitt, 2025)

Cryptocurrency exchanges operate in much the same way as other trading platforms. They offer accounts that allow you to set up different order types to buy, sell, and trade cryptocurrencies. There are two types of crypto asset exchanges. The first type is a centralized exchange, or CEX (centralized exchange), which has its headquarters and is listed in the register of enterprises in a given country [Hyeji et al., 2021]. The second type is a decentralized cryptocurrency exchange, or DEX (decentralized exchange), which is an entity independent of state authorities and institutions engaged in cryptocurrency trading and does not allow their storage, as tokens must remain on a non-custodial cryptocurrency wallet in this case. Using centralized and decentralized cryptocurrency exchanges involves certain differences related to security, anonymity, or costs [Essén, Ekholm, 2020].

Centralized cryptocurrency exchanges act as intermediaries between buyers and sellers and obtain funds through commissions and transaction fees. They operate similarly to traditional stock exchanges and are the first stage in the process of purchasing cryptocurrencies, as they accept fiat currency transfers and allow fiat withdrawals back to a bank account. The first step leading to purchasing a given cryptocurrency unit on a centralized cryptocurrency exchange is transferring fiat currency to an exchange account, where it can then be exchanged for a chosen token [Wang et al., 2021]. Popular cryptocurrency exchanges include Binance, Coinbase Exchange, Kraken, and KuCoin [Barbon, Ranaldo, 2023]. Like websites or stock trading apps, these exchanges allow investors to buy and sell digital assets. Assets can be sold at the prevailing price, known as spot, or orders can be left that will be executed when the asset reaches the target price desired by the investor, referred to as limit. CEX exchanges operate based on the order book system, meaning buy and sell orders are listed and sorted by intended purchase or sale price. The exchange algorithm then matches buyers and sellers based on the best possible execution price, considering the desired batch size. As a result, the price of digital assets will depend on the supply and demand for this asset relative to others, whether fiat currency or cryptocurrency [Qin et al., 2021]. The presence of a centralized counterparty on CEX imposes a default level of responsibility on it to maintain market order, fulfill KYC/AML controls on users, and obligate the exchange to ensure the security of the capital invested by investors. Furthermore, crypto-asset service providers prior accepting funds of their clients, must obtain authorization from a competent authority in an EU member state before operating in the EU (ESMA, 2023)

Centralized exchanges offer investors a less complex way to trade and invest in cryptocurrencies [Bentov et al., 2019], as well as security and reliability related to transactions and trading. They are also responsible for the assets deposited on them. Centralized exchanges also facilitate transactions through a developed, centralized platform. However, using CEX involves certain risks due to the fact that exchanges are operated by companies that are responsible for their clients' funds [Bentov et al., 2019]. Such exchanges hold cryptocurrencies of significant value, making them targets for hacker attacks and potential theft or embezzlement[1] [Bentov et al., 2019]. Moreover, unlike peer-to-peer transactions, centralized exchanges often charge high fees compared to DEX for their services.

The second type of crypto asset exchange is the decentralized exchange (DEX), which enables peer-to-peer transactions directly from digital wallets without the need for intermediaries, unlike centralized exchanges (CEXs). DEXs have gained significant attention and are now the fastest-growing sector within the DeFi ecosystem. A major advantage of DEXs over CEXs is that they allow users to retain control of their private keys. When market participants deposit their crypto tokens with a centralized exchange, they give up control of their assets, leaving them vulnerable to exchange risks. If the exchange is hacked and funds are stolen, investors could suffer significant losses. Additionally, trading on centralized exchanges requires trust in the platform, which goes against the core principles of decentralized finance. On the other hand, decentralized exchanges (DEXs) operate through smart contracts, removing counterparty risk for investors. Transactions are settled immediately after being confirmed and added to the blockchain [Sans et al., 2023].

Most decentralized exchanges (DEXs) operate using automated market maker (AMM) protocols, allowing for the direct exchange of two crypto tokens, such as X and Y. At the heart of an AMM protocol is a market structure called a liquidity pool, which consists of two separate pools: one containing X tokens and the other containing Y tokens. The relative amount of tokens in each pool sets the exchange rate between the two tokens.

