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RECEIVED 27 June 2025

ACCEPTED 24 July 2025

PUBLISHED 06 August 2025

CITATION

Von Hafe F, Wagle Y, Guede-Fernández F,
Giordano AP, Silva L and Azevedo S (2025) Legal
frameworks for blockchain applications: a
comparative study with implications for
innovation in Europe.

Front. Blockchain 8:1655230.

doi: 10.3389/fbloc.2025.1655230

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Legal frameworks for blockchain applications: a comparative study with implications for innovation in Europe

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Introduction: The decentralised nature of blockchain technology challenges traditional legal frameworks, creating regulatory gaps in asset classification, taxation, and consumer protection. In Europe, divergent approaches, from specialised blockchain laws to adaptations of general financial legislation, hinder cross-border deployment and limit blockchain's potential. These disparities make compliance difficult for firms and increase the risks for consumers. This study compares blockchain regulations across six European geographies: Switzerland, Liechtenstein, and Malta (blockchain-specialised regulators) versus the European Union (EU), Estonia, and Portugal (generalist regulators) to map key divergences in legal maturity, asset classification, taxation, anti-money laundering/know-your-customer enforcement, and supervisory structures. A secondary objective is to evaluate how these differences impact the scalability of innovation.

Methods: This study compares blockchain regulations across six European jurisdictions through a three-phase analysis. The scoping phase identified five regulatory themes and selected geographies based on maturity, innovation, and economic specialisation. Primary legal texts and policy data (2020–2025) were analysed to map convergences and divergences between blockchain-specialised and generalist regulators.

Results: The comparison reveals differences: blockchain-specialised geographies have dedicated Distributed Ledger Technology laws, centralised oversight, and crypto-friendly tax regimes; for example, Switzerland exempts private capital gains, and Malta offers Value Added Tax exemptions. In contrast, generalist regulators, such as the EU's Markets in Crypto-Assets Regulation (MiCA), which theoretically harmonise rules, face inconsistent enforcement across member states. Meanwhile, Portugal's tax exemptions and Estonia's rigid capital requirements create opposing market incentives. Only Liechtenstein's Blockchain Act comprehensively regulates Decentralised Finance, whereas other geographies either adapt existing financial regulations

or do not regulate it. NFTs face fragmented treatment, are excluded under MiCA, classified as securities in Estonia, and left to case-by-case analysis in Switzerland, which contributes to market uncertainty.

Discussion: This study reveals a tension in blockchain governance: specialised geographies demonstrate that comprehensive, tailored frameworks foster mature ecosystems. Conversely, generalist approaches struggle with fragmentation, as seen in MiCA's uneven enforcement and Estonia's restrictive licensing. Yet, regulatory ambiguity carries paradoxical benefits; Portugal's minimal rules and the EU's transitional gaps have also fueled competitive innovation. For policymakers, these results underscore the importance of striking a balance between oversight and flexibility to foster and scale up innovation.

KEYWORDS

blockchain, legal governance, market regulation, decentralized finance (DeFi), comparative law, digital asset regulation

1 Introduction

Blockchain technology's core features, decentralised governance, pseudonymous transactions, and rapid protocol evolution, create challenges for regulators worldwide (Tripathi et al., 2023). Unlike conventional systems, blockchain operates across borders without centralised intermediaries, introducing regulatory issues that existing legal frameworks were not equipped to address (Dominic Ochigbo et al., 2024). Legal frameworks not only serve to protect the market and its participants but also shape its structure by defining, for example, how assets are classified, tax reporting requirements, or consumer protection laws (OECD and KDI, 2021; Triveni and Sanjana, 2024). In 2024, compliance costs for crypto firms increased by 22%, averaging \$500,000 per year, with anti-money laundering/know-your-customer (AML/KYC) protocols accounting for approximately 30% of budgets. Decentralised Finance (DeFi) platforms experienced a 15% cost rise due to transparency regulations (Elad, 2025).

Legal frameworks for blockchain differ across geographies in terms of maturity, structure, and scope (EU Blockchain Observatory et al., 2024). Moreover, as blockchain-based products and services continue to evolve, legal frameworks must adapt dynamically, requiring continuous monitoring of regulatory changes to address emerging applications, such as privacy-preserving DeFi and cross-chain interoperability (Joseph Kuba Nembe et al., 2024). Even as European countries move toward harmonisation under the European Union's (EU) Markets in Crypto-Assets Regulation (MiCA), national-level differences persist, potentially limiting implementation and undermining consumer protection (Mkrtchyan and Treiblmaier, 2025). In Europe, countries have adopted divergent regulatory strategies, with some developing specialised blockchain regimes and others adapting existing regulations (CCAF, 2024), resulting in regulatory fragmentation that may hinder blockchain innovation and limit the utilisation of blockchain technology to its full potential (OECD and KDI, 2021). This variation presents challenges for multinational firms navigating compliance and for policymakers seeking to strike a balance between innovation and effective oversight (Lee, 2024).

The constant adaptation and change of regulatory frameworks leads to many existing analyses being outdated or incomplete. This requires that research on blockchain regulatory frameworks be

simultaneously structured (employing consistent analytical frameworks), comparative (assessing multiple regulatory models), and temporally sensitive (tracking legislative updates). Without it, market participants may face different risks: firms struggle with compliance uncertainty, investors encounter cross-border deployment risks, regulators lack benchmarks for effective oversight, and consumers remain exposed to inconsistent protections, ultimately constraining the growth of the ecosystem.

This paper aims to help address these issues by comparing blockchain regulatory frameworks across Europe. Our primary objective is to identify the key differences in how the selected geographies legislate blockchain applications. As a secondary goal, we will discuss how these legal divergences may impact blockchain innovation. By mapping both convergence and fragmentation in the regulation, this study contributes to ongoing academic and policy efforts aimed at striking a balance between technological innovation and effective oversight.

This paper is organised as follows: Section 2 outlines the materials and methods. Section 3 presents the results, first dividing each geography into groups (blockchain-specialised vs. generalist regulators), then analysing them individually before comparing frameworks both within and across groups to identify regulatory convergences and divergences. Section 4 discusses the implications of these differences for blockchain innovation.

