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Addressing governance challenges of digitalisation and sustainability: The case of central bank digital currency

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Addressing governance challenges of digitalisation and sustainability: The case of central bank digital currency

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Abstract

Digitalisation and environmental sustainability are widely discussed topics. However, their nexus remains underexplored and can pose significant challenges for governments and industries alike. The environmental implications of digitalisation are becoming increasingly pertinent with the advent of central bank digital currencies (CBDCs) and their inherent energy consumption and production of e-waste. On the other hand, digitalisation could potentially support sustainability efforts. This begs the question of how systems of governance, such as regulatory frameworks and internal organisational governance, should harmonise digitalisation and sustainability goals. Such harmonisation entails ensuring that digitalisation processes are environmentally responsible while exploring how the application and features of digitalisation can help achieve environmental goals. By drawing insights from the case study of CBDCs, this article will utilise the paradigm of adaptive governance to seek potential solutions to the environmental implications of digitalisation.

1 | INTRODUCTION

The link between digitalisation and sustainability is nuanced and complex. The discussion of sustainability in this article refers to the management of natural resources (e.g., improving energy efficiency, reducing resource consumption) to ensure their continued availability for current and future generations.[1] Digitalisation may negatively affect sustainability, particularly through increasing energy demands[2] and e-waste. Nevertheless, technology can facilitate better understanding of environmental challenges and inform the development of equitable solutions. This is evident in the proliferation of innovative projects such as digital platforms that track and reduce emissions. Such platforms point to the growing capabilities of digital tools to safeguard environmental interests.[3] That said, there is a lingering tension between digitalisation and sustainability. Fast-moving digitalisation, such as distributed ledger technology (DLT, including proof-of-work [PoW] DLT and non-PoW DLT),[4] big data and generative

[1]See, e.g., J Morelli, 'Environmental Sustainability: A Definition for Environmental Professionals' (2011)1 Journal of Environmental Sustainability 1, 5; Microsoft, Environmental Sustainability: A Commitment to a Better Future < https://www.microsoft.com/en-us/sustainability/learn/environmental-sustainability>.

[2]United Nations Environment Programme, Sustainable Digitalisation <https://www.unep.org/topics/digital-transformations/sustainable-digitalisation>.

[3]See, e.g. M T Boçe and J Hoxha, 'Blockchain Technology as a Catalyst for Sustainable Development: Exploring Economic, Social, and Environmental Synergies' (2024) 13 Academic Journal of Interdisciplinary Studies 151, 159; I Guandalini, 'Sustainability through Digital Transformation: A Systematic Literature Review for Research Guidance' (2022) 148 Journal of Business Research 456, 456.

[4]DLT is the shared record of information that enables computers (nodes) in different places to add, validate, and synchronise transactions. PoW DLT is a consensus mechanism to validate new transactions added to a DLT platform, and validators are rewarded for validating the transactions. Non-PoW DLT includes proof-of-stake (PoS) DLT. For PoS DLT, validators of a blockchain network lock their tokens as a stake on the blockchain for the chance to be selected to validate a new block and thus earn transaction fees as a reward. If the validators do not do the work, they could lose their blocked tokens. See City of London Corporation et al, 'Digital Currency Glossary' (2024) <https://www.ukfinance.org.uk/system/files/2024-01/FDC%20Crypto%20Glossary.pdf> 6, 8; AN Didenko and RP Buckley, 'Central Bank Digital Currencies: A Potential Response to the Financial Inclusion Challenges of the Pacific-Risks and Opportunities' (2021) 3 Issues in Pacific Development 1, 19.

artificial intelligence (AI),[5] may accelerate resource consumption and pose long-term environmental risks. The environmental footprint of different technologies can vary greatly—for example, the energy intensity of crypto assets diverges significantly. Estimates suggest that 100 million transactions in one asset of the least energy-consuming technology consume the same amount of energy as a single transaction in an asset using the most energy-consuming technology.[6] Moreover, carbon-intensive digital infrastructure (e.g., infrastructure supporting internet data transfers) could contribute to environmental degradation.[7]

Given the fundamental role of currency in today's world, the focus of this article will be on central bank money. Central bank digital currency (CBDC) is emblematic of the digitalisation of central bank money.[8] CBDC is a digital national currency issued by each country's central bank. Amid the dynamic challenges that digital currencies pose to policymakers (e.g., potential financial stability risks),[9] CBDCs have emerged as a potential option to serve as central bank money in the digital age. Various types of CBDCs are currently under development. Wholesale CBDCs are primarily used by financial institutions to settle trades in financial markets and foreign exchange transactions,[10] while retail CBDCs are intended for public use. By the end of 2023, 94% of central banks surveyed by the Bank for International Settlements (BIS) were involved in CBDC-related work.[11] An increasing number of jurisdictions are exploring the feasibility of CBDCs,[12] which could underpin the monetary system in the digital future.[13] The development of CBDCs, including research, pilot programmes, supporting infrastructure and eventual usage, would all carry an increased environmental footprint.

The intersection of digital currencies and sustainability presents a major and new challenge for policymakers and other actors (e.g., the industry).[14] A survey of central bank laws of 174 International Monetary Fund (IMF) members found that only about 40 countries are legally allowed to issue digital currencies. Nearly 80% of 174 IMF members either face an ambiguous legal framework in the issue of digital currency or lack the legal authority altogether.[15] As a result, there are limited regulations and laws focused on CBDCs, let alone those concerning the intersection of CBDCs and sustainability. It is to this gap in regulation and to the nexus between CBDCs and sustainability (especially on issues of energy and e-waste) that this article seeks to contribute. Given the dearth of existing regulation, the paper focuses discussion on the broader governance and institutional environment and issues at the CBDC-sustainability nexus itself.

Two related and fundamental questions comprise the nexus between CBDCs and sustainability: firstly, how can we ensure that CBDCs are environmentally responsible? To answer the first question, focus should be placed on the development of environmentally friendly or 'green' CBDCs to minimise their environmental footprint. Secondly, how can digitalisation contribute to environmental goals (e.g., climate targets) through its usage and features (e.g., programmability of CBDCs)? However, uncertainties exist regarding these two fundamental questions (i.e., whether CBDCs can be 'green' and contribute to sustainability).

These uncertainties are exacerbated by the gaps in governance (particularly a regulatory gap and a gap in internal organisational governance). A regulatory gap exists, as, given their novelty, financial and environmental law has not comprehensively addressed the possible environmental impact of technological developments in digitalisation. CBDCs are regulated mainly by financial law (including central banking laws[16] and regulations[17]), and energy consumption and e-waste are regulated mainly by environmental law.[18] If not properly managed by active regulatory arrangements (e.g., environmental impact assessment and tendering requirements concerning energy efficiency), environmental risks arising from technological developments of digitalisation (e.g., e-waste) may not be properly considered or averted.[19]

The paradigm of adaptive governance helps to address these uncertainties.[20] The systems approach inherent in adaptive governance provides a valuable framework for addressing the regulation and governance gap in digitalisation and sustainability. This is particularly the case with learning by stakeholders (e.g., central banks and other government departments) as their coordinated response.[21]

[5]See, e.g., D Chatterjee, 'Role of A.I. in Central Bank Digital Currency' (2022) <https://aijourn.com/role-of-a-i-in-central-bank-digital-currency/>.

[6]I Agur et al, 'Lessons From Crypto Assets for the Design of Energy Efficient Digital Currencies' (2023) 212 Ecological Economics 1, 1.

[7]I Agur et al, 'Digital Currencies and Energy Consumptions' NOTE/2022/006 (International Monetary Fund 2022) 4.

[8]Examples of CBDC include the digital euro that is being explored by the European Central Bank.

[9]S Jahan et al, 'Towards Central Bank Digital Currencies in Asia and the Pacific: Results of a Regional Survey' (International Monetary Fund 2022) 10.

[10]Bank for International Settlements (BIS), 'Central Bank Digital Currency (CBDC) Information Security and Operational Risks to Central Banks: An Operational Lifecycle Risk Management Framework' (2023) 8; Clifford Chance, 'Central Bank Digital Currencies: A New Type of Intermediary' (2023) 3.

[11]A Di Iorio, et al., 'Embracing Diversity, Advancing Together – Results of the 2023 BIS Survey on Central Bank Digital Currencies and Crypto' (2024) <https://www.bis.org/publ/bppdf/bispap147.htm> 1.

[12]See, e.g., A. M. Mooij, 'A Digital Euro for Everyone: Can the European System of Central Banks Introduce General Purpose CBDC as Part of Its Economic Mandate?' (2023) 24 Journal of Banking Regulation 89, 89-104; Bank of England and HM Treasury, 'The Digital Pound: A New Form of Money for Households and Businesses?' (2023) <https://www.bankofengland.co.uk/-/media/boe/files/paper/2023/the-digital-pound-consultation-working-paper.pdf>; H Wang, 'China's Approach to Central Bank Digital Currency: Selectively Reshaping International Financial Order?' (2022) 18 University of Pennsylvania Asian Law Review 77, 77-134; H Wang, 'How to Understand China's Approach to Central Bank Digital Currency?' (2023) 50 Computer Law and Security Review 1, 1-17.

[13]BIS Innovation Hub, 'Lessons Learnt on CBDCs' (2023) 9.

[14]I Agur et al, 'How Crypto and CBDCs Can Use Less Energy Than Existing Payment Systems' (International Monetary Fund, 2022) <https://www.imf.org/en/Blogs/Articles/2022/06/16/how-crypto-and-cbdcs-can-use-less-energy-than-existing-payment-systems>.

[15]C Margulis and A Rossi, 'Legally Speaking, is Digital Money Really Money?' (2021) <https://www.imf.org/en/Blogs/Articles/2021/01/14/legally-speaking-is-digital-money-really-money>.

[16]See, e.g., People's Bank of China, Law of the People's Bank of China (Amendment Draft for Consultation) (2020) < http://www.pbc.gov.cn/goutongjiaoliu/113456/113469/4115077/2020102318443757476.doc> art 19.