Liquidity pools enable two key functions: liquidity provision and token swapping. Anyone holding both tokens can participate as a liquidity provider by depositing an equal proportion of X and Y tokens into the pools, based on the current exchange rate. In return, the liquidity provider receives LP tokens, representing their share of the liquidity pool [Schoar, Schoar, 2022].

Examples of DEX include Uniswap, PancakeSwap, dYdX, and Kyber. Decentralized exchanges are based on smart contracts, through self-executing code segments on

[1] An example is the collapse of the FTX exchange in November 2022, where the management made unofficial decisions and siphoned capital from the exchange, leading to its downfall and the loss of part or all of the funds deposited by its users.

the blockchain [Kumar et al., 2020]. This form of exchange allows for greater privacy and faster token flows than a centralized exchange. However, in the case of DEX, the absence of an intermediary third party means that the user is entirely responsible for their assets, so decentralized exchanges are intended for advanced investors [Canessane et al., 2019]. To use DEX, only a non-custodial cryptocurrency wallet is needed – and due to its decentralized nature, there is no registration requirement from users of the decentralized exchange. Below table presents the key features and differences between centralized and decentralized cryptocurrency exchanges.

Table 1. Comparative Analysis of Centralized and Decentralized Cryptocurrency Exchanges

Features	CEX	DEX
Type of exchange	Centralized	Decentralized
Custody of assets	Yes	No, requires connection to a non-custodial cryptocurrency wallet
Security measures	No private key and seed phrase, access to customer service and technical support	Need to keep the private key to the decentralized cryptocurrency wallet; losing it means no access to the funds
Access to investment products	Limited access only to investment products available on the exchange	Access to the full spectrum of cryptocurrency projects and selected services available through decentralized finance
Connection with fiat money	The ability to buy cryptocurrencies using fiat currency	Fiat currencies excluded from trading, only cryptocurrencies tokens can be used
AML/CFT compliance	No anonymity, registration, provision of personal data, and account validation based on local regulations	Full anonymity, no registration and personal data provision required, and unrestricted access to funds
Transaction fees	High, the most expensive form of storing and exchanging cryptocurrencies	Low, associated only with transaction validation on the blockchain, currency exchange at market price
User experience level	Transactions through a developed, centralized platform, allowing novice investors a less complicated way to trade and invest in cryptocurrencies	No centralized administrator means the user is entirely responsible for their assets; intended for advanced investors
Regulatory oversight	Fall directly under the MiCA regulation as they are operated by identifiable entities.	Present challenges in terms of regulatory compliance and oversight, regulation requirements for users applies on level of exchange with CEX.
Customer protection	The exchange administrator registered in a given country is responsible for the security of funds held on the exchange. However, the risk of hacker attacks, theft, or embezzlement related to management actions exists	Full anonymity and user responsibility for accumulated assets, secured by a private key and seed phrase. No threats from hacker attacks, theft, or embezzlement related to management actions

Source: own research and analysis based on Wang et al. [2024].