2 Materials and methods

This study analyses and compares blockchain legal frameworks across six European geographies through three phases: scoping, data collection, and analysis (Etienne et al., 2018). The scoping phase aims to define the selection criteria for identifying the geographies to include in the study and determining the themes to analyse their regulatory frameworks, allowing for a structured comparison. In the second phase, data collection aims to gather the most recent legislative developments, ensuring the included references reflect current regulatory approaches. Finally, the analysis phase seeks to examine each geography's regulatory framework and identify both cross-geographical convergences and divergences. While the overall study design followed the three-phase method proposed by Etienne et al. (2018), Framework Analysis was employed specifically within

the scoping and analysis phases to ensure systematic identification and comparison of key regulatory features.

2.1 Scoping phase

As referred to, the scoping phase of the literature review process aimed to define the themes to study blockchain regulation in each defined geography and the themes to define the geographies to include in this study. To achieve this goal, two independent researchers analysed academic literature and policy documents, and, using Framework Analysis, identified thematic patterns aligned with the study's objectives (Furber, 2010). The five-step process included familiarisation with the data, identification of themes, indexing, charting, and mapping to develop a structured synthesis of key findings across studies. If doubts or disagreements arose, the authors discussed and solved them, and if necessary, another author was consulted. The following criteria were used to define the articles to be included in this review: (1) publication between 2020 and 2025, (2) articles being peer-reviewed studies, white papers, primary legislation, or official policy documents, and (3) direct relevance to blockchain regulatory frameworks in European jurisdictions.

First, this process resulted in the identification of five analytical themes. The five themes identified in the scoping phase using Framework Analysis served as the analytical categories in the comparative phase, guiding both intra- and cross-group evaluations: (1) regulatory maturity, (2) crypto-asset classification, (3) tax treatment, (4) AML/KYC enforcement, and (5) regulatory structure. These themes will be further developed and justified in the results section. Second, the Scoping Phase led also to the identification of three selection criteria of the geographies under study: (1) regulatory maturity: geographies were selected based on whether they presented either established or early-stage blockchain regulatory frameworks, allowing to compare more consolidated and emerging regulatory frameworks; (2) regulatory innovation: geographies were included if they had introduced legal or policy initiatives specifically targeting blockchain or Distributed Ledger Technology (DLT), regardless of whether these initiatives were fully developed or in early stages; (3) economic specialisation in blockchain: geographies were selected based on whether they have explicitly designed their economic or legal infrastructure to attract blockchain businesses (for example, licensing regimes, tax incentives, sandboxes) or those regulating blockchain as part of broader financial/digital policies (Nguyen and Nguyen, 2023; EU Blockchain Observatory et al., 2024). The last criterion was also used to group the selected geographies into blockchain-specialised regulators and generalist ones.

2.2 Data collection phase

The data collection phase involved desk research to identify and review relevant materials, including reports and publications from governmental bodies, international organisations, academic sources, newspaper articles, peer-reviewed articles, white papers, specialised media, and primary legislation (Etienne et al., 2018). For the analysis of each specific geography, documents were included based on the following criteria: they represented the most recent and relevant

normative documents from regulatory bodies, professional associations, or academic sources, and their content was directly related to blockchain legislation.

2.3 Analysis phase

The analysis phase was conducted in two parts (Etienne et al., 2018). First, each geography was treated as an independent case, analysed across the five predefined themes identified in the scoping phase. Second, a comparative analysis was conducted to assess differences and similarities across geographies, first by doing intra-group comparisons and then by comparing both groups.

3 Results

The following subsections describe the obtained results. First, the definition of the five themes to be studied and compared across different geographies is presented. The results then proceed with the following three subsections: first, individual analysis of each geography's legal framework, first the three specialised blockchain regimes (Switzerland, Liechtenstein, Malta) then the three generalist ones (EU, Estonia, Portugal); second, intra-group comparison identifying regulatory convergences and divergences among geographies that belong to the same group; and third, cross-group analysis contrasting specialised versus generalist frameworks to assess the differences.

3.1 Definition of the themes to analyse and compare across geographies

As described in the previous section, a set of five key regulatory themes were identified to guide the comparison across geographies: (1) regulatory maturity to assess the existence and comprehensiveness of blockchain-specific regulations, to allow the comparison of geographies with comprehensive legal frameworks and those in earlier stages (EU Blockchain Observatory et al., 2024); (2) crypto-asset classification to assess how geographies categorize digital assets as this may influence legal obligations and consumers' protection (Ankenbrand et al., 2020; Chason, 2022); (3) tax treatment to assess how different geographies tax crypto assets which may encourage or hinder innovation and participation in the market (Kofler et al., 2024; European Commission. Directorate General for Taxation and Customs Union, 2025); (4) AML/KYC enforcement to understand how geographies address financial crime risks and promote market integrity (FATF, 2021); (5) regulatory structure to assess whether supervision responsibilities are centralized within a single authority or distributed across multiple ones which can affect coordination, clarity, and enforcement effectiveness (Renda et al., 2022).

3.2 Individual geography analysis

This section presents the analysis of the legal frameworks across the six selected geographies individually. The three specialised regimes demonstrate different regulatory approaches: Switzerland's DLT Act

TABLE 1 Comparative table: Blockchain regulatory frameworks.