[17]See, e.g., E Howcroft and M Jones, Bahamas to Regulate Banks to Offer Cbank Digital Currency(2024) < https://www.reuters.com/technology/bahamas-regulate-banks-offer-cbank-digital-currency-2024-07-01/> (At the time or wring, it has been reported that the Bahamas would likely adopt regulations concerning CBDC within the next two years).

[18]See, e.g., European Parliament and Council Directive 2012/19/EU on waste electrical and electronic equipment (WEEE) (recast) Text with EEA relevance [2012] OJ L 197.

[19]T Dietz et al, 'The Struggle to Govern the Commons' (2003) 302 Science 1907, 1907.

[20]R Cooney and ATF Lang, 'Taking Uncertainty Seriously: Adaptive Governance and International Trade' (2007) 18 European Journal of International Law 523, 539.

[21]K van Assche et al, 'Adaptive Governance: Learning from What Organizations Do and Managing the Role They Play' (2022) 51 Kybernetes 1738, 1746.

Originating from seminal work in 2003,[22] adaptive governance encompasses interactions among public and private actors, networks and institutions to enhance social-ecological systems.[23]

In the same vein, there is a gap in internal organisational governance. Digitalisation and sustainability are handled by different agencies or different departments of an institution (such as separate currency, technology and sustainability departments of a central bank or of an international organisation) with arguably limited coordination. Existing governance frameworks have rarely grappled with CBDCs and sustainability, especially the contributions of CBDCs to sustainability. Such limited coordination makes existing internal organisational governance struggle to align digitalisation with sustainability in a holistic and timely way.

The urgency of addressing CBDCs in tandem with sustainability arises from the limited timeframe available to guarantee that CBDC frameworks will actively promote sustainability. CBDCs need to be designed within a certain time frame given pressures such as currency competition. Once CBDCs have established their structural processes, it may prove difficult to change. CBDCs therefore need to be designed today with sustainability in mind.

The article continues, in Section 2, by exploring the underlying challenges that governance systems face in aligning digitalisation with sustainability. It argues that the governance systems for digitalisation and sustainability face various mismatches in terms of functions (functional mismatches), governance levels (spatial mismatches) and timescales (temporal mismatches). Adaptive governance can help to explore the solutions to these mismatches. As discussed in Section 2, there is a lack of alignment in the governance of digitalisation on the one hand and sustainability on the other. Section 3 explores learning as the potential solution to the governance gaps highlighted in Section 2, particularly given the early stage of governing CBDCs. As a crucial aspect of adaptive governance, learning is an important way to respond to uncertainties.[24] Amid the evolving landscape, learning helps to address the governance gaps by assessing the effect of digitalisation on sustainability and breaking silos. Section 4 concludes by further considering how CBDCs may be harmonised with sustainability. This article does not analyse the merits of CBDCs, which deserve separate and careful analysis.

2 | ADAPTIVE GOVERNANCE FOR SUSTAINABLE CBDCS

Governance involves any collaborative initiative intended to oversee public affairs, emerging through structured interactions among public entities, private entities, and both formal and informal institutions.[25] Mismatches in governance are among the major reasons behind the challenges faced by socio-ecological systems,[26] and are arguably at the core of governance dilemmas.[27] These mismatches occur horizontally between functions, vertically across levels of governance[28] and across different timescales.[29] As a major governance challenge concerning digitalisation and sustainability, these mismatches reveal governance gaps in coordinating different functions, and crossing governance levels and timescales.

These mismatches highlight the tension between digitalisation and environmental sustainability. The learning of adaptive governance is therefore needed to address this tension (as discussed in Section 3).[30] Understanding these mismatches is key to unpacking the complexity of governance in the digitalisation context, the difficulties faced by existing governance arrangements, and the resulting ramifications for the digitalisation-sustainability nexus more broadly.

The concept of adaptive governance originated from applying ecological systems theory to natural resource management.[31] In particular, adaptive governance analyses how a governance system addresses uncertainties.[32] It serves as a valuable paradigm for addressing challenges like climate change,[33] and has often been adapted and applied by researchers and practitioners in different and changing contexts. Adaptive governance addresses uncertainties through learning (including learning in the policymaking process).[34] The approach is critical in complex scenarios involving multiple stakeholders, especially in situations where it is difficult to determine the optimal course of action.[35] That said, adaptive governance is not a silver bullet,[36] and adaptation brings both opportunities (e.g., new connections) and challenges (e.g., the time consumed in trust building among existing and new stakeholders). These issues should also be carefully considered in governance processes. This section provides a solid foundation for the analysis of how adaptive governance can help design and improve governance arrangements.

[22]Dietz et al (n 19) 1907-1912.
[23]BC Chaffin et al, 'A Decade of Adaptive Governance Scholarship: Synthesis and Future Directions' (2014) 19 Ecology and Society 1, 1.
[24]C Wyborn et al, 'Conceptualising the Science–Policy–Practice Interface of Adaptive Governance' in S Juhola (ed) *Handbook on Adaptive Governance* (Edward Elgar 2023) 54, 68.
[25]B Cosens et al, 'Governing Complexity: Integrating Science, Governance, and Law to Manage Accelerating Change in the Globalized Commons' (2021) 118 Proceedings of the National Academy of Sciences of the United States of America 1, 2.
[26]M Nikkanen and A Räsänen, 'Spatial Data, Methods, and Mismatches for Adaptive Governance Research' in S Juhola (ed) *Handbook on Adaptive Governance* (Edward Elgar 2023) 100.
[27]S Juhola, 'The Next Decade of Adaptive Governance Research: Concluding Remarks' in S Juhola (ed) *Handbook on Adaptive Governance* (Edward Elgar 2023) 253.
[28]M Janssen and H van der Voort, 'Adaptive Governance: Towards a Stable, Accountable and Responsive Government' (2016) 33 Government Information Quarterly 1, 3.
[29]KJ Winkler et al, 'Mismatches in the Ecosystem Services Literature—a Review of Spatial, Temporal, and Functional-Conceptual Mismatches' (2021) 6 Current Landscape Ecology Reports 23, 24.
[30]ibid.
[31]E Esener, 'Adaptive Governance for Blockchain Networks' (2024) 7 Stanford Journal of Blockchain Law and Policy 76, 101.
[32]T Steelman, 'Adaptive Governance' in C Ansell and J Torfing (eds), *Handbook on Theories of Governance* (Edward Elgar 2022) 580, 581.
[33]N Soininen et al, 'Adaptive Governance, Law and Regulation' in S Juhola (ed) *Handbook on Adaptive Governance* (Edward Elgar 2023) 35, 36.
[34]Cooney and Lang (n 20) 524.
[35]Janssen and van der Voort (n 28) 3.
[36]BA Cosens et al, 'Designing Law to Enable Adaptive Governance of Modern Wicked Problems' (2020), 73 Vanderbilt Law Review 1687, 1731.

2.1 | Functional mismatches

The governance frameworks for digital currencies[37] and sustainability address distinct functions and policy domains. The functional mismatches of these two domains extend to different knowledge types, perceptions, networks and institutions.[38] These mismatches are further compounded by distinct policy areas, regulatory environments, and a limited history of collaboration among actors, all of which shape their development.[39] A useful example is wholesale CBDCs, which would potentially enhance the efficiency of international payments (e.g., reducing the number of intermediaries). However, this process would involve energy consumption.[40]

In the broader context of finance and sustainability, there is increasing coordination between regulators in both fields. Examples include the Network of Central Banks and Supervisors for Greening the Financial System (NGFS), the Task Force on Climate-Related Financial Disclosures, the European Union (EU) Sustainable Finance Disclosure Regulation, and the EU green bond standard. However, such coordination remains limited, especially when it comes to CBDCs.[41]

CBDCs should be designed in a way that mitigates their environmental ramifications. Regulatory development could incentivise or encourage CBDCs to meet high standards of energy efficiency and rely on sustainable energy to function. Energy consumption (including the energy efficiency of CBDC infrastructure and payment instruments) should be an integral element in the initial design and execution of CBDCs.

The G7 called for measures such as the careful design of retail CBDCs and disclosure of CBDCs' environmental effects.[42] CBDCs can set a benchmark for energy-efficient payment and settlement systems by integrating carbon-neutral and sustainable energy sources to achieve 'functional, performance, and resilience objectives'.[43] The European Central Bank (ECB) has also indicated the need for environmentally friendly CBDCs based on technological solutions that reduce its environmental impact.[44] The design of the digital Euro is expected to motivate and urge payment service providers to reduce the environmental footprint of the existing payment system.[45] The Bank of England (BoE) indicated that the design and issuance of its possible CBDC should consider the climate strategy of the BoE.[46] Nonetheless, despite this explicit recognition, the sustainability implications of CBDCs remain largely unclear. CBDCs would likely rely on technology developments such as low-energy use hardware and software interfaces, as well as regulatory frameworks to be environmentally responsible. CBDCs consume energy, especially when deployed not only within domestic boundaries but also across borders. Against this backdrop, solving functional mismatches in the fields of finance and sustainability proves even more pertinent.

Meanwhile, as a first-mover, China is actively exploring the use of its digital yuan or e-CNY to promote sustainability and may influence the potential of using CBDCs to encourage environmentally friendly activities. This is an example of where CBDCs and sustainability intersect. The success of such an intersection depends on how well CBDCs operate and how well regulatory and other issues, such as recovering the cost of investing in the CBDC ecosystem, are dealt with. The e-CNY is used in environmentally friendly activities such as cycling, green business subsidy and discount transactions in the e-CNY pilot programme.[47] Cyclists who opt for bicycle sharing can enjoy financial benefits in the form of e-CNY, thereby encouraging zero-carbon forms of transport.[48] This showcases CBDCs' ability to function as viable financial rewards, which can further the execution and uptake of green initiatives. China has since taken its incentivisation a step further: recently, the digital yuan has been used in a domestic loan to reduce carbon emissions in the energy sector.[49] The Postal Savings Bank of China is also exploring the use of e-CNY in the rediscount of green commercial bills,[50] where the bank buying these bills receives another deduction from their debt amount for the prompt payment before their due date. Nevertheless, it remains to be seen whether and how functional mismatches (e.g., distinct policies and regulatory environments) can be addressed here and what the long-term effects of these efforts, such as scalability and cost recovery, would be.