Decentralized exchange (DEX) users do not have to transfer their assets to a third party, so there is no risk associated with hacker attacks. Additionally, due to the possibility of peer-to-peer cryptocurrency exchange, they prevent market manipulation, protecting their users from capital loss [McMenamin et al., 2022]. DEXs do not require clients to fill out know-your-customer (KYC) forms, offering privacy and anonymity, and allowing access to a wider range of cryptocurrencies and digital assets. Moreover, many altcoins are only available on decentralized exchanges. However, using decentralized exchanges is more complex because it requires the use of a non-custodial wallet. A special key (seed phrase), consisting of twelve words and a password, is required to operate it; losing these means irreversible loss of the tokens and no possibility of recovery [McMenamin et al., 2022]. DEXs require users to learn and familiarize themselves with the platform and process, unlike centralized exchanges, which offer a more convenient and user-friendly mechanism [Kumar et al., 2020]. Additionally, with DEXs, only crypto-asset trading is possible; fiat currency payments are not allowed. Therefore, it is first necessary to deposit funds in fiat currency on a CEX, and after purchasing a given crypto asset, it can be transferred to a decentralized cryptocurrency wallet and used on a DEX [Fareed, 2023]. Decentralized exchanges are, therefore, an essential tool for investors looking to transition between two crypto assets [Chalkias et al., 2022]. However, decentralized cryptocurrency exchanges are not without drawbacks; besides the need for a non-custodial wallet secured with a seed phrase, decentralized exchanges may experience liquidity issues and difficulties in finding buyers and sellers with low trading volumes [Platt et al., 2020]. To address this problem, Automated Market Makers (AMMs) have been developed, an innovative mechanism used by decentralized cryptocurrency exchanges that revolutionizes digital asset trading by enabling users to trade without the need for a traditional intermediary or order book dedicated to matching buyers with sellers, while maintaining liquidity and coverage for selected currency pairs. AMMs operate on models based on the concept of "liquidity," where the asset price is determined by defined algorithms. One of the largest decentralized exchanges using AMMs is Uniswap, in a simplified form DEX refers to the equation $x * y = k$, where x and y are the amounts of two exchanged assets that make up a given currency pair, and k is a constant. This model ensures that the total value of both assets in the pool remains constant because the change in the value of one asset must be offset by an increase in the number of tokens of the other asset, so that their final sum always equals k. AMMs use liquidity pools, to which users can deposit their assets, receiving in return LP tokens (liquidity provider tokens) that represent their share in the pool. When another user wants to make an exchange, interactions with the liquidity pool cause changes in asset stocks, resulting in an automatic change in their price according to the specified formula [Jiahua et al., 2023].

To sum up, centralized cryptocurrency exchanges are preferred by inexperienced investors as their operation is less complicated, more accessible, and intuitive, thanks to the constant possibility of contact with an administrator and consumer support. CEXs are the first entry point for an entity lacking knowledge in the field of crypto-asset trading. On the other hand, decentralized exchanges are usually preferred by experienced investors due to their decentralization, lower costs, and full access to decentralized finance.

Both Cryptocurrency exchanges are characterized by variations in security levels, access, usage costs, and transaction processing. The key difference between custodial and non-custodial wallets is full control over private keys [Samer, 2022].

Conclusion

There are two primary types of cryptocurrency exchanges: centralized exchanges (CEX) and decentralized exchanges (DEX). Centralized exchanges are characterized by a centralized management structure that controls user funds, offering a more streamlined and user-friendly experience. However, this centralization introduces risks, particularly related to security, as users must trust the exchange with their assets. If the platform is compromised or experiences an operational failure, users could face significant losses. Additionally, centralized exchanges typically require users to undergo identity verification and other regulatory procedures, which can be a barrier for some individuals seeking privacy or anonymity in their transactions.

In contrast, decentralized exchanges (DEXs) operate without a central authority, allowing users to retain control of their funds and trade directly with one another through smart contracts on a blockchain. This decentralization reduces reliance on intermediaries and enhances privacy, but it comes with its own challenges. DEXs tend to be more complex to navigate and may require a higher level of technical expertise. Additionally, the absence of a central authority means that users are responsible for their own security, including managing their private keys and safeguarding against risks such as hacking or losing access to their wallets.

Despite the growing adoption of both CEXs and DEXs, there is a noticeable gap in empirical research exploring the factors influencing the adoption of cryptocurrency exchanges. While many studies have focused on the technical aspects of cryptocurrencies, blockchain technology, and the economic implications of decentralized finance, few have delved into the behavioral and practical aspects of how individuals, businesses, and institutions decide to adopt these platforms. Understanding the motivations and barriers behind adopting cryptocurrency exchanges is crucial, as it can inform strategies to increase adoption, enhance user experience, and address key challenges such as security, accessibility, and regulatory compliance.