Geography	Regulatory maturity	Crypto asset classification	Tax treatment	AML/KYC enforcement	Regulatory structure
Switzerland	High (DLT Act 2021). Covers tokens and DLT trading—gaps: DAOs, NFTs, case-by-case	FINMA’s three types: Payment, Utility, and Asset tokens. NFTs: non-securities unless fractionalised	–0% capital gains (private individuals) - Income tax on mining/staking - VAT exempt for crypto-fiat	FATF-compliant. VASPs must follow FINMA AML rules (even DeFi)	Centralised: FINMA is the sole regulator
Liechtenstein	Very high (Blockchain Act 2020). Covers tokens and TT services. Gaps: NFTs	Token Container Model: Payment, Utility, Asset tokens. Legally recognised	- €100k capital gains exemption –12.5% corporate tax (lower for Security Tokens) - No VAT on crypto	FATF-compliant. FMA supervises AML for issuers and TT providers	Centralised: FMA + Office for Digital Innovation
Malta	Medium-high (VFSA 2018 + MiCA). Strict licensing. Lost “blockchain island” status	Financial Instrument Test (FIT): Virtual tokens, e-money, financial instruments, VFAs	–5% corporate tax for qualifying firms - VAT exempt for crypto-fiat	FIAU enforces EU AML. CASPs must report to FIAU.	Centralised: MFSA supervises CASPs
EU	Medium (MiCA 2023). Covers CASPs, stablecoins—gaps: DeFi, NFTs (under review)	3 types: Utility, Asset-Referenced (ARTs), E-Money Tokens (EMTs)	No harmonisation. DAC8 enforces CARF (tax reporting only)	EBA/ESMA sets standards—TravelRule for VASPs	Semi-centralised: EBA/ESMA + national regulators
Portugal	Low (No dedicated framework). Follows EU AML rules. MiCA pending	No formal classification. Treated as assets	–28% tax on short-term gains (<1 yr) –0% long-term (>1 yr) - Income tax on mining	The Bank of Portugal enforces AML (limited to VASPs)	Fragmented: BdP (AML) + CMVM (securities)
Estonia	Medium (Crypto Asset Act 2024). Aligns with MiCA. Phased licensing	4 types: Cryptocurrencies, Asset-backed, Utility, Security tokens	- Income tax on mining/staking - VAT on crypto-crypto services	FIU enforces strict real-time KYC. FSA takes over in 2026	Hybrid: FIU (AML) and FSA (future)

integrates blockchain into existing financial laws, Liechtenstein’s Token and Trusted Technology Service Provider Act (TVTSG) establishes comprehensive token governance, and Malta’s Virtual Financial Assets Act (VFSA) creates a hybrid EU-aligned system. Among generalist regulators, the EU’s MiCA provides harmonised rules with national implementation variances; Estonia enforces stringent licensing requirements, while Portugal maintains minimal specific regulation.

3.2.1 Switzerland

Switzerland (Box 1) operates as a civil law jurisdiction with a federalist structure (Ritaine and Papeil, 2014), implementing blockchain regulation through amendments to ten existing laws, including the Code of Obligations and Banking Act via its DLT Act (2021) (Homsy and Jaccard, 2025). The institutional framework features executive oversight by the Swiss Financial Market Supervisory Authority (FINMA) working alongside judicial interpretation of the civil and criminal courts (FINMA, 2017a), as demonstrated by the Federal Court’s 2023 ruling that DAO members can be treated as general partners subject to joint and several liability (Dechert, 2023). The system applies constitutional principles of proportionality (FINMA, 2017b) while increasing legal certainty, for example, by explicitly regulating the segregation of crypto-based assets in the event of bankruptcy (Widmer et al., 2023). Regulatory implementation reveals traditional legal constraints, as evidenced by the prohibition of algorithmic stablecoins under established banking regulations (Haerberli et al., 2024), alongside institutional adaptations such as the creation of specialised blockchain dispute resolution procedures.

3.2.2 Liechtenstein

Liechtenstein (Box 2) represents a civil law jurisdiction (Wolf et al., 2018) that established the world’s first comprehensive blockchain legislation through its TVTG (Liechtenstein Finance, 2025). The principality’s unitary legal system (Kley, 2001) enables centralised oversight by the Financial Market Authority (FMA) working in coordination with the Office for Digital Innovation (FMA, 2025b). The TVTG’s Token Container Model extends traditional civil law property protections to digital assets by explicitly categorising them into payment, utility, and asset tokens (Niedermüller and Epicoco, 2024). Implementation shows strict adherence to Financial Action Task Force standards, with the FMA requiring full compliance from all token issuers and service providers (Anti-Money Laundering and DNFBP Division, 2022). The framework currently excludes non-fungible tokens (NFTs) and DeFi protocols from specific regulation, maintaining these under general civil law provisions.

3.2.3 Malta

Malta (Box 3) has a hybrid regulatory approach as a common law jurisdiction within the EU framework (Sammut, 2022), implementing blockchain governance through its VFSA in conjunction with the EU’s MiCA (Biedermann and Moncada, 2024). The Malta Financial Services Authority (MFSA) serves as the centralised regulatory body, employing a British-inherited Financial Instrument Test to classify crypto-assets into four categories: virtual tokens, financial instruments, e-money tokens, and virtual financial assets (Vella, 2024). Malta’s constitutional principle of legal certainty can be inferred from the licensing

requirements for crypto-asset service providers, which include a minimum capital threshold of €730,000 (MFSA, 2025a). The system adheres to EU-aligned AML protocols through the Financial Intelligence Analysis Unit (FIAU), which mandates real-time transaction monitoring for licensed entities (Sanctions, 2024).

3.2.4 European Union

European Union (Box 4) operates as a supranational regulatory body with a civil law foundation (Tsebelis and Garrett, 2001), implementing blockchain governance through the MiCA and Digital Operational Resilience Act (DORA) (European Commission, 2023). The framework establishes a three-tiered classification system (utility tokens, asset-referenced tokens, and e-money tokens), administered through decentralised enforcement by national competent authorities (NCAs) under the oversight of the European Banking Authority (EBA) and the European Securities and Markets Authority (ESMA). The system applies the EU principle of proportionality (European Union, 2012) through graduated requirements based on market capitalisation and activity type, evidenced by stricter rules for asset-referenced tokens under MiCA Article 43 (ESMA, 2025). Implementation data reveals 27 national interpretation variances (Carata and Knottenbelt, 2024), particularly in the treatment of NFTs (excluded from the MiCA scope) and DeFi protocols. The framework mandates uniform AML compliance, though enforcement disparities persist.

3.2.5 Portugal

Portugal (Box 5) functions as a civil law jurisdiction within the EU framework (Hespanha et al., 2009), currently implementing blockchain regulation through transposition of EU directives rather than domestic legislation (Lima da Luz and Gomes da Silva, 2025). The Bank of Portugal (BdP) is the primary regulatory authority under Notice No 3/2021, which establishes AML requirements for virtual asset service providers (VASPs) while deferring to the Securities Market Commission (CMVM) for security-like tokens. The framework currently excludes Defi protocols and NFTs from specific oversight, maintaining them under general financial statutes.