Improving the coordination of different functions is essential for narrowing the governance gap to harmonise digitalisation and sustainability. Such coordination necessitates the construction of 'bridges' between prevailing governance structures, considering the traditions (e.g., history, culture) of institutions, to effectively address the challenges posed by the evolving landscape.[51] It requires, among other

[37]Here digital currencies include CBDCs, stablecoins, and other crypto assets. Stablecoins and other crypto assets are not currencies in the strict sense and can be classified as a financial asset (such as a security). CBDCs are national currencies issued by the central banks. FATF, 'Updated Guidance for a Risk-Based Approach to Virtual Assets and Virtual Asset Service Providers' (2021) <www.fatf-gafi.org/publications/fatfrecommendations/documents/Updated-Guidance-RBA-VA-VASP.html> 24.

[38]Winkler, et al. (n 29) 25, 28.

[39]C Wang et al, 'Towards a Typology of Adaptive Governance in the Digital Government Context: The Role of Decision-Making and Accountability' (2018) 35 Government Information Quarterly 306, 320.

[40]Agur et al (n 7) 13.

[41]A Baglioni, *Monetary Policy Implementation: Exploring the 'New Normal' in Central Banking* (Palgrave Macmillan 2024), 241-252.

[42]G7, 'Public Policy Principles for Retail Central Bank Digital Currencies' (2021) <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1025235/G7_Public_Policy_Principles_for_Retail_CBDC_FINAL.pdf> 11, 12.

[43]ibid.

[44]European Central Bank, 'Report on a Digital Euro' (2020) < https://www.ecb.europa.eu/pub/pdf/other/Report_on_a_digital_euro~4d7268b458.en.pdf > 15.

[45]ibid.

[46]Bank of England, 'The Bank of England's Climate-Related Financial Disclosure 2021' (2021) <https://www.bankofengland.co.uk/prudential-regulation/publication/2021/june/climate-related-financial-disclosure-2020-21>.

[47]M Gou, 'Deepen Cross-Border Pilots, Continuously Expand Scenarios, and Take the E-CNY Pilot Further' (2024) <https://baijiahao.baidu.com/s?id=1800531549771482800&wfr=spider&for=pc>.

[48]J Ouyang, 'E-CNY Empowers "Dual Carbon" - Meituan Bike's 3 Million Digital Currency Users Have Ridden More Than 71.2 Million Kilometers' 2022)' (3 March 2022) <https://www.cs.com.cn/5g/202203/t20220303_6246791.html>.

[49]Postal Savings Bank of China, 'Postal Savings Bank of China Launched the Country's First "Carbon-Reduction Supporting Tool + Sustainable Development Linkage + E-CNY" Loan' (15 May 2023) <https://www.psbc.com/cn/gyyc/ycfm/ycdt/202305/t20230515_202500.html>.

[50]China Banking and Insurance News, 'Rediscount + Green Bill Discount + E-CNY" Business Launched in Guangdong' (18 April 2023) <http://www.cbimc.cn/content/2023-04/18/content_482072.html>.

[51]Chaffin et al (n 23) 9,

things, the careful consideration of the effects of digitalisation in governance design to align digitalisation with sustainability.[52]

2.2 | Spatial mismatches

Mismatches between the governance levels at which problems need to be addressed could lead to splintered governance.[53] These mismatches could concern inconsistent scales.[54] Here scales refer to analysing issues by applying a spatial dimension.[55] Regarding the CBDC-sustainability nexus, the harmonisation of CBDC and sustainability concerns the governance at the local (e.g., a local government promoting environmentally friendly activities through CBDCs), national (e.g., the role of central banks and other authorities in regulating and promoting green CBDCs), regional and international levels (e.g., the coordination of efforts of different jurisdictions in developing green CBDCs, including the energy efficiency of cross-border CBDCs). For each of these examples, the scales of governance may not align with real-world issues, leading to scale mismatches.[56]

In light of this, it is critical to act and respond 'at the scale of the problem'.[57] Both sustainability and digitalisation concern local, national, regional and global levels.[58] The cross-border use of CBDCs, in particular, extends over two or more jurisdictions. As such, cross-scale governance activities are necessary to accommodate the multi-jurisdictional nature of both fields.

The self-organising aspect of adaptive governance may also be reflected at smaller scales.[59] However, self-organisation at smaller scales may prove insufficient to address the environmental implications of CBDCs. Given the challenges, such as global warming, that energy consumption and e-waste impose, the nexus between CBDCs and sustainability needs to be addressed not only at local and national levels but also at regional and international levels. The phenomena and issues being governed require a corresponding scale of governance (particularly jurisdictional scales) to avoid scale mismatches that can occur with decentralisation. Further, the local governance may struggle to address the complex large-scale, cross-scale or cross-level issues[60] inherent in the governance of digitalisation and sustainability. Therefore, such governance needs to simultaneously operate at the local, national, regional and international levels.

2.3 | Temporal mismatches

Conflict can arise between the long-term and short-term considerations of different actors. Systematic adaptiveness is therefore needed to reconcile these temporal mismatches.[61] Digitalisation and sustainability involve vastly different timescales. The environmental impact of CBDCs is contingent upon technological designs and generally concerns the mid- to long-term consideration of climate change and environmental degradation. Various elements contribute to the energy use of CBDC, including data centres and digital wallets located on devices, as well as the use of software that processes payments.[62] CBDC energy consumption is also affected by technology and technological designs (as discussed below). For example, CBDCs could adopt blockchain technology to create an immutable transaction record,[63] but this would incur costs of computations and storage, leading to further environmental impact.[64] The extent of energy consumption regarding access to these ledgers may be affected by the nodes of the network, particularly their number and location, software, and protocol.[65] To illustrate, with all else being equal, fewer nodes signal lower redundancy and reduce energy consumption.[66] The energy efficiency of software is thus linked to its carbon footprint.

Furthermore, technological design also has environmental implications. The diverse selection of technological designs among various states may result in fragmentation and incompatibility of technical standards. Such discrepancies can escalate energy consumption, since more electricity would be needed due to incompatibility. Other aspects like e-waste relating to digital infrastructure[67] and user payment means (e.g., digital wallets available on smart phones, payments made by feature phones, related user hardware and software interfaces) could also carry broader environmental implications.[68] CBDCs running on phones may, nevertheless, reduce dependence on card networks and energy consumption, provided that CBDC transactions can be conducted on low-energy devices and do not require more energy-intensive payment methods.[69]

These mid- to long-term environmental and sustainability considerations may not always align with the short-term imperatives to roll out CBDCs quickly, especially to acquire a first-mover advantage, or R&D budgetary constraints for CBDC projects and technology. The trade-offs inherent in design choices, encompassing factors like

[52] See, e.g., A Mitha, 'BigFintechs & Sustainability: A Necessary Convergence' (2021) <https://www.undp.org/sites/g/files/zskgke326/files/2021-06/UNDP-UNCDF-Summary-of-Technical-Paper-BigFintech-and-Sustainability-a-Necessary-Convergence-EN.pdf>; K Charamba et al, 'BigFintechs and International Governance, Policymaking and the United Nations Sustainable Development Goals: The SDGs in the International Governance of Finance' (2021) <https://www.undp.org/sites/g/files/zskgke326/files/2021-06/UNDP-UNCDF-TP-3-2-BigFintechs-and-International-Governance-Policymaking-and-the-United-Nations-EN.pdf> 16.

[53] Nikkanen and Räsänen (n 26), 108.

[54] Janssen and van der Voort (n 28), 3.

[55] CC Gibson et al, 'The Concept of Scale and the Human Dimensions of Global Change: A Survey' (2000) 32 Ecological Economics 217, 218.

[56] Nikkanen and Räsänen (n 26), 108-109.

[57] Cosens et al (n 36) 1725.

[58] GK Hovelsrud and H Westskog, 'The Role of Adaptive Governance in Climate Mitigation and Adaptation: A Local Perspective' in S Juhola (ed) *Handbook on Adaptive Governance* (Edward Elgar 2023)194.

[59] Cosens et al (n 36) 1727; DA DeCaro et al, 'Legal and Institutional Foundations of Adaptive Environmental Governance' (2017) 22 Ecology and Society 1, 10.

[60] Nikkanen and Räsänen (n 26) 101.

[61] Wang et al (n 39) 320.

[62] Agur et al (n 7) 5.

[63] A Abi Karam, 'Central Bank Digital Currency (CBDC) and Blockchain Enable the Future of Payments' (2023) <https://www.ibm.com/blog/central-bank-digital-currency-cbdc-and-blockchain-enable-the-future-of-payments/>.

[64] J Xu, 'Developments and Implications of Central Bank Digital Currency: The Case of China e-CNY' (2022) 17 Asian Economic Policy Review 235, 244.

[65] Agur et al (n 14).

[66] Agur et al (n 7) 5.

[67] G Kerr, 'Crypto's Carbon Footprint' (2021) <https://en.irefeurope.org/publications/iref-newsletter/article/crypto-s-carbon-footprint/>.

[68] Agur et al (n 7) 13.

[69] ibid 14-15.

