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Sandboxes, Crypto-Asset Rules and Central Bank Digital Currency: A Three-Layer Model of Digital Financial Policy

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ABSTRACT

Digital financial policy is usually discussed as a set of separate problems: whether to operate a regulatory sandbox, whether and how to bring crypto-assets within the regulatory perimeter, and whether to issue a central bank digital currency. This article argues that the three are better understood as layers of a single institutional design problem, distinguished by the type of uncertainty each addresses and by the reversibility of the commitment each requires. Sandboxes form an experimentation layer addressing operational uncertainty about novel business models, with low commitment and high reversibility. Codified regimes such as the European Union's Markets in Crypto-Assets Regulation form a rule layer addressing legal uncertainty about asset classification and issuer obligations, with medium commitment. Central bank digital currency forms an infrastructure layer addressing structural uncertainty about the future of the monetary system, with very high commitment and near-irreversibility. Using the innovation-trilemma framework of Brummer and Yadav (2019), the article shows that each layer resolves the trilemma at a different point and that the layers are complements rather than substitutes: a sandbox without a rule layer generates cases that cannot be scaled, and a rule layer without an infrastructure layer regulates private money without providing a public alternative. The argument is developed against the evidence base to January 2025 and applied to the sequencing problem faced by emerging and transition economies. The article concludes that sequencing errors, rather than instrument choice, account for most disappointing outcomes, and proposes readiness conditions for advancing from one layer to the next.

KEYWORDS regulatory sandbox; central bank digital currency; MiCA; fintech regulation; experimental governance; financial inclusion; payment systems

JEL G28; E42; E58; O31; K22

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1. Introduction

Since 2016, when the United Kingdom's Financial

Conduct Authority admitted the first cohort to its regulatory sandbox, digital financial policy has passed through three overlapping waves. The first was experimental: dozens of jurisdictions

established sandboxes, innovation hubs and accelerators, on the premise that regulators lacked the information required to write rules for business models they did not yet understand. The second was codificatory: as crypto-asset markets grew, collapsed and grew again, jurisdictions moved from case-by-case treatment to comprehensive statutory regimes, of which the European Union's Markets in Crypto-Assets Regulation (MiCA) is the most complete. The third is infrastructural: by late 2024, according to the most widely used tracker, 134 countries and currency unions representing some 98% of global GDP were investigating central bank digital currency, with 44 pilot projects running and three full launches completed – in the Bahamas, Jamaica and Nigeria – while the Eurosystem was two thirds of the way through a preparation phase due to conclude in October 2025, when its Governing Council is to decide whether to proceed further.

These three waves are usually studied separately, by different literatures, with different methods. Sandboxes belong to the regulatory-governance and innovation literature; crypto-asset regulation to financial law; CBDC to monetary economics. The separation is analytically costly, because policymakers do not face them separately. A finance ministry deciding whether to fund a CBDC pilot is making a choice against the alternative uses of the same scarce technical and political capital – including the operation of a sandbox and the drafting of a crypto-asset statute. Treating the three as unrelated produces the pattern observed repeatedly in the last decade: jurisdictions that announce a CBDC before they have a functioning fast-payment system, that legislate for crypto-assets before they have supervisory staff who can read a whitepaper, or that operate a sandbox whose graduates have no legal route to authorisation because the rule layer they would graduate into does not exist.

This article proposes a unifying frame. The three instruments are layers of one design problem, distinguished by the type of uncertainty each addresses and by the reversibility of the commitment each entails. The frame yields a sequencing logic, a set of readiness conditions, and a diagnosis of the most common policy failures.

Section 2 develops the three-layer model. Section 3 reviews the literature on each layer. Section 4 explains the method. Sections 5 to 7 analyse the experimentation, rule and infrastructure layers in turn. Section 8 examines the interactions between

them. Section 9 develops policy implications with particular reference to emerging and transition economies. Sections 10 and 11 address limitations and conclude.

2. The Three-Layer Model

The organising insight is that "regulatory uncertainty" in digital finance is not one thing. It has three distinguishable forms, and each calls for a different instrument.