3.2.6 Estonia

Estonia (Box 6) is a civil law jurisdiction (European Judicial Network, 2023), implementing blockchain regulation through a phased approach that began with the Money Laundering and Terrorist Financing Prevention Act (MLTFPA) and evolved with the 2024 Crypto Asset Market Act, aligning with MiCA (Charlton Quantum, 2024). The Financial Intelligence Unit (FIU) is the primary enforcement authority, implementing Europe's strictest AML regime through real-time transaction monitoring and 24-h reporting windows (Riigi Teataja, 2017). Estonia's digital governance principles manifest in its four-tier crypto asset classification system (cryptocurrencies, asset-backed tokens, utility tokens, security tokens). The framework currently treats fractionalized NFTs as securities under existing financial laws.

3.3 Comparison across geographies

As described in the “Materials and Methods” section, to systematically examine blockchain regulations across geographies, two comparisons were conducted: first, within each group of geographies, and second, between the two groups. Table 1 provides a consolidated overview of key convergences and divergences identified through this granular examination, particularly highlighting contrasts between specialised and generalist approaches in critical areas, such as DeFi governance and NFT classification. This jurisdictional-level analysis establishes the foundation for subsequent cross-comparison of regulatory paradigms.

BOX 1 Switzerland's blockchain regulatory framework.

Regulatory Maturity: Switzerland is considered to have high blockchain regulatory maturity, anchored in its DLT Act, which was enacted in 2021 (State Secretariat for International Finance, 2023). This legislation integrates blockchain applications into existing financial and civil law, explicitly addressing the tokenisation of assets, DLT trading facilities, and the legal recognition of ledger-based securities (Favrod-Coune and Belet, 2023). The framework has enabled Switzerland to develop a robust blockchain ecosystem, most notably through Crypto Valley in Zug, which hosts prominent organisations including the Ethereum Foundation and SEBA Bank (Zehnder, 2024). However, the DLT Act currently excludes provisions for Decentralised Autonomous Organisations (DAOs), which represents a regulatory gap (Mehmetaj, 2025).

Crypto Asset Classification: The FINMA maintains a classification system that distinguishes between payment tokens (subject to AML regulations but not securities laws), utility tokens (providing application access and generally exempt from securities regulation, unless used for investment), and asset tokens (representing assets or rights and, according to the FINMA's Initial Coin Offerings (ICO) are treated as securities) (FINMA, 2022; UBS, 2022). Switzerland applies existing financial laws to NFTs through FINMA's case-by-case approach. While most NFTs (digital art, collectibles) are not considered securities, those exhibiting investment characteristics like fractionalization or revenue streams may fall under financial market rules (Maeder and Jann, 2022) (Maeder and Jann, 2022; FINMA, 2022). This includes potential licensing requirements under the Financial Market Infrastructure Act (FinMIA) or prospectus obligations.

Taxation Regime: Cryptocurrencies are treated as assets and included in the wealth tax base, with their value assessed at the end of the year. Income generated from crypto-related activities, including mining, staking, or professional trading, is taxed as income. In contrast, private individuals' capital gains are usually exempt (Sackheim and Howell, 2020; Wimmer, 2025). Crypto-to-fiat exchanges are exempt from Value Added Tax (VAT), whereas VAT applies to transactions that utilise cryptocurrency as a form of payment (Haeberli et al., 2024).

AML/KYC Framework: Switzerland adheres to Financial Action Task Force (FATF) standards (Financial Action Task Force, 2023) requiring VASPs, including exchanges and wallet providers, to comply with customer due diligence, transaction monitoring, and suspicious activity reporting (Swiss Banking, 2020). Revisions to the AML Act in 2020 extended these requirements to blockchain-specific services, and FINMA's guidance ensures that such obligations also apply to decentralised platforms (FINMA, 2021).

Supervisory Structure: Switzerland employs a centralised regulatory model with FINMA serving as the sole authority responsible for licensing, supervision, and compliance across blockchain and crypto-asset activities (Zehnder, 2024).

BOX 2 Liechtenstein's blockchain regulatory framework.

Regulatory Maturity: Liechtenstein has established a comprehensive regulatory framework for blockchain and DLT through the TVTG Act, which took effect on 1 January 2020 (Government of Liechtenstein, 2019). This act is considered the world's first comprehensive blockchain law (Liechtenstein Finance, 2025). It integrates blockchain-specific laws into existing legislation, including tokenisation processes, the provision of trusted technology (TT) services, and the legal recognition of digital assets (Niedermüller and Epicoco, 2024). It provides legal clarity for market participants and defines the obligations of service providers. The TVTG also provides partial regulatory coverage for NFTs by broadly defining "tokens" as representations of rights or assets, regardless of fungibility (CMS, 2024a).

Crypto Asset Classification: Under the TVTG, crypto-assets are categorised according to their purpose and economic function: payment tokens (treated as e-money if fiat-backed), utility tokens (granting access to digital services), or asset tokens (representing assets or legal claims) (Kaur, 2024). The law defines each category and establishes specific regulatory requirements to ensure consistency between the asset's function and its legal treatment. Due to the Token Container Model, all tokens are legally recognised (Niedermüller and Epicoco, 2024). The framework's application to NFTs depends on their functional characteristics, with fractionalized NFTs potentially qualifying as asset tokens, despite being theoretically covered under this framework, practical guidance or tailored supervisory practices specific to NFTs remain limited (CMS, 2024a).

Taxation Regime: Individuals pay wealth tax on their holdings and income tax on trading and mining profits, but are exempt from tax on capital gains up to € 100,000 annually. Businesses benefit from a 12.5% corporate tax rate (often lower with deductions) and special exemptions for Security Token trading. The system distinguishes between token types: Security Tokens are tax-exempt, while Utility and Payment Tokens are subject to standard corporate rates. VAT does not apply to crypto transactions, and the treatment of NFTs remains unclear (Niedermüller and Epicoco, 2024).

AML/KYC Framework: Liechtenstein enforces AML/KYC obligations by the standards set by the FATF. The TVTG subjects all issuers of crypto assets and TT service providers to the requirements set out in the Due Diligence Act, including customer identification, transaction monitoring, and the reporting of suspicious activity (Anti-Money Laundering and DNFBP Division, 2022).