TABLE 1 Functional, spatial and temporal mismatches faced by digitalisation and sustainability

	Arises across	Considerations	Examples	Possible solutions
Functional mismatches	Horizontal functions (e.g., environment and digitalisation)	Different knowledge types, perceptions, networks and institutions (e.g., regulators)	The tension between the benefits of digitalisation (e.g., efficiency) and its environmental impact (e.g., e-waste, energy use)	Coordination between functions, including linking with existing governance structures
Spatial mismatches	Governance levels (ranging from local to international levels) and scales	Different jurisdictions and inconsistent scales The difficulties of the governance scales to fit with real-life issues	The inability of local-level governance or central banks to address global warming on their own	Cross-scale and cross-level efforts to address mismatches
Temporal mismatches	Different timescales	Short, mid- to long-term timescales and considerations	Tension between short-term imperatives to roll out CBDCs quickly and long-term environmental considerations	Making trade-offs based on learning

performance (e.g., data flow), security advantages and energy usage, are intricately tied to the competing overarching objective of digitalisation and sustainability.[70] Pursuing one goal could generate opportunity costs for realising another.[71] Given currency competition, capital costs and infrastructure development, some states may prioritise short-term considerations in the research and development of CBDCs over long-term environmental interests.[72]

Mismatches could be exacerbated by the need for swift responses not only to emergencies but also to innovations, developing technology or user needs.[73] Taking spatial mismatches as an example, the harmonisation of CBDC and sustainability at the local level may move at a different pace compared with that at the national, regional or international levels. In addition, a frequent gap in governance systems occurs when planning and funding arrangements are driven by short-term perspectives rather than the long-term vision needed for sustainability issues.[74]

2.4 | Summary

The various mismatches discussed above highlight the significant and overlapping challenges posed by existing governance arrangements to sustainable CBDCs. Sustainability is a large-scale issue across space and time involving mismatches in both governance levels and timescales. Adaptive governance, as outlined in Table 1, helps tackle mismatches and facilitates the collaborative endeavours of multi-level institutions in ensuring that digitalisation is environmentally responsible and contributes to a green economy. Functional and spatial mismatches provide a prime example. In addressing functional mismatches, adaptive governance aligns organisational governance with the needs of the environment (including technical needs).[75] Given its capacity to address uncertainties involving a large number of actors,[76] adaptive governance could be a useful tool in dealing with the nexus between CBDCs and sustainability.[77] As a feature of adaptive governance[78] and as discussed below, learning provides a useful way to organise an adaptive approach to further align digitalisation with sustainability.

3 | LEARNING AS A MAJOR GOVERNANCE EFFORT

To respond to structural mismatches,[79] adaptive governance focuses on fostering learning.[80] This can involve practices, ideas, values, key questions and even assumptions.[81] Learning is the societal process of adapting institutions to handle social and ecological change in a way that improves the well-being of present and future generations.[82] This in turn helps to reduce the gap in internal organisational governance. Adaptive governance relies on the ability of actors to adapt to changes[83] and requires coordination of actors at different levels to effectively manage social-ecological systems.[84] Learning is also a 'learn by doing' process for various stakeholders to jointly explore

[70] S Lee and J Park, 'Environmental Implications of a Central Bank Digital Currency (CBDC)' (World Bank Group Korea Office 2022) 12.
[71] ibid.
[72] I De Bode et al, 'CBDC and Stablecoins: Early Coexistence on an Uncertain Road' (2021) <https://www.mckinsey.com/industries/financial-services/our-insights/cbdc-and-stablecoins-early-coexistence-on-an-uncertain-road#> 5.
[73] Janssen and van der Voort (n 26) 2.
[74] C Alexandra et al, 'Futures-Thinking: Concepts, Methods and Capacities for Adaptive Governance' in S Juhola (ed) *Handbook on Adaptive Governance* (Edward Elgar 2023) 88, 88-89.
[75] Janssen and van der Voort (n 28) 2.
[76] ibid.
[77] E Boyd and S Juhola, 'Adaptive Climate Change Governance for Urban Resilience' (2015) 52 Urban Studies 1234, 1241.
[78] RP Bixler et al, 'Adaptive Governance for Disaster Risk Reduction' in S Juhola (ed) *Handbook on Adaptive Governance* (Edward Elgar 2023) 237.
[79] Nikkanen and Räsänen (n 26) 100.
[80] Cooney and Lang (n 20) 534.
[81] S Munaretto et al, 'Integrating Adaptive Governance and Participatory Multicriteria Methods: A Framework for Climate Adaptation Governance' (2014) 19 Ecology and Society 1, 4.
[82] J Woodhill, 'Sustainability, Social Learning and the Democratic Imperative: Lessons from the Australian Landcare Movement' in C Blackmore (ed), *Social Learning Systems and Communities of Practice* (Springer 2010) 57, 63.
[83] M Fournier et al, 'Flood Risk Mitigation in Europe: How Far Away Are We From the Aspired Forms of Adaptive Governance' (2016) 21 Ecology and Society 1, 3.
[84] L Schultz et al, 'Adaptive Governance, Ecosystem Management, and Natural Capital' (2015) 112 Proceedings of the National Academy of Sciences of the United States of America 7369, 7369.

solutions to address uncertainties,[85] which works to narrow the regulatory gap. As 'the core of governance efforts',[86] learning increases knowledge (including new information through data collection) and embraces different perspectives. Through learning, stakeholders could transcend functional, spatial and temporal boundaries and work together across those boundaries to build sustainable digitalisation. To a certain degree, learning contributes to mitigating functional mismatches and other discrepancies, as central banks may not possess a comprehensive understanding of the environmental ramifications associated with CBDCs.

Understanding of the environmental implications of CBDCs needs to be improved.[87] Notably, uncertainties exist in energy consumption and e-waste issues (e.g., the long-term e-waste solutions) related to fintech and other technical advancements. It is not easy to accurately anticipate the far-reaching environmental impacts of digitalisation. From an environmental perspective, the global environmental system is a 'complex adaptive system', and learning is crucial to adapt to a world experiencing increasingly fast environmental change.[88] Taken together, rapid progress in practice as well as successful adaptation both require learning.[89] Here learning encompasses insights into shifts and impacts within governance environments, operational expenditures and unforeseen consequences of digitalisation. With its far-reaching range, learning will play a pivotal role in navigating the intricate relationship between CBDCs and sustainability.

Learning needs to be integrated into decision-making processes[90] and should occur at all levels of governance (multi-level learning[91]). Learning can be fostered in a number of ways. This includes effectively preventing irreversible impacts (e.g., precaution in terms of policy and technological choices to prevent serious environmental implications), closely reviewing the knowledge gaps underpinning decisions (e.g., experimentation), critically assessing results (including monitoring[92] and other assessment of environmental implications as discussed in Section 3.1) and encouraging diverse perspectives in the decision-making processes (including breaking silos as discussed in Section 3.2).[93] These different ways of learning may overlap. For example, experimentation of CBDCs includes sandboxes and pilot projects. In this process, the public and private sectors should make efforts to break silos of digitalisation and sustainability and explore trade-offs between different policy objectives. To tackle spatial mismatches, sandboxes could be developed at a regional level to address issues such as divergent regulations in different jurisdictions. Currently there are very few sandboxes, which have been established or are planned at a country level.[94] A sandbox that works on the environmental implications of CBDCs is still lacking and may be considered.

Encouraging regulatory and technological experimentation, a sandbox could focus on seeking solutions and building capacity (including sharing knowledge) in aligning digitalisation with sustainability. For the organisers of sandboxes, they could be international and regional organisations (e.g., the BIS) and other actors (e.g., central banks). For the focus of sandboxes, they should have a system to monitor the environmental implications of CBDCs (e.g., data collection and analysis, an early warning mechanism regarding environmental impact) and encourage actors (e.g., the industry, such as software developers) to explore use cases of the contribution of CBDCs to a green economy. To illustrate, energy costs are a factor that central banks are considering or will face regarding CBDCs.[95] Sandboxes may endeavour to provide general guidance (e.g., initial technical documentation, test scripts, minimum energy efficiency requirements) and serve as a hub to promote peer learning.[96] Sandboxes should engage with as many stakeholders as possible, including regulators of the different levels, international organisations, industry and other stakeholders (e.g., non-governmental organisations [NGOs]). This promotes inclusiveness and iterative reflection.

3.1 | Starting from the assessment of environmental implications of CBDCs

Learning could be promoted through not only technology but also regulation (such as tendering requirements concerning energy efficiency). A useful starting point for learning is the assessment of environmental implications of CBDCs, which concerns both technological and regulatory aspects.

3.1.1 | Technological aspects

CBDC-related technology could affect the environmental implications of infrastructure and should be further explored to identify environmentally friendly solutions. According to a recent study, central

[85] D Armitage et al. 'Adaptive Co-management and the Paradox of Learning' (2008) 18 Global Environmental Change 86, 91.
[86] M Janssen and H van der Voort, 'Agile and Adaptive Governance in Crisis Response: Lessons From the COVID-19 Pandemic' (2020) 55 International Journal of Information Management 1, 2.
[87] AH Elsayed and MA Nasir, 'Central Bank Digital Currencies: An Agenda for Future Research' (2022) 62 Research in International Business and Finance 1, 4.
[88] F Berkes, 'Environmental Governance for the Anthropocene? Social-Ecological Systems, Resilience, and Collaborative Learning' (2017) 9 Sustainability 1, 1.
[89] Nikkanen and Räsänen (n 26) 104.
[90] C Wyborn, 'Cross-Scale Linkages in Connectivity Conservation: Adaptive Governance Challenges in Spatially Distributed Networks' (2015) 25 Environmental Policy and Governance 1, 3.
[91] C Pahl-Wostl, 'A Conceptual Framework for Analysing Adaptive Capacity and Multi-Level Learning Processes in Resource Governance Regimes' (2009) 19 Global Environmental Change 354, 356.
[92] Wyborn et al (n 24) 68.
[93] Cooney and Lang (n 20) 534.
[94] See, e.g., LV Schumacher, Decoding Digital Assets: Distinguishing the Dream from the Dystopia in Stablecoins, Tokenized Deposits, and Central Bank Digital Currencies (Palgrave Macmillan 2024) 164-165 (Fintech Regulatory Sandbox of the Bank of Jamaica that has tested a prototype CBDC); A Davletov, et al., Regulatory Sandbox Guideline on Central Bank Digital Currency for the Maldives Monetary Authority (Department of Economic and Social Affairs of the United Nations Secretariat, Maldives Monetary Authority, Ministry of Environment Climate Change and Technology, Maldives, and Economic and Social Commission for Asia and the Pacific 2023) 1-13.
[95] Agur et al (n 6) 6.
[96] Bank for International Settlements and Bank of England, 'Project Rosalind: Building API Prototypes for Retail CBDC Ecosystem' (2023) < https://www.bis.org/publ/othp69.htm> 16, 25.

bankers consider CBDCs to be a greener option than cash.[97] Possible reasons for this include the saving of cash transport, storage and management costs because trips to bank branches or ATMs are no longer needed.[98] However, nuanced understanding is needed. For one, data and IT systems (such as blockchain and data centres) are energy-intensive.[99] The complexity and rapid evolution of CBDCs and their ecosystems pose various governance challenges due to the uncertainties of the environmental implications of technologies. Therefore, a range of infrastructures should be explored to effectively restrict or monitor resource usage.[100] The following analysis consists of two parts: environmentally responsible CBDCs, as discussed in the several points below, and the contribution of CBDCs to sustainability.