Operational uncertainty concerns how a novel business model behaves in practice: what risks it generates, which existing rules apply awkwardly, what consumer outcomes it produces at scale. Neither the firm nor the regulator can resolve this by analysis alone, because the relevant information is generated only by operation. The appropriate instrument is controlled experimentation: a bounded, time-limited, supervised deployment with restricted customer numbers and explicit exit criteria. Commitment is low; reversal is cheap and carries no systemic consequence.

Legal uncertainty concerns how an activity is classified and which obligations attach: whether a token is a security, whether an issuer must hold reserves and in what form, which authority supervises, and how cross-border activity is treated. This uncertainty cannot be resolved experimentally, because its source is the indeterminacy of the rule rather than ignorance about the activity. The appropriate instrument is codification: a statutory regime specifying classifications, authorisation conditions, prudential requirements and supervisory competence. Commitment is medium; the regime can be amended, though amendment is slow and affects firms that have organised themselves around the original rules.

Structural uncertainty concerns the architecture of the monetary and payment system: whether public money remains available in digital form, whether payment infrastructure is contestable or concentrated in a small number of private schemes, whether monetary sovereignty is eroded by foreign-currency stablecoins, and what happens to bank funding under stress. This is not resolvable by experiment or by rule alone, because it concerns the system's design rather than the behaviour of participants within it. The appropriate instrument is infrastructure provision, of which CBDC is the most discussed but not the only form – fast retail payment systems, public digital identity and open

banking or open finance mandates address the same layer. Commitment is very high and effectively irreversible: once a public payment instrument exists and is used, withdrawing it is politically and operationally infeasible.

The layers are ordered by commitment, and the ordering has a practical consequence. Information flows upward: experimentation reveals which activities recur and what risks they carry, which is what a well-drafted rule layer needs; operation of the rule layer reveals where private provision systematically fails, which is what justifies infrastructure. Authority flows downward: a sandbox is only useful if there is a rule layer for successful applicants to graduate into, and infrastructure only functions if the rule layer defines who may connect to it and on what terms. A jurisdiction that builds the layers out of order will find that each is less effective than it would have been in sequence.

This frame maps onto the innovation trilemma identified by Brummer and Yadav (2019), which holds that financial regulators cannot simultaneously maximise market integrity, rule clarity and financial innovation; any two can be pursued at the cost of the third. Each layer resolves the trilemma at a different point. A sandbox sacrifices rule clarity – participants operate under bespoke, non-generalisable conditions – to preserve integrity and enable innovation. A codified regime sacrifices some innovation, by imposing authorisation costs that exclude small entrants, to obtain clarity and integrity. Infrastructure provision changes the terms of the trilemma rather than resolving it, by placing a baseline service outside the competitive market altogether. Understanding the layers as different trilemma resolutions explains why they are complements: a jurisdiction that holds only one position is exposed on the dimension that position sacrifices.

3. Literature Review

The experimentation layer. The theoretical case for sandboxes draws on the experimentalist-governance tradition, in which provisional goals are set centrally, implementation is devolved, outcomes are reported and compared, and rules are revised in light of results. Zetzsche, Buckley, Arner and Barberis (2017) supplied the influential framing of the sandbox as one point on a spectrum of regulatory approaches to innovation, alongside doing nothing, case-by-case relief and

structured experimentation, and cautioned that sandboxes are appropriate only where the regulator has the capacity to supervise participants intensively. Allen (2019) provides the sharpest critique, arguing that sandboxes risk becoming a channel for selective deregulation, that admission decisions confer a competitive advantage that regulators are poorly placed to allocate, and that the evidence for their innovation-enhancing effect is weak relative to the attention they receive. The World Bank's *Global Experiences from Regulatory Sandboxes* (2020) documents wide variation in design and outcomes and finds that sandboxes are most useful where the underlying constraint is genuine legal ambiguity rather than the absence of a business case. More recent systematic review evidence in the regulatory-governance literature confirms the general pattern: effects on participant firms are positive but modest, effects on aggregate innovation are difficult to identify, and the most consistently documented benefit is the regulator's own learning rather than the participants' commercial outcomes.