Supervisory Structure: Compliance is supervised by the FMA and the Office for Financial Market Innovation and Digitalisation, which ensures that even innovative blockchain applications adhere to financial crime prevention protocols (EU Blockchain Observatory Forum expert panel et al., 2024; Taras Shevchenko National University of Kyiv et al., 2024; FMA, 2025a).

BOX 3 Malta's blockchain regulatory framework.

Regulatory Maturity: Malta has developed a structured regulatory framework for crypto-assets, underpinned by the implementation of MiCA, while retaining its Virtual Financial Assets Act (VFAA) for specific areas (Biedermann and Moncada, 2024). The MFSA is responsible for supervising entities authorised under MiCA, including crypto-asset service providers (CASPs) (MFSA, 2025a), ensuring adherence to capital requirements, governance standards, and operational integrity (CMS, 2024b).

Crypto Asset Classification: The Financial Instrument Test (FIT) is used to determine whether a cryptocurrency was classified as a virtual token (digital asset used solely for purchasing goods or services within a specific DLT platform or a limited network of platforms), financial instrument (any financial instrument listed in the Second Schedule of the Maltese Investment Services Act), e-money (electronically stored monetary value that represents a claim on the issuer, created when funds are received, and intended to be used for payment transactions), or a virtual financial asset (digital asset used as a medium of exchange, unit of account, or store of value that does not fall into any of the three previously defined categories) (Vella, 2024). The VFAA framework excludes NFTs that are typically classified as virtual tokens, unless they qualify as virtual financial assets under investment criteria. However, there is limited legislation in this area (Financial Services Commission, 2024).

(Continued in next column)

BOX 3 (Continued) Malta's blockchain regulatory framework.

Taxation Regime: Transactions involving crypto-to-fiat conversions are exempt from VAT. At the same time, corporate participants, including issuers and CASPs, remain subject to standard tax obligations, with specific provisions allowing qualifying companies to benefit from reduced effective tax rates, ranging from 35% to nil, through Malta's imputation system (KPMG, 2019). The taxation of NFTs depends heavily on whether they are classified as DLT assets (Pareek, 2025b).

AML/KYC Framework: Malta enforces robust AML/KYC regulations in line with EU directives. CASPs are required to verify customer identities, monitor transactions, and report suspicious activities to the FIAU (Sanctions, 2024). These requirements also apply to NFT platforms when dealing with transactions involving virtual financial assets.

Supervisory Structure: Malta employs a centralised regulatory structure, with the MFSA overseeing licensing and compliance for CASPs, and the FIAU responsible for AML/Combating the Financing of Terrorism (CFT) enforcement (MFSA, 2025b).

BOX 4 EU Blockchain Regulatory Framework.

Regulatory Maturity: The EU has established a regulatory framework for blockchain and crypto-assets, primarily through MiCA and the DORA (European Commission, 2023), which aims to introduce a harmonised legal framework across member states, while allowing for minor deviations (Carata and Knottenbelt, 2024; EU Blockchain Observatory et al., 2024). MiCA addresses previously unregulated areas, such as token issuance, trading, and custody services (Bosch et al., 2022), becoming the world's first comprehensive framework for cryptocurrencies. However, its current scope excludes DeFi and NFTs (unless they demonstrate a fungibility characteristic), although these are under active review, with consultations currently being conducted to extend MiCA to partially decentralised systems by 2026 (Maia and Vieira Dos Santos, 2021; Barczentewicz and De Gândara Gomes, 2024). DORA enhances systemic stability by mandating Information and Communication Technology (ICT) risk management standards for financial entities, thereby mitigating operational vulnerabilities in blockchain adoption (European Banking Authority, 2024).

Crypto Asset Classification: MiCA also establishes a classification system for crypto-assets, distinguishing between utility tokens (which grant access to a specific application or service, that require minimal regulation unless they resemble securities), asset-referenced tokens (ARTs) (stablecoins backed by baskets of assets, such as, commodities or currencies, facing strict reserve and disclosure rules), and e-money tokens (which represent digital equivalents of fiat currency and are used primarily for payment purposes, they must be issued by licensed credit institutions or e-money firms, with full-reserve backing and 24/7 redemption rights) (European Commission, 2023). NFTs fall outside this classification unless they meet the fungibility criteria (ESMA, 2024), leaving their regulatory treatment to national authorities during the period before the framework's review (European Crypto Initiative, 2024).

Taxation Regime: The taxation of crypto-assets remains uncoordinated, as fiscal policy falls under the jurisdiction of individual nations (Solodan, 2019). However, within its powers, the EU has introduced the Directive on Administrative Cooperation 8 (DAC8), which implements the OECD's Crypto Asset Reporting Framework (CARF) to increase reporting requirements for crypto-asset service providers, improving tax transparency and compliance across borders. However, DAC8 does not harmonise tax rates, preserving national fiscal autonomy, and tax authorities lack the tools to verify crypto self-reporting, which risks the effectiveness of CARF (Council of the EU, 2023).

AML/KYC Framework: Regarding AML/KYC enforcement, the Fifth and Sixth AML Directives require service providers to register with national authorities and implement due diligence procedures (European Commission, 2024). These requirements are also extended to NFT marketplaces operating as obligated entities under national implementations (Mosna and Soana, 2023). These obligations are further reinforced under MiCA, with the EBA providing supervisory guidance to promote regulatory coherence (Ann Petit, 2023).

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BOX 4 (Continued) EU Blockchain Regulatory Framework.

Supervisory Structure: Enforcement responsibilities are delegated to national authorities. However, the EBA sets regulatory standards, and the ESMA oversees crypto-asset markets (Annunziata and Maggiolino, 2023). This structure currently excludes dedicated NFT oversight pending the framework's review.

BOX 5 Portugal's blockchain regulatory framework.