Future research should focus on exploring how different groups – ranging from individual investors to large financial institutions – begin integrating cryptocurrency exchanges into their financial activities. This research should consider factors such as ease of use, trust in the platform, regulatory considerations, the role of education, and the perceived risks and rewards of participating in the cryptocurrency market. By addressing these areas, future studies can help bridge the gap in knowledge and contribute to the development of more efficient, secure, and user-friendly platforms that promote wider adoption of cryptocurrency exchanges. Understanding the process of adoption could also lead to more effective policy-making, particularly as governments and regulatory bodies seek to navigate the rapidly evolving landscape of digital currencies and blockchain technology.

Bibliography

Bank for International Settlements [2023], *The crypto ecosystem: key elements and risks Report submitted to the G20 Finance Ministers and Central Bank Governors*, ISBN 978-92-9259-670-5.

Barbon A., Ranaldo A. [2023], *On the quality of cryptocurrency markets: Centralized versus decentralized exchanges*, Cornell University, https://doi.org/10.48550/arXiv.2112.07386.

Bentov I., Ji Y., Zhang F., Breidenbach L., Daian P., Juels A. [2019], *Tesseract: real-time cryptocurrency exchange using trusted hardware*, CCS '19: Proceedings of the 2019 ACM SIGSAC Conference on Computer and Communications Security, November, p. 1521–1538, https://dl.acm.org/doi/abs/10.1145/3319535.3363221.

Canessane R.A., Srinivasan N., Abinash B., Ashwini S., Kumar B.M. [2019], *Decentralised applications using Ethereum Blockchain*, International Conference on Science Technology Engineering and Mathematics (ICONSTEM), Chennai, India, p. 75–79, https://doi.org/10.1109/ICONSTEM.2019.8918887.

Chalkias K., Chatzigiannis P., Yan J. [2022], *Broken proofs of solvency in Blockchain custodial wallets and exchanges*, Cryptology ePrint Archive, https://eprint.iacr.org/2022/043.

Chen You-Ping, Ju-Chun Ko [2019], *CryptoAR Wallet: A Blockchain cryptocurrency wallet application that uses augmented reality for on-chain user data display*, Proceedings of the 21st International Conference on Human-Computer Interaction with Mobile Devices and Services, MobileHCI'19, New York, p. 1–5, https://doi.org/10.1145/3338286.3344386.

Crypto-assets – European Commission [2023], https://finance.ec.europa.eu/digital-finance/crypto-assets_en (Accessed: 25.02.2025).

ESMA [2023], *Markets in crypto-assets regulation* (MiCA), https://www.esma.europa.eu/esmas-activities/digital-finance-and-innovation/markets-crypto-assets-regulation-mica (Accessed: 25.02.2025).

Essén A., Ekholm A. [2020], *Centralization vs. decentralization on the Blockchain in a health information exchange context*, Digital Transformation and Public Services, p. 58–82.

Fareed T. [2023], *A systemic review of payment technologies with a special focus on digital wallets*, in: Turi A.N. (ed.), *Financial technologies and DeFi. Financial innovation and technology*, Springer, Cham, p. 89–97, https://doi.org/10.1007/978-3-031-17998-3_6.

Hyeji J., Sung H. Han, Ju Hwan Kim, Kimin Kwon [2021], *Usability evaluation for cryptocurrency exchange*, in: Gutierrez A.M.J., Goonetilleke R.S., Robielos R.A.C. (eds.), *Convergence of ergonomics and design*, "Advances in Intelligent Systems and Computing", vol. 1298, Springer International Publishing, Cham, p. 192–196, https://doi.org/10.1007/978-3-030-63335-6_20.

Jiahua Xu, Paruch K., Cousaert S., Feng Y. [2023], *SoK: Decentralized exchanges (DEX) with automated market maker (AMM) protocols*, "ACM Computing Surveys", vol. 55(11), p. 1–50, https://doi.org/10.1145/3570639.

Kancelaria Prezesa Rady Ministrów [2024], *Projekt ustawy o kryptoaktywach*, Chancellery of the Prime Minister Republic of Poland, gov.pl, https://www.gov.pl/web/premier/projekt-ustawy-o-kryptoaktywach (Accessed: 1.06.2024).