The rule layer. Arner, Barberis and Buckley's work on the evolution of FinTech and RegTech established the developmental sequence from digitisation of existing services to platform-based provision to embedded finance, and argued that regulatory architecture lags each transition. Zetzsche, Buckley, Arner and Föhr (2018) analysed decentralised finance and token issuance and identified the classification problem as the central obstacle. Brummer's work on cryptoasset disclosure, and the substantial doctrinal literature on MiCA, address how a codified regime allocates obligations between issuers, offerors and service providers. The stablecoin literature – including the Bank for International Settlements' analyses of singleness of money and the "no-questions-asked" property – supplies the prudential rationale for reserve, redemption and governance requirements.

The infrastructure layer. Auer and Böhme (2020) provide the canonical design taxonomy, deriving a "CBDC pyramid" that maps consumer needs onto architectural choices – direct, intermediated or hybrid architecture; account-based or token-based access; conventional or distributed infrastructure; domestic-only or cross-border access. Bindseil's work on retail CBDC and financial intermediation develops the disintermediation concern and the case for holding limits and tiered remuneration. The BIS Annual Economic Reports and the CPMI's work on cross-border payments situate CBDC

within the wider payments reform agenda, and consistently make the point that most of the welfare gains attributed to CBDC – speed, cost, availability – are also obtainable from well-designed fast payment systems.

What the literature lacks is an integrating treatment. The sandbox literature rarely asks what participants graduate into; the crypto-regulation literature rarely asks where the supervisory capacity comes from; the CBDC literature rarely asks what the marginal contribution of a CBDC is in a jurisdiction that has not yet built a fast payment system. This article addresses that gap.

4. Method

The study is conceptual and comparative-institutional. It develops an analytical framework and applies it to documented policy experience, drawing on official sources: central bank publications and press releases, the enabling legislation of the regimes discussed, international financial institution reports, and published tracker data on CBDC status. No original quantitative dataset is constructed, and no causal claims are advanced about the effect of any instrument on measured innovation or inclusion outcomes; where the empirical literature is cited, its findings are reported with the qualifications the underlying studies attach to them.

The evidence base runs to 31 January 2025. Numerical statements about CBDC status reflect the position reported in late 2024 and change frequently; readers should verify against the current source before citation.

5. The Experimentation Layer

Sandboxes have spread more widely than any other fintech policy instrument, and they are also the instrument whose claimed benefits are least well evidenced. Four findings from the accumulated experience are robust enough to build on.

The principal beneficiary is the regulator. The most consistently documented output is supervisory learning: staff acquire operational familiarity with business models, identify which existing requirements are genuinely obstructive and which merely appear so, and build informal channels to the industry. This is a real benefit, and it argues for retaining sandboxes even where participant outcomes are unimpressive – but it

means the sandbox should be evaluated as a supervisory capacity-building instrument rather than as an innovation subsidy.

Admission is a selection problem the regulator is poorly placed to solve. Sandbox admission confers a signalling benefit – publicised participation attracts investment and customers – which means the regulator is allocating a scarce, valuable good on criteria that are necessarily judgemental. Where admission is competitive and the criteria are opaque, the instrument invites both the appearance and the reality of favouritism. Transparent published criteria, fixed cohort sizes and explicit statements that admission is not an endorsement mitigate but do not eliminate this.

Sandboxes cannot cure the absence of a rule layer. A firm that completes a sandbox test successfully must then be authorised under a general regime. Where none exists, the sandbox becomes a permanent holding pen: participants operate indefinitely under bespoke conditions, competitors who were not admitted operate under ordinary law or not at all, and the regulator accumulates a portfolio of individually negotiated arrangements that it lacks the capacity to supervise. This is the single most common design failure, and it is a sequencing error rather than a flaw in the instrument.