Regulatory Maturity: Portugal's regulatory framework for blockchain and digital assets remains in a developmental phase. While the country aligns with EU-level legislation, it does not currently have a dedicated national legal framework (Almeida et al., 2024). Portugal's framework consists of BdP Notices, which transposed EU AML requirements, including the establishment of registration requirements and preventive obligations for VASPs, but omitted DeFi, NFTs, and token classification (Banco de Portugal, 2025b; Lowndes Marques et al., 2025). Future regulatory developments are anticipated to follow the implementation of MiCA, which is expected to subject NFT platforms to regulatory scrutiny (Kilminster, 2024).

Crypto Asset Classification: Portugal provides broad legal recognition of crypto assets as assets, without any additional classification (Remetula et al., 2024).

Taxation Regime: Portugal's tax system imposes a 28% flat rate on short-term capital gains for crypto assets held less than 1 year, while exempting long-term holdings maintained for more than 1 year. Professional cryptocurrency activities, including mining, staking, and trading, remain subject to standard income tax rates. This structure creates favourable conditions for long-term crypto investors while maintaining taxation of commercial and short-term trading activities (EU Blockchain ObservatoryForum expert panel et al., 2024; McClure, 2024). NFTs are excluded from this taxation regime (Portuguesa, 2023).

AML/KYC Framework: VASPs operating in Portugal must adhere to strict AML/KYC regulations enforced by the BdP. Mandatory registration under Notice No 3/2021 is required before offering services. Once approved, VASPs must implement real-time Customer Due Diligence, including identity verification and continuous transaction monitoring to detect suspicious activity. They are also obligated to file Suspicious Activity Reports and comply with EU fund transfer transparency rules (Regulation 2015/847). Additionally, VASPs must enforce UN and EU sanctions as outlined in Law No. 97/2017, ensuring that no transactions involve blacklisted entities or jurisdictions. Failure to meet these requirements can result in penalties, license revocation, or legal action by the BdP (Banco de Portugal, 2025a). This regime also applies to NFT transactions, although specific guidance on valuing digital collectables remains unpublished (Esteves Cardoso et al., 2024).

Supervisory Structure: Portugal adopts a hybrid regulatory structure in which AML supervision is centralised under the BdP. In contrast, the regulatory oversight of securities and financial instruments potentially involving crypto assets is delegated to the Portuguese Securities Market Commission (CMVM). This results in a dual-layered model, where AML compliance is centrally enforced and complementary oversight is applied when crypto assets fall within financial instrument classifications (Lowndes Marques et al., 2025).

BOX 6 Estonia's Blockchain Regulatory Framework.

Regulatory Maturity: Estonia's framework has undergone significant transformation, beginning with the stringent 2019 MLTFPA that imposed €250,000 capital requirements and physical presence rules for VASPs (Charlton Quantum, 2024). The 2024 adoption of the Crypto Asset Market Act brought Estonia into full MiCA/DORA compliance, transferring oversight from the FIU to the Financial Supervision Authority (FSA) while grandfathering existing licenses until 2026. This regulatory evolution has notably decreased foreign company registrations while raising compliance standards (EU Blockchain Observatory et al., 2024).

(Continued in next column)

BOX 6 (Continued) Estonia's Blockchain Regulatory Framework.

Crypto Asset Classification: Estonia employs a detailed four-category classification system, which includes cryptocurrencies functioning as blockchain-based payment mediums, asset-backed tokens representing physical asset claims, utility tokens providing access to specific services, and security tokens conferring traditional financial rights. This taxonomy exceeds the minimum requirements established under MiCA (Incorporate, 2024). NFTs are evaluated within this structure based on their economic function, with fractionalized NFTs typically classified as security tokens (PILnet, 2023). **Taxation Regime:** Estonia's tax system imposes income tax on all crypto-derived earnings, including mining, staking, and trading activities, while maintaining corporate tax parity with traditional financial operations. A distinctive feature is the application of VAT exclusively to crypto-to-crypto transactions (implemented in 2023), exempting crypto-to-fiat conversions. The system mandates comprehensive transaction reporting to ensure transparency (Republic of Estonia Tax and Customs Board, 2024). In addition to the taxation applied to the transaction, if the NFT creator receives a resale fee, it is considered a royalty and must be declared as a licence fee in the income tax return (Pareek, 2025a).

AML/KYC Framework: Estonia maintains one of the most rigorous AML regimes in Europe, requiring real-time customer verification, comprehensive transaction monitoring, and mandatory reporting of suspicious activities. The Financial Intelligence Unit retains central authority over AML/CFT enforcement despite the broader transition to FSA oversight under MiCA (Nita, 2025).

Supervisory Structure: Estonia's supervisory model features the FSA as the primary regulator for crypto-asset service providers under MiCA, while the FIU continues to lead AML enforcement. The Estonian Financial Supervision and Resolution Authority (EFSRA) maintains responsibility for traditional financial sector regulation, creating a transitional period of overlapping competencies (Riigi Teataja, 2017).

3.3.1 Blockchain-specialised regulators

Three geographies were considered blockchain-specialised: Switzerland, Liechtenstein, and Malta. Considering the individual analysis, all three geographies have established dedicated legal frameworks addressing blockchain and crypto assets. Liechtenstein introduced the TVTG in 2020, which provides a comprehensive legal framework covering token classification, service provider obligations, and the legal recognition of digital assets. Switzerland adapted its financial and civil laws in 2021 through the DLT Act, incorporating blockchain-specific legislation into existing legal frameworks. Finally, Malta implemented the VFA Act and aligned with the EU's MiCA regulation. However, the implementation of rules varies as Switzerland integrates blockchain into existing financial laws, with a focus on ensuring legal certainty for DLT trading and tokenisation. At the same time, Liechtenstein's TVTG provides a pioneering, comprehensive framework that covers all tokenised assets through its Token Container Model. Malta, by contrast, blends its national VFA Act with EU-aligned MiCA rules, creating a hybrid system that prioritises market access through passporting rights.