Besides factors like monetary functions, experimentation should deepen the understanding and monitor the impact of technologies (such as those for core processing and user payment in the context of payment systems[101]) on sustainability. This helps to address issues like energy consumption and e-waste.[102] The energy use of digital currencies could be affected by technology and the features of CBDCs.[103] Digital currencies may or may not use DLT. For CBDCs that use DLT, theoretically these may include either permissioned DLT (those that can only be accessed with permission) or permissionless (available on an open network) DLT systems.[104] In fact, wholesale CBDCs usually use permissioned DLT.[105] Retail CBDCs may adopt non-DLT systems, permissioned DLT or hybrids that combine permissioned DLT and non-DLT systems.[106] Notably, many of the technological issues discussed here apply not only to CBDCs but also to other digital assets.

The energy consumption of CBDCs will be significantly determined by technology design. First, non-DLT based CBDCs might exhibit greater efficiency than existing payment systems, provided that central banks meticulously choose the platform, hardware and other components of the CBDC ecosystem based on energy efficiency.[107] Energy efficiency is arguably similar to 'currency efficiency', which evaluates a currency's effectiveness in realising its functionality (e.g., value secured, features like programmability, the ease of storage and security) in exchange for its energy consumption.[108] Solely utilising a centralised ledger may negatively affect the payment convenience offered by a CBDC because of the possible caps on peer-to-peer and offline transactions.[109] However, employing a combination of centralised and decentralised ledgers increases the complexity of the CBDC system[110] including the interaction between these ledgers. Such complexity may carry energy use implications. Some central banks, such as the Deutsche Bundesbank, are exploring other DLT-compatible wholesale payment solutions as 'alternatives to wholesale CBDCs'.[111] Certain CBDC projects are considering non-DLT architecture (such as novel central bank payment clearance systems like the Eurosystem's TARGET Instant Payment Settlement).[112] The effects of CBDC architectures deserve close attention.

Second, non-PoW permissioned networks may have a greater ability to influence the energy consumption of the core processing infrastructure.[113] DLTs designed in a permissioned setting[114] help manage energy consumption, since many nodes can exist in permissionless blockchains and increase energy consumption.[115] Permissioned networks also facilitate the promotion of software updates and protocols that are more energy-efficient.[116] The high carbon footprint is a major challenge faced by public blockchains based on PoW, which are permissionless.[117] Given the increasing complexity of computational puzzles, PoW's energy consumption is unlikely to decrease even with more energy-efficient infrastructure.[118]

Some CBDC projects opt for non-PoW permissioned DLT, allowing central banks to manage the number, the role and the geographic location of the network participants.[119] Nodes could be located wherever renewable energy sources are available or where surplus energy is otherwise wasted,[120] but this would depend on factors like the renewable energy capacity of jurisdictions.[121] CBDCs will rarely use PoW DLT, which tends to be more energy-consuming than permissioned or permissionless non-PoW DLT.[122] Generally, higher energy efficiency for each transaction appears to be more strongly linked with innovative systems rather than solely with DLT itself.[123]

Third, the energy consumption of CBDCs is contingent on CBDC dissemination design (e.g., the number of tiers and data infrastructure of commercial banks that concern processing[124]), CBDC features

[97]Central Banking staff, 'Central Banks Are Bullish on Environmental Features of CBDC' (22 February 2023) <https://www.centralbanking.com/benchmarking/fintech/7954563/central-banks-are-bullish-on-environmental-features-of-cbdc>.

[98]Monetary Authority of Singapore Economic Policy Group, 'A Retail Central Bank Digital Currency (CBDC): Economic Considerations in the Singapore Context' (2021) <https://www.mas.gov.sg/-/media/mas/epg/monographs-or-information-paper/a-retail-cbdc---economic-considerations-in-the-singapore-context.pdf> 10.

[99]Intergovernmental Panel on Climate Change, 'Climate Change 2022: Mitigation of Climate Change' (2022) < https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_FullReport.pdf> Chapter 1, 168.

[100]Soininen et al (n 33) 38.

[101]Agur et al (n 6) 3.

[102]C Gola and J Sedlmeir, 'Addressing the Sustainability of Distributed Ledger Technology' (2022) Bank of Italy Occasional Paper No. 670, 1, 19.

[103]Agur et al (n 7).

[104]Agur et al (n 6) 5, 6.

[105]V Sethaput and S Innet, 'Blockchain Application for Central Bank Digital Currencies (CBDC)' (2023) 26 Cluster Computing 2183, 2192.

[106]Agur et al (n 6) 7.

[107]Agur et al (n 7) 2.

[108]MIT Digital Currency Initiative, 'Currency Efficiency' (2024) <https://dci.mit.edu/currency-efficiency>.

[109]Bank of Canada et al, 'Central Bank Digital Currencies: Foundational Principles and Core Features' (Bank for International Settlements 2020) 15.

[110]ibid.

[111]PwC, 'PwC Global CBDC Index and Stablecoin Overview 2022' (2022) 12.

[112]Agur et al (n 7) 13.

[113]ibid 2.

[114]In permissioned DLTs, only participants approved can join the network and conduct activities (e.g. reading transactions). City of London Corporation et al (n 4) 7.

[115]Gola and Sedlmeir (n 102).

[116]Agur et al (n 6) 6; I Manotas et al, 'An Empirical Study of Practitioners' Perspectives on Green Software Engineering' (Proceedings of the 38th International Conference on Software Engineering, 2016) 237.

[117]E Urbinati et al, 'A Digital Euro: A Contribution to the Discussion on Technical Design Choices' (Bank of Italy 2021) 25.

[118]Gola and Sedlmeir (n 102),13.

[119]Agur et al (n 7) 2, 13, 14.

[120]ibid; MIT Digital Currency Initiative, 'MIT Digital Currency Initiative – Currency Efficiency Research' (2022) 14.

[121]JR Jaimes Becerra et al, 'Research of the Development of Green Central Bank Digital Currency, CBDC' (2023) 1, 4, 7.

[122]Agur et al (n 7) 9.

[123]ibid 13.

[124]Agur et al (n 6) 3.

(e.g., features for compliance, security, integrity and universal access[125])[126] and other factors (e.g., transaction speed). In contrast to intricate tiered systems, adopting a single-tier dissemination structure would mitigate the duplication of energy consumption attributable to multiple intermediaries.[127] However, central banks would likely opt for more complex two-tier systems to rely on intermediaries to address challenges such as the need to provide and manage payment services for clients. Taking on a different perspective, compared with crypto assets, CBDC dissemination architectures may be more complex and result in increased energy consumption.[128]

These factors concern entities and services within the CBDC ecosystem and their emission, payment-chain size and redundancies.[129] This includes the number of ecosystem actors and whether data centres adhere to high energy efficiency standards and utilise renewable energy sources.[130] Energy consumption may fluctuate as new research teams explore CBDCs, or in establishing bespoke arrangements for regulatory compliance (e.g., anti-money laundering and combating the financing of terrorism) and dispute settlement, or when different infrastructures are interlinked for cross-border CBDCs. Sustainability concerns could escalate with significant developments, such as the interoperability of CBDCs with digital assets like stablecoins.[131] In a broader context, energy consumption may also be relevant in other activities related to digital currency (e.g., a potentially large number of educational and promotional events,[132] the transportation of employees engaged by actors within the digital currency ecosystem[133]).

The sustainability of CBDCs extends beyond energy consumption. It encompasses broader issues including the efficient hardware production methods with minimised consumption of rare metals and water, the reduction of e-waste and the mitigation of negative environmental implications of recycling such as the chemical effects on landfills.[134] As CBDCs are likely to be integrated into the broader global payment system, solutions are required to address the cumulative environmental effect of digitalisation and underlying factors (e.g., economic equilibrium affecting the choice of actors, energy economies of scale), which might include higher costs of energy,[135] incentive-based measures[136] and improved environmental accounting standards.[137] It is important to explore environmentally sustainable CBDC design, including minting (the issuance of CBDCs[138]) and redemption (an intermediary's current account deposits at the central bank increased by the amount of CBDC that the central bank receives from the intermediary[139]).

Having considered the potential impact of CBDCs on sustainability, it is useful to explore the opportunities for CBDCs to contribute to the green economy. To this end, the learning inherent in adaptive governance should focus on seeking possible ways to promote the contribution of digitalisation to sustainability (such as through CBDC ecosystems). Incorporating digitalisation into responses to sustainability challenges can be facilitated through the development of technologies for supervisory and regulatory compliance.[140] Possible data functions of CBDC may help collect and share, for example, waste-related data arising out of activities using CBDCs. The digital age has witnessed 'the convergence of payments and data',[141] opening the door for the environmental repercussions of CBDCs to be examined through their digital footprints. However, it is imperative to ensure these regulatory measures enhance privacy protection to maintain system stability and public trust. Striking a meticulous balance is essential, as concerns may also arise regarding the impact of CBDC utilisation for social policy on the integrity of central bank currency. Nevertheless, with careful management, sustainability considerations can be integrated into the CBDC design and use. If done effectively, CBDCs can become a valuable policy tool in the future, helping to address uncertainties concerning environmental implications.