Thematic and cross-border sandboxes outperform open-entry ones. Sandboxes organised around a defined policy question – remittance costs, agricultural insurance, SME credit assessment, digital identity in onboarding – produce comparable cases and therefore generalisable lessons. Open-entry sandboxes produce a heterogeneous portfolio from which little can be generalised. Cross-border arrangements, in which several regulators run a common cohort, additionally address the problem that a firm's viability often depends on operating in more than one small market.

6. The Rule Layer

MiCA is the most complete codified crypto-asset regime in force and therefore the natural reference point. Its architecture rests on three classifications – asset-referenced tokens, e-money tokens, and other crypto-assets – with obligations calibrated to each, and on an authorisation regime for crypto-asset service providers with passporting across the internal market. Rules for asset-referenced and e-money tokens applied from 30 June 2024 and the

service-provider regime from 30 December 2024, with transitional arrangements for incumbent firms running into 2025 and, in several Member States, beyond. The regime is therefore only weeks old in its most demanding limb, and the questions it has already raised – the treatment of stablecoins issued partly outside the Union, the perimeter around decentralised finance, and the status of staking services – indicate that even a regime designed to be comprehensive will require iteration soon after application.

Four design lessons generalise beyond the European context.

Classification must be exhaustive, not illustrative. A regime that enumerates token types and leaves an undefined residual reproduces the classification uncertainty it was enacted to remove. MiCA's approach – defining categories and applying a general regime to everything not otherwise captured, while expressly excluding instruments already covered by financial-services law – is preferable to a list-based approach that requires amendment each time a new structure appears.

Reserve and redemption requirements are the core prudential content. For payment-purpose tokens, the substantive protections are the composition and segregation of reserves, the enforceability of redemption at par, and the supervisory power to intervene before a run. The remainder of a crypto-asset statute is important but secondary.

Authorisation costs are a distributive choice. Comprehensive authorisation regimes impose fixed compliance costs that fall most heavily on small firms and therefore consolidate the market. In a large market this may be an acceptable price for integrity; in a small one it can eliminate the domestic sector entirely, leaving consumers served by unregulated offshore providers – the opposite of the intended outcome. Proportionate regimes with simplified authorisation below defined thresholds are not a concession to weak standards but a recognition that an unenforceable prohibition protects no one.

Territorial scope determines effectiveness. The practical question in most jurisdictions is not how to regulate domestic issuers, of which there may be none, but how to treat foreign-issued stablecoins circulating domestically. The available instruments – reverse-solicitation limits, requirements to establish a local entity, restrictions on domestic intermediaries dealing in unauthorised assets, and payment-system access conditions – are

second-best, and their effectiveness depends on control of the domestic banking and payment interfaces rather than on the crypto-asset statute itself.

7. The Infrastructure Layer

CBDC is the highest-commitment instrument in digital financial policy, and its diffusion has been rapid in exploration and slow in issuance. The gap between 146 jurisdictions exploring and three that have completed retail launches is the central empirical fact, and it requires explanation.

Part of the explanation is that the case for retail CBDC is jurisdiction-specific and often weaker than assumed. Four motivations are typically advanced.

Financial inclusion. Where a substantial unbanked population exists and mobile penetration is high, a low-cost public payment instrument with offline capability can extend access. But the binding constraints on inclusion are usually identity documentation, agent networks for cash-in and cash-out, and the cost of the device – none of which a CBDC addresses. Where mobile money has already achieved deep penetration, the marginal contribution of a CBDC to inclusion is small.

Payment efficiency and contestability. Where domestic payments are expensive and concentrated in a small number of card schemes or bank-owned rails, a public instrument can discipline pricing. This is the strongest general argument, and it is the one that most closely explains the European project's motivation, alongside strategic autonomy concerns. But it is also the argument most vulnerable to the observation that a well-designed fast retail payment system delivers most of the same benefit at a fraction of the institutional cost.

Monetary sovereignty. Where foreign-currency stablecoins circulate widely, domestic monetary transmission and capital-flow management weaken. A domestic digital currency is one response; regulation of access to domestic payment and banking interfaces is another, and usually cheaper.