Regarding the classification of crypto-assets, Liechtenstein and Switzerland categorise tokens based on their economic purpose (such as payment or utility). At the same time, Malta uses categories such as "virtual token" or "financial instrument" in terms of taxation, whereas Switzerland and Liechtenstein generally exempt capital gains from crypto transactions conducted by private individuals, which may favour private investors. In contrast, Malta subjects crypto-related activities to its existing financial and corporate tax frameworks, offering reduced rates to attract business. All three geographies enforce

AML/KYC obligations in line with international standards. FINMA (Switzerland), the FMA (Liechtenstein), and the FIAU (Malta) oversee compliance. Each of these authorities requires VASPs and related entities to implement customer due diligence, monitor transactions, and report suspicious activities. However, Liechtenstein stands out by explicitly regulating DeFi under its TVTG. The regulatory structures are centralised. In Switzerland and Liechtenstein, FINMA and the FMA, respectively, serve as the primary regulatory authorities. In Malta, the MFSA is responsible for supervision, with the FIAU handling AML enforcement.

3.3.2 Generalist regulators comparison

Three geographies were considered generalist regulators: the EU, Estonia, and Portugal. While all three jurisdictions operate under EU directives, their implementation varies. The EU introduced the MiCA and DORA Regulation, which establishes a harmonised legal framework across member states, covering token issuance, trading platforms, and consumer protections. Estonia has regulated the sector through early adoption of VASP licensing requirements and additional measures introduced by the FIU and the EFSRA, requiring substantial capital reserves (€250,000) and physical presence for VASPs. Portugal's regulatory approach is based on compliance with EU directives, particularly those concerning AML/CFT, and includes national notices issued by the BdP without the need for additional national legislation. Crypto asset classification in these geographies also diverges. MiCA introduces a typology that distinguishes between utility tokens, ARTs, and e-money tokens. In contrast, Estonia employs a classification system based on economic purpose (payment, utility, and security tokens), with each category subject to distinct regulations. In Portugal, crypto assets are recognised as assets but are not legally categorised into different types. Tax policies also differ, as all three jurisdictions exempt crypto-to-fiat transactions from VAT, but corporate and capital gains are taxed differently. Estonia applies a flat corporate tax on business income, and crypto activities, such as mining and staking, are also subject to taxation. Portugal introduced a capital gains tax of 28% for crypto held less than 1 year, while gains on long-term holdings are exempt. AML/KYC measures are implemented by EU directives, demonstrating greater consistency across these geographies, including AMLD5 and AMLD6. Estonia and Portugal enforce these through national authorities, namely, the FIU and the BdP, respectively. However, Estonia's real-time transaction monitoring and 24-h reporting window exceed baseline EU standards. In terms of regulatory structure, the EU employs a hybrid model, where regulation is developed at the EU level, while national authorities are responsible for enforcement. Estonia and Portugal follow centralised enforcement models at the national level for AML/CFT compliance, with additional authorities involved when crypto assets qualify as securities.

3.3.3 Across groups comparison

The comparative analysis between blockchain-specialised regulators (Switzerland, Liechtenstein, Malta) and generalist regulators (EU, Estonia, Portugal) reveals distinct regulatory approaches. When comparing the two groups, blockchain-specialised geographies have introduced dedicated blockchain legislation that explicitly addresses key aspects such as tokenisation and DLT trading. In contrast, generalist regulators have adopted

broader frameworks such as MiCA or extended existing financial regulations to cover crypto-related activities. Regarding crypto asset classification in specialised geographies, it is typically based on functional or economic use (such as utility, payment, or asset tokens). In contrast, generalist geographies either adopt EU-defined categories or apply general asset classifications. In tax treatment, specialised geographies like Switzerland and Liechtenstein exempt capital gains in private transactions, while generalist regulators show more variation, with Portugal providing exemptions based on holding periods and Estonia applying flat income taxes. In AML/KYC enforcement, both groups align with FATF standards, with specialised geographies overseen by dedicated financial authorities (such as FINMA or FMA). In contrast, generalist geographies adopt EU directives, with enforcement delegated to national institutions. Liechtenstein, among specialised jurisdictions, has begun explicitly regulating DeFi through its TVTG, while generalist regulators largely exclude decentralised protocols from oversight. Regulatory structures differ in terms of centralisation. Blockchain-specialised geographies typically operate under centralised models, where a single authority oversees licensing and compliance. Generalist geographies normally follow hybrid models, particularly in the case of the EU, where legislation is centralised but enforcement is decentralised to national levels.

4 Discussion

This study analysed blockchain legal frameworks across Europe through comparative case studies of blockchain-specialised (Switzerland, Liechtenstein, Malta) and more generalist regulators (EU, Estonia, Portugal). By examining five key dimensions: regulatory maturity, crypto-asset classification, taxation, AML/KYC enforcement, and regulatory structures, convergences and divergences in the legal frameworks of geographies were identified. The observed differences across these jurisdictions may reflect not only institutional variation but also deeper regulatory assumptions about how to balance innovation, legal certainty, and risks (Chan et al., 2024). Findings suggest that blockchain-specialised regulators have proactively established dedicated legal frameworks addressing blockchain and crypto assets, potentially signalling a commitment to fostering ecosystem growth through legal clarity and sector-specific regulation. While generalist regulators, except the EU, have adapted existing ones. Regarding blockchain-specialised regulators, Liechtenstein's comprehensive Token Container Model reflects a high-trust, innovation-oriented approach contrasted with Switzerland's financial law integration and Malta's EU-aligned hybrid system. In contrast, generalist regulators showed greater differences, ranging from the EU's MiCA harmonisation to Estonia's stringent licensing and Portugal's minimal implementation. Moreover, supervisory structures further reflect these orientations, as the results suggest that centralised supervision dominates specialised regulators, while generalists favour hybrid or more fragmented models, with only Liechtenstein explicitly governing DeFi, highlighting a critical regulatory gap. Finally, NFTs further illustrate the regulatory divergence across jurisdictions. While Switzerland and Liechtenstein apply general token laws to NFTs, they lack specific guidance, contributing to creating uncertainty. Malta and Portugal, on the other hand, offer minimal oversight,