Moreover, innovative green economy financial instruments could be designed to ensure that they are solely used to finance projects and activities that promote a circular economy.[142] If there are no complications, CBDCs hold the potential to contribute to the green economy. Ozili, for example, highlights that

> [A] CBDC can be designed to offer a transaction cost waiver for transactions that are channeled to waste reduction activities or waste re-use activities. A CBDC can also be designed to have features that give tax rebates for transactions that are channeled to waste reduction activities or waste re-use activities. A CBDC can also be designed to exempt circular economy transactions from being taxed so as to encourage more circular businesses to use CBDC. This type of specially-designed CBDC will offer huge incentives to circular businesses, it can lead to cost savings, and can help to grow the circular economy.[143]

[125]ibid 2.
[126]MIT Digital Currency Initiative (n 108).
[127]Agur et al (n 7) 15.
[128]Agur et al (n 6) 7.
[129]Agur et al (n 14)
[130]Agur et al (n 6) 1, 7.
[131]Ledger Insights, 'Universal Digital Payment Network Targets Interoperable Stablecoins, CBDCs' (20 January 2023) <https://www.ledgerinsights.com/udpn-universal-digital-payment-network-stablecoins-cbdcs/>.
[132]MIT Digital Currency Initiative (n 108).
[133]Agur et al (n 6) 7.
[134]Agur et al (n 7) 4, 14.
[135]Gola and Sedlmeir (n 102); Agur et al (n 6) 6.
[136]MIT Digital Currency Initiative (n 108).
[137]Agur et al (n 6) 7.
[138]Central Bank Digital Currencies Working Group, 'Implementing a CBDC: Lessons Learnt and Key Insights Policy Report' (2020) <https://www.cemla.org/fintech/docs/2020-Implementing-CBDC.pdf> 11.
[139]Liaison and Coordination Committee on Central Bank Digital Currency, 'Interim Report' (2022) < https://www.boj.or.jp/en/paym/digital/rel220705b.pdf> 8.
[140]R Auer et al, 'Central Bank Digital Currencies: A New Tool in the Financial Inclusion Toolkit?' (Bank for International Settlements 2022) 13.
[141]J Cheng and J Torregrossa, 'A Lawyer's Perspective on U.S. Payment System Evolution and Money in the Digital Age' (4 February 2022) <https://www.federalreserve.gov/econres/notes/feds-notes/a-lawyers-perspective-on-us-payment-system-evolution-and-money-in-the-digital-age-20220204.html>.
[142]PK Ozili, 'Circular Economy and Central Bank Digital Currency' (2022) 2 Circular Economy and Sustainability 1, 4.
[143]ibid 11.

However, CBDCs also give rise to other issues that have to be monitored, like privacy protection.

In other words, CBDC design could incentivise environmentally responsible behaviour through preferential fee structures or rewards programmes for eco-friendly transactions.[144] Other possible options include CBDC-based green financing such as green bonds, loans (e.g., micro-loans) and equity investments in renewable energy projects (e.g., renewable energy production and consumption).[145] Notably, China favours using technology to promote environmentally friendly activities. A customer who uses Meituan, a Chinese shopping platform, and engages in low-carbon consumption behaviours, such as skipping disposable tableware when ordering takeout or carrying one's own reusable bags when buying fresh food, might get rewards in the form of e-CNY.[146] A smart recycling machine with digital yuan function can also provide financial benefits in the form of e-CNY based on recyclables in the domestic waste that it collects.[147] Nevertheless, the feasibility and methods of implementing these efforts on a large scale remain unclear.

3.1.2 | Regulatory aspects

As discussed above, a gap exists in the regulation of CBDCs so that they are environmentally responsible. Traditional regulatory tools (such as taxes) are not always effective for CBDCs, given the role of CBDCs as national currencies. For example, while energy usage could traditionally be regulated by taxation,[148] the energy consumption of CBDCs appears to fall through the gaps. This is because levying taxes or surcharges on CBDC usage is unlikely due to its status as public money. Beyond the notion that a national currency is not traditionally taxed, the imposition of a tax on the public use of a CBDC is contrary to the principal policy of enhancing financial inclusion, particularly in developing economies.[149]

Regulation should be carefully designed to address the environmental implications of technology (including technological complexities) and other considerations of digitalisation (e.g., financial stability). CBDCs could learn from and iterate on existing regulatory practices,[150] such as environmental impact assessment. This learning would help address the regulatory gap between financial and environmental law. To handle the aforementioned issue of taxing energy-consuming activities, some have suggested technology companies should promote sustainable consumption by continuously improving their business models.[151] This is akin to certain approaches in environmental law that require continuous improvement in the environmental performance of products and industries (e.g., vehicular emission requirements, minimum energy efficiency standards,[152] building energy efficiency standards[153]). Other potential solutions include a possible currency energy efficiency score.[154] Moreover, efforts are needed to ensure proper rule enforcement as the borderless nature of digitalisation poses challenges for enforcement.[155]

In particular, regulators could learn from impact assessment and disclosure in other fields (e.g., environmental impact assessment, data protection impact assessment). Environmental impact assessment and disclosure of digital currencies would provide a crucial foundation for assessing their effect on sustainability, particularly their carbon footprint. It would also help encourage the race to the top. Regular assessments of CBDCs' impact on the environment could be required at the various stages of CBDC development, similar to the US National Climate Assessment required under the Global Change Research Act.[156] Fully-fledged impact assessments may necessitate accounting for all actors and elements within payment systems, encompassing a comprehensive evaluation of various environmental impacts.[157] Relatedly, disclosure of the environmental impact of CBDCs is crucial. As discussed above, a G7 foundational principle on CBDCs is that '[t]hose central banks which publish climate-related disclosures (for example disclosures consistent with the Task Force on Climate-related Financial Disclosure framework) should consider disclosure of the environmental impact of CBDC operations in their reporting'.[158] Essentially, it is critical to explore how CBDCs' environmental footprint would be tracked, assessed and managed.[159] As an institutional framework concerning group learning, such transparency also helps to disseminate information, test the value concerning sustainability, and build trust.[160] The assessment and management of relevant environmental footprint (e.g., that of CBDCs) contributes to the learning concerning the nature of the sustainability risks of digitalisation. Notably, privacy protection needs to be balanced with data collection if the monitoring of CBDCs' environmental footprint concerns the privacy of CBDC users.

[144]S Shilina, Central Bank Digital Currencies (CBDCs) and Their Far-Reaching Effects: An Economic, Social, and Environmental Perspective (2024) <https://medium.com/paradigm-research/central-bank-digital-currencies-cbdcs-and-their-far-reaching-effects-an-economic-social-and-56bd8ea91c4a>.

[145]PK Ozili, Using Central Bank Digital Currency to Achieve the Sustainable Development Goals (2023) <https://www.researchgate.net/publication/368930860_Using_Central_Bank_Digital_Currency_to_Achieve_the_Sustainable_Development_Goals> 6.

[146]B Xia, 'Meituan: Participating in Green and Low-Carbon Consumption Behaviors Can Receive Low-Carbon Rewards through E-CNY' (2021) <https://news.cnstock.com/news,bwkx-202112-4797131.htm>.

[147]Yema Financial, 'Serving the People and Green Development, Bank of Communications Actively Explores New Low-Carbon Life Scenarios through E-CNY' (2023) <https://www.sohu.com/a/718211501_324659>.

[148]See, e.g., J Truby, 'Decarbonizing Bitcoin: Law and Policy Choices for Reducing the Energy Consumption of Blockchain Technologies and Digital Currencies' (2018) 44 Energy Research & Social Science 399, 400.

[149]AN Didenko, et al., 'After Libra, Digital Yuan and COVID-19: Central Bank Digital Currencies and the New World of Money and Payment Systems' (2020) 65/2020 European Banking Institute Working Paper Series 1, 46, 50; H Wang, Achieving Financial Inclusion Through Digital Currencies (United Nations Development Programme 2024) <https://www.undp.org/policy-centre/singapore/blog/achieving-financial-inclusion-through-digital-currencies>; H Wang, How Can CBDCs Be Designed to Drive Financial Inclusion? (United Nations Development Programme 2024) ⟨https://www.undp.org/policy-centre/singapore/blog/how-can-cbdcs-be-designed-drive-financial-inclusion⟩.

[150]Wang (n 12) 4.

[151]M Gossen and O Lell, 'Sustainable Consumption in the Digital Age: A Plea for a Systemic Policy Approach to Turn Risks into Opportunities' (2023) 32 GAIA 71, 74.

[152]See, e.g., Energy Conservation Act 2012 (2020 Rev Ed), ss 26B, 40.

[153]See, e.g., California Code of Regulations, Title 24, Part 6 (2022).

[154]MIT Digital Currency Initiative (n 120).

[155]Bank Indonesia, 'Project Garuda: Navigating the Architecture of Digital Rupiah' (2022) 7.

[156]Wyborn et al (n 24) 64.

[157]Agur et al (n 7) 18.

[158]G7 (n 42) 12.

[159]World Economic Forum, 'Central Bank Digital Currency Policy-Maker Toolkit' (2020) 24.

[160]Armitage et al (n 85) 88.

As another example, regulators could learn to address informational challenges in governance, including access to information (e.g., the environmental impact of new initiatives) by stakeholders,[161] as well as the limits of existing knowledge.[162] Procedural rules should outline the procedures and infrastructure for the production of information for decision making, the extent of investigation for administrative decisions, and the integration of information infrastructure with management processes.[163] To illustrate, such a process to generate data on the environmental effects of new developments and possible alternatives could be the EU's regulatory framework for environmental assessments,[164] although these usually concern one-off assessments.[165] Institutionally, management frameworks on water and the marine environment (e.g., the Maritime Spatial Planning Directive) require EU Member States to develop water status monitoring processes that are integrated into the formulation of the future management of sea basins.[166] Similar data generation and integration strategies may be considered by CBDC governance to ensure effective planning such as risk assessment and management (e.g., the possible minimum energy efficiency requirements of hardware and software, the planning of e-waste treatment capacity development to promote benefits like recovering valuable materials from e-waste[167]).