Preservation of public money. As cash use declines, the share of the population with access to a central bank liability falls toward zero, leaving all retail money as private bank or e-money liabilities. This is a genuine structural argument and it is not addressed by any private alternative. It is, however, an argument for availability rather than for volume, which has design implications: holding limits, non-remuneration and tiered access are consistent with it, whereas maximising CBDC adoption is not.

The design choices that follow are well mapped in the literature. The architecture question – whether the central bank holds retail claims directly, whether intermediaries do so, or whether a hybrid arrangement places claims on the central bank while intermediaries handle distribution and customer service – determines the operational burden on the central bank and the disintermediation risk to banks. The consensus has settled decisively on hybrid or intermediated models. The privacy question is the most politically salient and the least technically settled: full anonymity is incompatible with anti-money-laundering obligations, full traceability is incompatible with public acceptance, and the workable middle – tiered thresholds with lighter due diligence for small balances and offline functionality with cash-like properties for small transactions – has yet to be tested at scale in a large economy.

The Eurosystem's trajectory illustrates both the deliberation and its cost. Having begun a preparation phase in November 2023, the Governing Council is to decide at its conclusion in October 2025 whether to proceed to a further stage. The Eurosystem has been explicit that no issuance decision can be taken before the enabling regulation is adopted, and that regulation is still before the co-legislators. Close to a decade will therefore separate the start of the investigation phase in October 2021 from any possible issuance. That timescale is the true measure of the infrastructure layer's commitment cost, and it is why the layer should be approached last.

Wholesale CBDC and cross-border projects present a different calculus. Because they operate between a small number of supervised institutions rather than with the public, they avoid the privacy, disintermediation and inclusion controversies entirely, and the growth in wholesale cross-border initiatives – including the substantial transaction volumes reported by the largest multi-central-bank platform – suggests that this is where near-term institutional returns are highest.

8. Interactions Between the Layers

Three interaction effects deserve emphasis, because they are the mechanism by which sequencing errors produce poor outcomes.

Upward information flow. Sandbox operation reveals which activities recur, which risks are real, and where existing rules obstruct without

protecting. A rule layer drafted after several sandbox cohorts is drafted on evidence; one drafted before is drafted on the drafter's assumptions or, more commonly, on a transplanted foreign text. Similarly, operation of the rule layer reveals whether private provision reaches underserved populations and whether payment pricing is competitive – the evidence required to justify or refuse an infrastructure investment.

Downward authority flow. Sandbox graduates require an authorisation regime to enter; without one, the sandbox has no exit. Infrastructure requires a rule layer to define who may connect, on what terms, with what obligations – a CBDC distributed through intermediaries needs a supervisory regime governing those intermediaries. Building infrastructure above an undeveloped rule layer means either that the central bank must perform functions it is not equipped for, or that access is restricted to incumbent banks, which forfeits the contestability benefit that motivated the project.

Capacity competition. All three layers draw on the same scarce resource: a small number of officials who understand both financial regulation and technology. A CBDC project absorbs this resource for years. The opportunity cost is rarely stated in project appraisals, and it is often the largest cost involved.

9. Policy Implications for Emerging and Transition Economies

For jurisdictions in Central Asia, the South Caucasus, South-East Europe and comparable settings, the framework yields a sequencing rule with explicit readiness conditions.

Layer one first, and cheaply. Establish an innovation office before a sandbox; establish a thematic sandbox before an open-entry one; publish admission criteria; and set an explicit expectation that the sandbox's principal output is regulatory learning. Where the domestic market is small, join or initiate a cross-border sandbox with neighbouring regulators rather than operating alone.

Readiness condition for advancing to layer two: the authority can articulate, from its own case experience, which activities require authorisation and what the principal risks are – rather than reproducing a foreign statute's categories.