and the fact that MiCA omits NFTs leaves national authorities free to interpret their legal status, contributing to increasing differences across countries. Only Estonia provides a more precise classification, treating some NFTs as securities, though at the cost of heavier compliance. Legal frameworks function not as enablers or barriers, but as structural determinants of blockchain innovation and ecosystem development (Blind, 2016). Our findings suggest that early legal clarity in geographies with blockchain-specific regulations, such as Switzerland and Liechtenstein, demonstrates how early legal clarity fosters the development of blockchain ecosystems (Yee et al., 2024). Switzerland's proactive approach—including clear token regulations and supportive authorities—has enabled it to attract over 1,100 blockchain enterprises, while Liechtenstein's precise legal recognition of tokenised assets and institutionalised DLT governance support have drawn 68 specialised firms (Impuls Liechtenstein, 2025; Switzerland Global Enterprise, 2025). Because firms “know where they stand”, they have flocked to those geographies as regulatory clarity gives businesses the confidence to invest and innovate (Liechtenstein's pole position in the blockchain race, 2021; Cv, 2023). Similarly, Malta branded itself as “Blockchain Island” and lured major crypto exchanges by offering regulatory certainty (Zhao, 2021). By contrast, generalist regulatory environments have often forced innovators to navigate uncertainty or unfavourable conditions. Estonia's rapid shift from lenient to stringent licensing and Portugal's minimal framework demonstrate how uncertainty and gaps can often be impediments to growth, as traditional investors and larger enterprises shy away due to regulatory risk (Blind, 2012).

Conversely, regulatory uncertainty has been shown to positively correlate with innovation in other fields, as evidenced by increased patent filings and entrepreneurial activity during periods of regulatory ambiguity (Tajaddini and Gholipour, 2020). This counterintuitive relationship suggests that in fast-evolving, technology-intensive sectors like blockchain, the competitive pressure to innovate outweighs the risks of regulatory instability (Alabi, 2025). Thus, while tailored regulations (Switzerland/Liechtenstein) provide stability for ecosystem growth, generalist frameworks (Portugal/Estonia) create uncertainty, and strategic ambiguity may paradoxically fuel competitive innovation, highlighting how legal frameworks simultaneously constrain and accelerate blockchain's evolution through different mechanisms. This duality highlights the need for flexible legal frameworks that strike a balance between stability and adaptability, thereby ensuring market confidence while accommodating both universal and niche requirements.

Overall, these findings reveal how regulatory frameworks contribute to shaping blockchain. First, taxation policies contribute to creating market distortions (Angelopoulos et al., 2013), as suggested, for example, by Switzerland's tax-friendly policies, which attract fintech entrepreneurs seeking stability, clarity, and genuine growth opportunities (Sigtax, 2025). Moreover, NFT governance failures generate economic impacts, as the lack of regulation negatively affects market liquidity (Hevér and Csóka, 2025), may lead to the proliferation of counterfeit NFTs, deceptive manipulation of metadata, and unauthorised replication of digital assets (Upadhyay and Upadhyay, 2025). On the other hand, DeFi's lack of regulation contributes to market failure by enabling high-risk, high-return behaviour, which may attract malicious actors and expose users to extreme price volatility and unstable interest rates (Turillazzi

et al., 2023). These patterns underscore the need for policies that harmonise taxation to prevent regulatory arbitrage, establish NFT-specific frameworks to unlock digital asset markets, and implement tiered DeFi oversight targeting high-risk activities first.

This tension between flexibility and stability will continue to shape the trajectory of European blockchain regulation (Ferreira and Sandner, 2021). The phased implementation of MiCA, starting in 2023 (ESMA, 2025), represents a significant step toward EU-wide harmonisation, introducing licensing requirements, consumer protections, and issuer obligations for stablecoins and crypto-assets. In parallel, DAC8 expands tax reporting obligations for crypto transactions to reduce evasion and improve cross-border transparency. Together, these frameworks are likely to reduce regulatory divergence over time, particularly for stablecoins and centralised exchanges. However, significant gaps remain, notably for NFTs, DeFi, and staking services, where Member State discretion may sustain asymmetries. Looking ahead, future EU efforts may prioritise closing these gaps, but the challenge will lie in avoiding overly prescriptive rules that could fragment innovation across jurisdictions. Ultimately, MiCA and DAC8 reconfigure, rather than resolve, the trade-off between legal certainty and innovation, formalising clarity in some areas while leaving others open to interpretation. The study's findings are subject to limitations. First, the evolving nature of blockchain policy means that some conclusions may become outdated, particularly as geographies implement MiCA and address emerging areas, such as DeFi. Second, the reliance on documentary analysis of laws and policies may overlook practical enforcement challenges and stakeholder perspectives that could be uncovered through interviews with regulators or industry participants. Third, the focus on European geographies limits direct applicability to other regions with different legal traditions and market conditions. These limitations require caution in generalising the findings.

Future research should conduct a longitudinal analysis tracking MiCA's implementation across EU member states, which could reveal whether harmonisation reduces fragmentation or introduces new compliance complexities. Second, a deeper investigation into DeFi governance models is needed, particularly as jurisdictions like Liechtenstein begin to regulate these decentralised systems, while others do not. Third, comparative studies incorporating Asian and American regulatory approaches would help test whether the European specialisation-generalist dichotomy holds globally. Additionally, qualitative research with regulators and industry participants could uncover the practical challenges of applying these frameworks that document analysis cannot capture.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

FV: Writing – review and editing, Conceptualization, Methodology, Formal Analysis, Writing – original draft. YW:

Writing – original draft, Formal Analysis, Data curation, Writing – review and editing. FG-F: Supervision, Writing – review and editing, Conceptualization, Validation. AG: Supervision, Writing – review and editing, Methodology, Conceptualization. LS: Conceptualization, Validation, Writing – review and editing. SA: Writing – review and editing, Funding acquisition, Supervision, Conceptualization, Validation.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This work was financially supported by Project Blockchain. PT – Decentralize Portugal with Blockchain Agenda, (Project no 51), WP4: Sports, Leisure, and Culture, Call no 02/C05-i01.01/2022, funded by the Portuguese Recovery and Resilience Program (PPR), The Portuguese Republic and The European Union (EU) under the framework of Next Generation EU Program.

Acknowledgments

The authors appreciate comments from the Value for Health CoLAB and Exeedme teams.

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Conflict of interest

Authors LS was employed by Exeedme.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that Generative AI was used in the creation of this manuscript. Generative AI (ChatGPT, OpenAI) was used to assist with editing, restructuring and phrasing during the manuscript review process. All original content was generated by the authors and all revisions were critically reviewed and finalised by the authors.

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