Kumar M., Nikhil N., Singh R. [2020], *Decentralising finance using decentralised Blockchain oracles*, International Conference for Emerging Technology (INCET), Belgaum, India, p. 1–4, https://doi.org/10.1109/INCET49848.2020.9154123.

Markets in crypto-assets (MiCA/MiCAR) – CSSF [2025], https://www.cssf.lu/en/markets-in-crypto-assets-mica-micar/ (Accessed: 25.02.2025).

McDevitt A. [2025], *The rise, fall, and rise of crypto: Lessons from FTX amidst a changing regulatory landscape*, https://www.int-comp.org/insight/the-rise-fall-and-rise-of-crypto-lessons-from-ftx-amidst-a-changing-regulatory-landscape/ (Accessed: 25.02.2025).

McMenamin C., Daza V., Fitzi M., O'Donoghu P. [2022], *FairTraDEX: A decentralised exchange preventing value extraction*, ACM CCS Workshop on Decentralized Finance and Security, Association for Computing Machinery, New York, p. 39–46, https://doi.org/10.1145/3560832.3563439.

Platt M., Pierangeli F., Livan G., Righi S. [2020], *Facilitating the decentralised exchange of cryptocurrencies in an order-driven market*, Conference on Blockchain Research & Applications for Innovative Networks and Services (BRAINS), Paris, p. 30–34, https://doi.org/10.1109/BRAINS49436.2020.9223286.

Qin K., Zhou L., Afonin Y., Lazzaretti L., Gervais A. [2021], *CeFi vs. DeFi – comparing centralized to decentralized finance*, Cornell University, https://doi.org/10.48550/arXiv.2106.08157.

Samer B., Qais H., Khalil Y. [2022], *Comparison of hardware and digital crypto wallets*, "Journal of Southwest Jiaotong University", vol. 57(6), http://jsju.org/index.php/journal/article/view/1414 (Accessed: 30.05.2024).

Sans T.., Ziming L., Oh K. [2023], *A decentralized mnemonic backup system for non-custodial cryptocurrency wallets*, in: Jourdan G.-V., Mounier L., Adams C., Sèdes F., Garcia-Alfaro J., *Foundations and practice of security*, Lecture Notes in Computer Science, Springer Nature Switzerland, Cham, p. 355–370, https://doi.org/10.1007/978-3-031-30122-3_22.

Schoar M., Schoar A. [2022], *Cryptocurrencies and decentralized finance*, Bank for International Settlements.

Taylor S., Ho-Yong Kim S., Akram Zainol Ariffin K., Siti Norul Huda Sheikh A. [2022], *A comprehensive forensic preservation methodology for crypto wallets*, "Forensic Science International: Digital Investigation", vol. 42–43, https://doi.org/10.1016/j.fsidi.2022.301477.

UKNF [2021], *Ostrzeżenie Urzędu KNF o ryzykach związanych z nabywaniem oraz z obrotem kryptoaktywami (w tym walutami wirtualnymi oraz kryptowalutami)*, The Polish Financial Supervision Authority (UKNF), Warsaw, 12 stycznia, https://www.knf.gov.pl/knf/pl/komponenty/img/Ostrzezenie_UKNF_o_ryzykach_zwiazanych_z_nabywaniem_oraz_z_obrotem_kryptoaktywami_72241.pdf (Accessed: 30.05.2024).

Ustawa z dnia 1 marca 2018 r. o przeciwdziałaniu praniu pieniędzy oraz finansowaniu terroryzmu, https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20180000723 (Accessed: 3.03.2025).

Wang Q., Rujia Li W., Qi Wang, Chen S. [2021], *Non-fungible Token (NFT): Overview, evaluation, opportunities and challenges*, Cornell University, http://arxiv.org/abs/2105.07447.

Wang Y.., Lu W., Liu M.-B., Ren R., Härdle W.K. [2024], C*ross-Exchange crypto risk: A high-frequency dynamic network perspective*, "International Review of Financial Analysis", vol. 94, https://doi.org/10.1016/j.irfa.2024.103246.