Layer two proportionately. Codify classifications exhaustively; concentrate prudential content on

reserve, redemption and segregation requirements for payment-purpose tokens; scale authorisation to firm size; and give priority to the territorial-scope provisions that determine how foreign-issued instruments circulating domestically are treated. Build supervisory staffing before the regime applies, not after; a statute with no one able to enforce it is worse than none, because it converts a known gap into an unknown one.

Readiness condition for advancing to layer three: a fast retail payment system is operational and widely adopted; interoperability between mobile money, bank accounts and merchant acceptance is achieved; digital identity infrastructure supports remote onboarding; and payment pricing data demonstrate a residual competition problem that public provision would address.

Layer three only on evidence, and consider the alternatives first. In most emerging economies the payment-efficiency and inclusion objectives attributed to CBDC are more cheaply achieved through a fast payment system, interoperability mandates, agent-banking rules and open-finance data-access requirements. Where a CBDC case survives that comparison, wholesale and cross-border applications should be prioritised over retail, because they deliver measurable settlement and remittance gains without engaging the privacy, disintermediation and adoption problems that have slowed retail projects everywhere. Where a retail project proceeds, hybrid architecture, holding limits, non-remuneration and offline capability should be treated as defaults, and the project should be appraised against the full opportunity cost of the supervisory capacity it will absorb.

A final implication concerns regional coordination. For small economies, each layer has substantial fixed costs and modest variable costs – a sandbox framework, a crypto-asset statute and a payment infrastructure each cost nearly as much to design for a market of five million as for one of fifty million. Shared sandbox cohorts, harmonised crypto-asset classifications with mutual recognition of authorisations, and interoperable rather than duplicated payment infrastructure spread those fixed costs across a group of jurisdictions, and simultaneously create a market large enough that foreign providers find compliance worthwhile.

10. Limitations

The article is conceptual and does not test its framework empirically. The three-layer model is an

analytical construction; the ordering it proposes is derived from the logic of commitment and information flow rather than from measured outcomes, and jurisdictions that departed from it have not been systematically compared with those that followed it. The CBDC status figures cited reflect a rapidly changing position at the end of 2024 and should be verified before reuse. The treatment of MiCA reflects the regime at the point of full application and does not anticipate how supervisory practice will develop. Finally, the policy implications in Section 9 are calibrated to small and middle-income jurisdictions with limited supervisory capacity and are not intended to apply to large financial centres, where the fixed costs the argument turns on are comparatively minor.

Three empirical extensions would test the framework: comparative measurement of sandbox-graduate authorisation rates across jurisdictions with and without a codified rule layer; event-study analysis of domestic fintech authorisation volumes following the entry into application of comprehensive crypto-asset regimes; and cross-country assessment of whether jurisdictions with mature fast payment systems derive smaller marginal benefits from retail CBDC than those without.

11. Conclusion

Digital financial policy is not a menu of independent options. Regulatory sandboxes, codified crypto-asset regimes and central bank digital currency address different kinds of uncertainty, require different levels of commitment, and depend on one another: experimentation supplies the evidence for rules, rules supply the authority structure for infrastructure, and infrastructure supplies the public baseline that rules alone cannot create.

The empirical record supports the ordering. Sandboxes have proliferated and delivered supervisory learning but disappointing participant outcomes, largely where the rule layer they should feed did not exist. Codified regimes have arrived and are already being revised, confirming that the rule layer is iterative rather than final. CBDC exploration is near-universal while issuance is negligible, and the most advanced project in a major currency area has taken the better part of a decade to approach a pilot at a development cost above €1 billion – a reminder that the infrastructure layer is not a technology project but a constitutional

commitment about the form of public money.

For jurisdictions building digital financial policy, the practical conclusion is that instrument choice matters less than sequence. Most disappointing outcomes in the last decade were not the result of choosing the wrong instrument but of deploying the right instrument before the layer beneath it existed. Building upward – experimentation, then rules, then infrastructure – with explicit readiness conditions at each transition, and pooling fixed costs regionally where markets are small, is the design that the accumulated evidence supports.

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LEGAL INSTRUMENTS AND CASES

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