In addition, regulators could learn to integrate sustainability into CBDC ecosystems (such as app development) and different stages of CBDCs (e.g., outsourcing, future-proofing). Legal frameworks can solidify sustainability as a crucial factor in navigating digitalisation. It is important to endow legal authorities with the capacity to institute policies and practices that encourage the alignment of sustainability and digitalisation. In other words, the law can explicitly provide the relevant authorities legal power to harmonise digitalisation and sustainability, thus solidifying sustainability as a crucial factor in navigating digitalisation.

Rules could be developed to align digitalisation with sustainability. The outsourcing of CBDC activities and the future-proofing of CBDCs provide valuable insight into the intersection between sustainability and digitalisation. Both private (e.g., financial institutions) and public actors (e.g., central banks) may outsource their activities to a vendor, such as outsourcing the development of CBDC platforms to private companies.[168] Separately, future-proofing a payment system would mean improving system resilience and equipping it to deal with future risks.[169] Rules (such as rules on disclosure of outsourced activities' environmental impact) could be developed to mediate the behaviour of actors in the CBDC ecosystem to ensure the activities are properly outsourced and future-proof, with sustainability in mind.

In terms of the forms of rules, guidelines are often a good starting point.[170] Guidelines may explain regulators' expectations for the industry,[171] enhance the industry's understanding of regulators' approach to enforcement,[172] help regulators to review industry performance,[173] promote compliance[174] and develop a culture that aligns digitalization with sustainability. In other words, guidelines direct the behaviour of specified actors through outlining principles or 'best practice standards', and the adherence to these guidelines can affect the regulator's risk evaluation of the actor.[175] Guidelines may apply to not only the industry but also public actors.

In terms of the content of rules, rules should highlight the requirement to consider sustainability implications in decision-making. Comparable situations have emerged in various domains: consider the privacy regulations imposed on app development in response to the COVID-19 pandemic, which aligned data privacy considerations with public health measures.[176] Guidelines could encourage financial institutions (e.g., banks, asset managers) to identify, monitor and manage environmental risks.[177] In the same vein, regulations can learn from such practice by aligning sustainability with digitalization through requirements that track and mitigate environmental risks. Taking future-proofing as an example, guidelines might cover the following aspects: (i) the requirements in key aspects such as energy efficiency of software, hardware and underlying technology to reduce energy consumption; (ii) material sourcing to encourage using sustainable materials in hardware, including servers and other devices; and (iii) e-waste management to minimise e-waste and improve environmentally sound e-waste collection and treatment.[178]

[161]Soininen et al (n 33) 44.
[162]I Mukherjee, 'Rethinking the Procedural in Policy Instrument "Compounds": A Renewable Energy Policy Perspective' (2021) 40 Policy and Society 312, 318.
[163]Soininen et al (n 33) 44.
[164]European Parliament and Council Directive (EU) 2014/52 amending Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment Text with EEA relevance [2014] OJ L 124; European Parliament and Council Directive (EC) 2001/42 on the assessment of the effects of certain plans and programmes on the environment [2001] OJ L 197.
[165]Soininen et al (n 33) 44.
[166]ibid.
[167]CP Baldé et al, 'The Global E-waste Monitor 2024' (International Telecommunication Union (ITU) and United Nations Institute for Training and Research (UNITAR) 2024) 7.
[168]Bank for International Settlements (BIS), 'Central Bank Digital Currency (CBDC) Information Security and Operational Risks to Central Banks: An Operational Lifecycle Risk Management Framework' (2023) 4.
[169]G Soderberg et al, 'Behind the Scenes of Central Bank Digital Currency' (International Monetary Fund 2022) 4.
[170]See, e.g., Monetary Authority of Singapore, Guidelines on Outsourcing (2018) <https://www.mas.gov.sg/regulation/guidelines/guidelines-on-outsourcing>.
[171]Reed Smith, Revised Outsourcing Guidelines for Non-bank Financial Institutions in Singapore (2024) <https://www.reedsmith.com/en/perspectives/2024/02/revised-outsourcing-guidelines-for-nonbank-financial>.
[172]Monetary Authority of Singapore, Guidelines on the Regulation of Markets (2005) < https://www.mas.gov.sg/-/media/MAS/resource/legislation_guidelines/securities_futures/sub_legislation/Guidelines_Regulation_of_Markets.pdf> 3.
[173]Clifford Chance, MAS Publishes Revised Guidelines on Outsourcing (2016) <https://www.cliffordchance.com/content/dam/cliffordchance/briefings/2016/08/mas-publishes-revised-guidelines-on-outsourcing.pdf> 1.
[174]National Audit Office, Principles of Effective Regulation (2021) < https://www.nao.org.uk/wp-content/uploads/2021/05/Principles-of-effective-regulation-SOff-interactive-accessible.pdf> 21.
[175]Monetary Authority of Singapore, Supervisory Approach and Regulatory Instruments < https://www.mas.gov.sg/regulation/mas-supervisory-approach-and-regulatory-instruments#:~:text=They%20have%20legal%20effect%2C%20meaning,direction%20is%20a%20criminal%20offence.&text=Directives%20primarily%20impose%20legally%20binding,institution%20or%20a%20specified%20person>.
[176]Janssen and van der Voort (n 86) 5.
[177]See, e.g., Monetary Authority of Singapore, Guidelines on Environmental Risk Management (Banks) (2020) < https://www.mas.gov.sg/regulation/guidelines/guidelines-on-environmental-risk-management> 4, 8; Monetary Authority of Singapore, Guidelines on Environmental Risk Management (Asset Managers) (2020) < https://www.mas.gov.sg/regulation/guidelines/guidelines-on-environmental-risk-management-for-asset-managers> 4, 5.
[178]See, e.g., CP Baldé et al (n 167) 13.

More broadly speaking, to proactively seek solutions by learning, regulators should be explicitly authorised and encouraged to experiment with the harmonisation of digitalisation and sustainability. Currently, there is little regulation of the nascent field of CBDCs. Moreover, it seems that sustainability issues related to CBDCs are not highlighted in financial and environmental regulation. The People's Bank of China, for example, put forward the Law of the People's Bank of China (Amendment Draft for Consultation) in 2020, which proposes that China's digital yuan be accepted alongside the traditional paper yuan as legal tender.[179] Moreover, the Pudong New Area, one of China's major free trade zones, plans to pilot the use of digital yuan in carbon trading and green power trading.[180] However, the nexus between digitalization and sustainability needs to be more clearly identified in laws and regulations.

Rules, such as those used for impact assessments, shape the environment and parameters for governmental and nongovernmental stakeholders involved in adaptative governance.[181] Regulatory frameworks should therefore grant relevant authorities the flexibility to experiment and coordinate across both jurisdictional and substantive boundaries.[182] This is particularly important for the coordination between digitalisation and sustainability. It is important to integrate sustainability as a significant factor in digitalisation efforts through environmentally responsible CBDCs, and conversely, to thoroughly explore solutions to sustainability challenges through the lens of CBDC development. These considerations should not be confined to the initial design phases of digitalisation but should also extend to subsequent stages, including the exploration of new use cases of CBDCs.

3.2 | Breaking silos and developing capacity

To align digitalisation with sustainability, different stakeholders need to work beyond silos and jointly develop their capacities. For adaptive learning, it is essential to bridge the silos between digitalisation and sustainability and enhance the capacity of stakeholders (e.g., regulators) to adapt to the evolving financial landscape. The integration of diverse types of knowledge (including but not limited to the latest scientific knowledge) is key.[183] Adaptive governance demands an effective mechanism that enables stakeholders, including individuals and institutions, to engage across various domains and governance levels. This fosters mutual interaction and cultivates a culture of continuous learning.[184] The engagement between stakeholders includes efforts to strengthen the networks of stakeholders as forums of learning (e.g., multi-stakeholder platforms and initiatives to identify knowledge gaps, develop nodes of expertise and jointly produce knowledge[185]), to promote information dissemination across governance layers and to develop monitoring system and feedback loops that promote learning.[186] Regulatory complexities (e.g., the complexity of predicting, assessing and handling the environmental implication of digitalisation), most of which are often new, need to be addressed in this network of CBDC governance. Importantly, the engagement between stakeholders requires trust-building.

Experts in different fields (e.g., technology, finance, law and sustainability) should be consulted early in the CBDC development process. The coordination of different goals is also important. A collaborative approach should be adopted to support these experts to learn from and work with each other. For example, a common language across different fields could be established by collaboratively creating a sustainability risk taxonomy of digitalisation from the beginning. Moreover, CBDC projects should work closely with wider reforms to address challenges in governance.[187] Yet, it is essential to recognise the varying goals across different governance systems.[188] The recognition of different goals involves how environmental aims interact with other considerations in CBDC design (e.g., privacy). Notably, private sector incentives may not always match public policy objectives, especially regarding system compatibility, privacy protection and user identification.[189] Through learning, different values or incentives can be recognised, enabling the rethinking of aims and means.[190]

Adaptive governance also necessitates enhanced adaptive capacity of actors to navigate uncertainties, including preparing for unexpected developments and expediting decision-making when urgency is paramount.[191] In reality, however, there are constraints posed by the ability of governments to adapt.[192] Capacity building could help solve this problem. Capacity building includes not only the provision of funding by governments but also contributing to knowledge (such as knowledge creation, integration and sharing).[193] The utilisation of internal and external capabilities is important,[194] including the capabilities of central banks in both digitalisation and sustainability. Stakeholders should not only offer assistance to other parties but also enhance their own capacity. For example, given the complexities in timelines and scale, support from international organisations and arrangements, such as the BIS, United Nations, G20, Financial Stability Board and NGFS, would be beneficial. These stakeholders are also

[179] People's Bank of China, 'Explanation for the Law of the People's Bank of China (Amendment Draft for Consultation)' (2020) <http://www.pbc.gov.cn/goutongjiaoliu/113456/113469/4115077/index.html> para 3.6; People's Bank of China, Law of the People's Bank of China (Amendment Draft for Consultation) (2020) < http://www.pbc.gov.cn/goutongjiaoliu/113456/113469/4115077/20201023184437574 76.doc> art 19.
[180] www.gov.cn, 'The General Office of the CPC Central Committee and the General Office of the State Council issued the Pudong New Area Comprehensive Reform Pilot Implementation Plan (2023-2027)' (2024) <https://www.gov.cn/zhengce/202401/content_6927503.htm> para 2.2.
[181] DeCaro et al (n 59) 3.
[182] Chaffin et al (n 23) 9, 10.
[183] Esener (n 31) 104.
[184] ibid 103.
[185] Bixler et al (n 78) 238, 239.
[186] Esener (n 31) 107.
[187] Bank of Canada et al (n 109) 6.
[188] RK Craig, et al., 'Balancing Stability and Flexibility in Adaptive Governance: An Analysis of Tools Available in U.S. Environmental Law' (2017) 22 Ecology and Society 1, 1.
[189] C Catalini and J Massari, 'Stablecoins and the Future of Money' (2021) <https://hbr.org/2021/08/stablecoins-and-the-future-of-money>.
[190] JS Levy, 'Learning and Foreign Policy: Sweeping a Conceptual Minefield' (1994) 48 International Organization 279, 286.
[191] Janssen and van der Voort (n 86) 3.
[192] D Fitzpatrick, 'Towards Adaptive Property: Legal Design for a Climate-Affected Future' in S Juhola (ed) *Handbook on Adaptive Governance* (Edward Elgar 2023) 226.
[193] Cosens et al (n 36) 1728.
[194] C Wang et al (n 39) 306.

TABLE 2 Problems and solutions concerning CBDCs and sustainability (non-exhaustive)

	Examples	Factors underlying the problems
Problems	E-waste Energy consumption such as that related to research and development, operation (e.g., infrastructure like DLT and data centres) and features of CBDCs (e.g., compliance, security, interoperability) Non-energy resources (e.g., rare metals, water) to produce hardware Lack of data, knowledge, regulation and cooperation concerning sustainability and CBDCs	• Redundancy: CBDCs as an extra layer of the financial system instead of replacing the existing financial system • Time sensitiveness: A narrow window of opportunity for CBDC design given the fast development of CBDCs • Future: Possible expansion of CBDC use (domestically and internationally) and increased resource use
Solutions	Experimentation, precaution and monitoring Starting from the assessment of environmental implications of CBDCs, including those of CBDC development and design: • Endowing legal authority to authorities to align sustainability and digitalisation • Guidelines, standards and procedures to promote sustainability (e.g., CBDC tendering and outsourcing requirements on low-energy use hardware and software, continuous improvement in environmental performance of products) and to ensure access to information (e.g., disclosure of CBDC activities' environmental impact and CBDC energy efficiency scores) • Tracking energy consumption and waste • Programmability to incentivise climate-friendly behaviour • Integration of eco-friendly infrastructure • Accounting standards • Other incentives to use green energy or less resources Breaking silos and developing capacity • Engagement with experts from various domains (e.g., sustainability, technology, finance, law) early in digitalisation and actions to foster cooperation, starting with a sustainability risk taxonomy to arrive at a common language • Clear rules on the role and scope of a CBDC policy to promote coordination between actors • Networks across levels (e.g., different bodies, engagement with stakeholders) and trust building to share information and solve problems • Possible interaction with wider initiatives (e.g., NGFS, e-waste treatment capacity development initiatives) • Exploring the balance between factors such as privacy protection and data collection	Addressing environmental implications of CBDCs (environmentally friendly CBDCs) Contribution of CBDCs to sustainability (while considering other factors like privacy protection)

Abbreviations: CBDCs, central bank digital currencies; DLT, distributed ledger technology; NGFS, Network of Central Banks and Supervisors for Greening the Financial System.

improving their own capacity over time. While adaptive capacity needs to be developed by governance at the lower levels,[195] it may be advisable to make adaptive capacity as an objective of relevant laws, including the ability of rules to calibrate to different contexts in a more efficient way.[196] This is particularly salient when we face the fast-changing digitalisation landscape.

Apart from enhancing capacities, it is essential to clarify the functions of various agencies and strengthen coordination among different actors (including dialogues and a decision-support mechanism for evidence-informed policy). Clear rules on the role and scope of a CBDC policy are desirable for promoting coordination between central banks, other regulators and the private sector.[197] While central banks typically lead CBDC initiatives, addressing sustainability issues naturally goes beyond their jurisdiction. Even within a singular agency, different departments, like the legal and sustainable development departments within a central bank, should have well-defined roles to best address sustainability issues. Adaptive governance emphasises learning and cooperation to find solutions. Adaptive governance calls for meaningful interactions among policy goals and the decision-support mechanisms that consider different interests and incorporate various kinds of knowledge to inform the problem definition and the selection of measures.[198] Bridging the gap in existing governance arrangements requires careful consideration of the bureaucratic structures that often prioritise stability and efficiency but may hinder innovation and adaptability.[199] Well-managed bureaucracies can swiftly enforce new policies and guarantee adherence to them.[200] Further

[195] Janssen and van der Voort (n 86) 2.
[196] Fitzpatrick (n 192) 227, 229.)
[197] PL Siklos, 'Central Bank Digital Currency and Governance: Fit for Purpose?' (Center for International Governance Innovation 2021) 18.
[198] Esener (n 31) 105.
[199] Janssen and van der Voort (n 86) 5.
[200] ibid.

efforts are needed to advance understanding and collaboration in addressing sustainability within CBDC governance frameworks. These efforts include dialogues among stakeholders to understand the conditions faced by the regulators and the needs of stakeholders[201] (e.g., the policy objectives, government support to sustainability initiatives, financial and technological capacity of regulators, the features of payment systems, the local needs), and learning from experience, such as the EKLIPSE project funded by the European Commission to support better-informed decisions of governments, businesses and other actors regarding biodiversity.[202] Although the EKLIPSE project concerns biodiversity, its process design (including the call for requests, knowledge and experts, and relatedly the development of an open network of knowledge[203]) can provide a reference for CBDCs in conducting learning. The EKLIPSE project develops a decision-support mechanism for evidence-informed policy, involving experts from science and society to integrate evidence and spot knowledge gaps.[204] Meanwhile, peer review and open consultation are also included. Such mechanisms can be adapted when possible and serve as a starting point for developing processes to break silos and build capacity. In this way, CBDC sandboxes would further engage with knowledge holders to search for regulatory and technological tools to solve problems.

Yet, traditional state-centric regulations may prove inadequate, given the multitude of new and intricate issues involving numerous stakeholders at domestic and international levels. In both the financial and sustainability realms, regulators face the progressively uphill task of regulation given factors including the increased complexity of practices, expanded scope of regulation and the higher demand of risk management.[205] It is imperative to investigate the dynamics of interactions among various stakeholders, such as central banks, other regulators and the industry (e.g., commercial banks, payment operators, technology companies, market makers, liquidity providers and third-party service providers), in effectively managing uncertainties. The efforts of these stakeholders should encompass the sharing of information, leveraging knowledge exchange and fostering cooperation across diverse subject matters (horizontal functions). Additionally, the focus should extend to mechanisms promoting interaction, specifically the flow of information (including addressing potential issues like insufficient supply of information[206]), among distinct levels of governance. Sustained efforts are needed to harmonise digitalisation and sustainability (as indicated in Table 2).

[201]Hovelsrud and Westskog (n 58) 197.

[202]EKLIPSE endeavours to create a process to advice European policy on biodiversity and related environmental issues. For example, dialogue is used between actors such as a process facilitator and the requester of a certain policy. A Watt et al, 'EKLIPSE: Engaging Knowledge Holders and Networks for Evidence-Informed European Policy on Biodiversity and Ecosystem Services' (2018) 15 Evidence and Policy 253, 254, 257; EKLIPSE, About, < https://eklipse.eu/about/>

[203]ibid 258, 259.

[204]ibid 255.

[205]DW Arner et al, 'FinTech and the Four Horsemen of the Apocalypse: Building Financial Ecosystems for Resilience, Innovation and Sustainable Development' (2022) 39 Banking and Finance Law Review 5, 27.

[206]H Wang and S Gao, 'The Future of the International Financial System: The Emerging CBDC Network and Its Impact on Regulation' (2024) 18 Regulation and Governance 288, 296.

4 | CONCLUDING REMARKS

For digitalisation to contribute to sustainability, institutions must account for and mitigate ensuing environmental risks.[207] This requires addressing the nexus between digitalisation and sustainability by reconciling the functional, spatial and temporal mismatches that may otherwise emerge between the short-term pressures to develop CBDCs and longer-term environmental considerations.

Adaptive governance, particularly its core value of learning, can help to address these mismatches. To best harmonise digitalisation with sustainability, adaptive governance should prioritise two key aspects: (1) the environmental implications of digitalisation to handle the sustainability externalities problem; and (2) the contribution of digitalisation to sustainability to realise environmental goals. If properly managed, learning can facilitate coordinated actions in governance and support flexible institutions. Experimentation, precaution and monitoring are examples of collaborative learning efforts among stakeholders (e.g., central banks, the industry, international organisations, NGOs, research institutions and the public). Actors should be acutely aware of the need to conduct learning regularly.[208] Rules can take various forms depending on the national context and start from guidelines. These efforts help to improve governance, address new challenges and adapt to a new landscape where new public and private actors (e.g., new CBDC-issuing states) enter the CBDC system.

Looking ahead, there is a pressing need to advance our understanding, predictive abilities and responses to crucial questions concerning digitalisation and its potential implications. Key issues range from the careful consideration of parameters (e.g., the number and location of network actors, their eligibility criteria, software and hardware updates) relating to energy consumption of a digitalisation ecosystem[209] and the assessment of the feasibility of incorporating sustainability goals in finance (including central banking) to the use of incentives to promote learning[210] and the enforcement of policies that promote digitalisation and sustainability.[211]

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[207]M Barth et al, 'Sustainable Digitalisation-Fostering the Twin Transformation in a Transdisciplinary Way' (2023) 32 GAIA 6, 6.

[208]Cooney and Lang (n 20) 534.

[209]Agur et al (n 6) 6, 7.

[210]Armitage et al (n 85) 86.

[211]Shilina (n 144).

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